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The Working of Gas Producers.

ALTHOUGH anthracite suction gas producers are now extensively employed for small power plants, many persons are prejudiced against them owing largely to the lack of impartial data respecting their efficiency, cost of operation, and reliability, coupled, no doubt, in some cases with the difficulty of securing capable operators. Independent and authoritative tests of their working have been very few. The most notable ones were those conducted in 1905 by the Highland and Agricultural Society of Scotland*, and in the following year by the Royal Agricultural Society†, but, as many readers will remember, a great deal of dissatisfaction was expressed at the time with the results and conduct of the latter tests. Dissatisfaction is, perhaps, to be expected more or less in trials where commercial interests are involved, but all the same it tends to deprive the results of that confidence which is so desirable in scientific data. For this reason Bulletin No. 50 describing some tests by the engineering experiment station of the University of Illinois is interesting. Unlike the tests made by the two Agricultural Societies, which included the working of the gas engines attached to them, and indeed largely centred round their performances, those by Messrs. Garland & Kratz at Illinois were made with the producer alone, the necessary suction being induced by means of a steam injector. No doubt, for acceptance tests it is desirable to run both producer and engine tests in conjunction, but for studying the operation of the producer under different conditions and with different varieties of fuel, or for obtaining data on the efficiency and composition of the gas produced, the method adopted by the authors of the Bulletin possessed decided advantages. The plant in question was designed for a maximum production

* See "Mechanical Engineer," Nov. [illegible], 1905, page [illegible], Vol. XVI.
† See "Mechanical Engineer," [illegible], Vol. XIX.
See also tests by Gibson & Gray [illegible] "Effect of Varying Degrees of [illegible]tion of our Supply." Proc. Inst. C.E., [illegible], Part III, [illegible].

of 8,100 cub. ft. per hour (nominally 60 h.p.), and the items on which attention was chiefly concentrated in the tests were (1) the weight and heating value of the coal, and (2) the volume and heating value of the gas produced. The anthracites tested were, of course, of American origin, varying roughly in size from what would pass through a ⅜in. mesh up to that which would pass through a 2in. mesh. The average percentage of ash was about 15 per cent., and its composition differed somewhat in the source. The differential effect of these variations in quality are not of particular value to British readers, but some other effects recorded are worth noting. The average engineer regards the chemical reactions in a gas producer as comparatively simple and easy to understand, but in reality they are complex, and the more they are investigated the more complex they seem to be.

The percentage of CO_2 (carbon-dioxide) in the gases passing off is ordinarily considered to be a measure of the efficiency of a producer as it is in the case of a boiler furnace. But whereas in boilers efforts are made to secure a high percentage of CO_2 in the effluent gases, as a sign of complete combustion and efficient furnace working, the aim in a producer making a combustible gas usually is to keep the proportion of CO_2 as low as possible, since it is a measure of wasted heat. This reasoning is correct, speaking generally, but it is not always true. If, for example, the heat represented by the CO_2 is utilised for the decomposition of water and the production of hydrogen, there is no appreciable loss. On the other hand, if the CO_2 is the result of an excessive air supply, it betokens inefficiency, and is usually confirmed by a higher temperature of the producer gas. The influence of size of fuel where screened coal is used on what is termed "catalytic action"—under which a number of obscure and little understood effects resulting from the chemical reactions of the surfaces of solids in contact with gases are grouped—received attention in the course of the experiments. Catalytic effects appear to depend upon the state or form of the fuel, and the impurities contained in them, and this feature of producer working has already been the subject of investigation at the Illinois University.* From these and the present tests it would appear that while the catalytic action of charcoal, coke, or anthracite may vary greatly, the action between two fuels which differ only in size is, probably, not great. How great it may be, however, with different fuels was illustrated in Dr. Clement's previous experiments, in which CO_2 was passed over charcoal, coke, and anthracite ground to size, and placed in electrically-heated porcelain tubes, the percentage of CO formed by the reaction of CO_2 C being noted at varying temperatures and velocities. With charcoal, for instance, at a temperature of 1,100° C., and a velocity of 1ft. per second, 85 per cent. of CO was formed; while under the same conditions it was for coke only 9 per cent., and for anthracite 11 per cent. At a temperature of 1,300° C., and the same velocity, the percentages were: Charcoal, 100; coke, 74; anthracite, 45. Although the figures are only relative, they afford an indication of the important part which is played by temperature, time of contact, and catalytic action of different fuels in producer working, and throw a light not only on the complex chemical problems of producer working, but explain in some measure the disparities in results found in practice.

Where graded fuel is used, the size of the fuel theoretically has no effect on the volume of fuel, or of the interstices for a given fuel bed since the number of pieces required to fill the producer varies inversely as the cube of the mean diameter of the pieces, while the volume of each piece varies directly as the cube of the mean diameter. The amount of draught, however, required to force the gases through will be different, owing to the increased frictional resistances of smaller interstices. The purely mechanical effect of larger fuel will be to decrease the area of surface exposed to the gases, and also the drop in the pressure through the fuel bed, and this latter within wide limits, as the tests showed, has no effect on the composition of the escaping gas. The weight of coal gasified per square foot of grate is, of course, a measure of the producer's capacity. The rating here is somewhat different to the States, owing, doubtless, to the differences in the fuels used. In British practice, from 20lbs. to 30lbs. per square foot of grate area per hour is allowed, whereas anthracite producers in the States are usually rated at 10lbs. to 15lbs. The authors found, however, in their tests, that within a range of 7·6lbs. and 49·8lbs. per square foot per hour, the producer could be operated with satisfactory results. Theoretically, in fact, the amount of fuel gasified depends entirely on the nature of the fuel and the depth of the bed necessary to give proper time of contact with the gases. In practice, the nature of the ash, its temperature of fusion, and the question of cleaning impose practical limits for any given fuel.

The formation of clinker is, of course, due to incombustible matter in the fuel which fuses at the temperature of the fuel bed, and there are two ways of dealing with it. The more practical one is to keep the temperature below this point by the admission of steam and utilising the heat for the production of hydrogen; the other is to add a flux, such as limestone or other cheap material, to make the clinker more fusible and run from the fuel bed, but this is attended with such difficulties owing to the risk of freezing of the liquid slag in the fuel bed at cleaning times that it may be dismissed as impracticable. When a fuel has no tendency to clinker, the highest efficiency appears to accrue when the amount of water results in the presence of between 2 and 4 per cent. of CO_2 in the gases leaving the producer, but this requires a deep fuel bed and a high temperature within the combustion zone to secure the completion of the CO reaction, and in small producers this cannot always be attained owing to the tendency of the fuel to pack or "arch," and the consequent necessity of poking to ensure its descent. This arching, of course, increases the percentage of CO_2, and by raising the temperature of the gas lowers the efficiency, and suggests some grate-shaking arrangement as a desirable appurtenance in producers of small size. Another point in connection with the water supply to which attention may be called is that its reaction with incandescent carbon to form hydrogen takes place faster at the lower temperature than does the CO_2 reaction, and consequently when a producer is operating with large fuel or with a shallow fuel bed, it is necessary, in order to keep down the temperature of the gases and maintain efficiency, to use larger quantities of water than is the case with a deeper fuel bed, because there is not sufficient time for the CO_2 reaction to take place unless the producer is worked more slowly, in other words, at a diminished rating.

* See Bulletin No. [illegible] University of Illinois Engineering Experiment Station on the Rate of [illegible] Clement, Adams and Haskins.

Uses of Gas for Industrial Purposes.—At a recent meeting of the Special Purposes Section of the North of England Gas Managers' Association, Mr. J. H. Singleton gave an address on "The Uses and Advantages of Gas for Industrial Purposes."

BOOK REVIEWS.

Theory and Practice in Designing. By Henry Adams, M.Inst. C.E., &c. London: Constable & Co. 9in. by 6in. 240 pp. Price 6s. net.

This is one of the best elementary books on the design of girders, roofs, and similar structures with which we are acquainted. The subject is one with which the author is thoroughly *au fait*, and his treatment is just such as will commend it to the mechanical engineer and architect, or to the student as an introduction to more advanced and elaborate treatises. The work throughout is simple and practical; only the simplest mathematics are used, and this is amplified by numerous worked out examples. The arrangement is progressive, and permits those with comparatively little knowledge of the subject to follow it by easy stages, from the consideration of stresses in simple elements up to the problems involved in the designing of compound structures. We recommend it heartily alike as a text book or a handy work of reference.

* * *

The Heat Treatment of Tool Steel. An illustrated description of the physical changes and properties induced in tool steel by heating and cooling operations. By Harry Brearley. London: Longmans, Green, & Co. 9in. by 6in. 160 pp. Price 10s. 6d net.

Having regard to the importance of heat treatment on tool steel and the extent to which tool steel is used, it seems rather strange there is so little literature on the subject. The explanation probably lies in the fact that those who have the knowledge seldom have the time, while those who have the time seldom have the ability or the desire to convey it to others. Happily, the author possesses both these necessary qualifications, and as a Sheffield expert connected with one of its leading firms, has had unrivalled opportunities of making researches and obtaining information. As a result of this combination, we are favoured with an invaluable work of reference, both to the maker and the user of tool steel, and especially the latter, who has hitherto been very largely dependent on the user for an explanation of any defects discovered, troubles experienced in use, or for any remedies for abating them. The author is thoroughly scientific, and largely avails himself of the microscope and the methods of physical chemistry in his explanation of the structure and properties of steel, and let us add also in his dissipation of the element of superstition which still clings in some quarters round some of the elementary phenomena of hardening and tempering. A belief, for instance, still lingers in the minds of some Sheffield cutlers that Sheffield water possesses special virtues for hardening purposes, and that these may be exalted by the addition of other substances. A similar belief also exists amongst the workmen at Solingen, in Germany, and these the author dismisses with gentle ridicule. That there is much still to learn in connection with steel everyone will admit who is familiar with the amazing variety of chemical compounds included under this descriptive word, and mystery here, as elsewhere, is usually only another name for ignorance. Happily existing ignorance is rapidly dissolving under the piercing eye of the microscope and the sensitive tests of the chemist and physicist. Space forbids more than a brief outline of the salient features of the book. The early chapters are devoted to the structure and methods of classification of steel, followed by a discussion of the influences of heat in forging, hardening, and tempering. Then come some other chapters of special interest. "The hardening of typical tools" is discussed in one; another is devoted to the causes of defects sometimes developed in tools during their treatment in the hand of the user; while a third describes the equipment and working of a hardening plant, the manipulation of pyrometers, &c. The book, in short, gives the ripe experience of a steel expert in terms which can be easily understood by the less technical but equally interested user or workman, and in view of the dearth of literature of this kind will prove a welcome addition to many an engineer's library.

* * *

A Course of Elementary Workshop Arithmetic. By Henry Darling, Assoc.M.Inst.C.E. London: Blackie & Son, Ltd. 7½in. by 5in. 172 pp. Price 1s. 6d.

This little manual consists of a graded course of simple arithmetic and mensuration, suitable for classes drawn from workshops and factories. It covers the elementary and intermediate stage for workshops arithmetic covered by the syllabus of the N.U.T., and also the syllabus of entrance examinations for apprentices in H.M. dockyards. The examples are chosen with care and judgment, and with a view to illustrate the practical application of simple geometrical principles. The book is one that may be commended to those who have the teaching of elementary classes in industrial centres.

* * *

Dynamo and Motor Attendants and their Machines. By Frank Broadbent, M.I.E.E. London: S. Rentell & Co., Ltd. 7½in. by 5in. 152 pp. Price 1s. 6d. net.

This is a little handy manual designed for the help and guidance of motor attendants in the course of their daily duties. The principal features and details of an electrical installation are given in language as free as possible from technicalities, and is accompanied with practical hints and instructions as to what to do in the case of faults and breakdowns. It is just the kind of book the average attendant needs who, without being an expert electrician, is required to operate and keep an electrical plant in good working condition, and to be capable of dealing with any running difficulties in a fairly intelligent manner.

* * *

The Law Relating to Engineering. A series of six lectures delivered before the Society of Engineers and the Junior Institute of Engineers. By L. J. W. Costello, M.A., LL.B., with an introduction by Lord Justice Fletcher Moulton. London: Percival, Marshall, & Co. 9in. by 5¾in. 169 pp. Price 5s. 3d. post free.

The responsibilities of a professional engineer are so varied and so serious in connection with contracts and obligations of one kind and another that he is fortunate indeed if at some time he is not made painfully conscious of them by legal entanglements. However much, therefore, he may dislike the law and its machinery, he will find that a rough idea of its general principles, so far as it affects his commercial relations with others, is a valuable acquisition. It was a happy idea that led the two institutions named to secure the delivery of these lectures to their members. Without being a lawyer, an engineer has often to draw up specifications and contracts with legal exactitude, and their technical details are often so complicated that he is often unable to pass the responsibility to a professional lawyer. In countries where law is embodied in codes, it is comparatively easy to know those portions of it which bear on a particular calling, but in England, where law is governed by principles rather than by cut-and-dried schedules, it is not so easy, and the principles can only be mastered by considering their effects as exemplified in specific cases, and it was by a collection of these Mr. Costello sought to convey in his lectures a general idea of their outline and bearing on the engineer's profession. That much needless trouble and annoyance arises from a misconception or ignorance of the legal liabilities in many matters which the engineer is compelled to arrange is undoubted, and for this reason we are glad the lectures have been reproduced in a form which permits of their being carefully perused by a wider circle than was possible when they were delivered. It is a volume which every engineer holding a responsible position will find not only advantageous to read, but to keep handy for reference.

Elementary Manual on Heat Engines, Steam, Gas, and Oil. By Andrew Jamieson, M.Inst.C.E. Thirteenth edition. London: Charles Griffin & Co. 7½in. by 5in. 425 pp. Price 3s. 6d.

This book has been so long before the engineering public and is so well known that a detailed outline of its contents in view of previous references is not called for, and we must content ourselves, therefore, with a brief mention of the additions and emendations of its contents. These consist mainly of two additional chapters on gas and oil engines, with suitable questions bearing on the text. The general scope of the book is such as is required by first-year students under the Board of Education and the City and Guilds of London Institute.

* * *

Steam Turbine Design, with Special Reference to the Reaction Type, including chapters on condenser and propeller design. By John Morrow, M.Sc., lecturer on engineering, Armstrong College, Newcastle-on-Tyne. London: Edwin Arnold. 9½in. by 6¼in. 470 pp. Price 16s. net.

In a sense, all steam turbines may be said to be reaction motors in so far as mechanical rotation is effected by the absorption of the kinetic energy in a flow of steam moving from a higher to a lower pressure, but the way in which the velocity of flow is mechanically regulated in practice has led to two very distinct types of design known respectively as the Impulse type and the Reaction type. Speaking broadly, in the former the current of steam acquires kinetic energy at the expense of heat energy in passing through fixed diverging nozzles, and this kinetic energy is absorbed in the rotating blades. In the Reaction type, the kinetic energy is developed in two steps, a certain amount being developed in the fixed blades, and a further amount in the moving blades, the sum of these two quantities being absorbed in the rotating blades. In the former, as in the latter, the drop from boiler heat and pressure to condenser heat and pressure is usually effected owing to practical considerations in a number of stages, but whereas in the Impulse type the fall is intermittent, in the Reaction the fall is more or less continuous. The latter type is the characteristic feature of the Parson turbine, which was the first practical turbine design, and the discussion of its principles of design and constructive features constitute the major portion of the subject matter in the book before us. Exception may, perhaps, be taken by some to this rather limited treatment in view of the numerous designs by Continental and American makers now available; but none can be taken to its thoroughness. Further the author clearly indicates the scope in his title, while it is but fair to add that extended treatment of other types would inevitably have entailed some sacrifice of completeness in the matter presented, and we are the less inclined to grumble seeing the exceptional position and privileges the author has enjoyed, and the fruits of which he has given us in such full measure. The book is without doubt the most complete presentation of the problems associated with the Parsons type of turbine that has so far been given, and as such will, no doubt, be appreciated by a wide circle of readers. The author's treatment is in every way worthy of his professional reputation. The matter is excellently arranged, the style clear and concise, and the argument with the mathematics and thermo-dynamic reasoning essential to its elucidation easy to follow. We cannot finish this brief notice without a word of praise for the numerous excellent illustrations, and the very admirable way in which the publishers have done their share of the work.

The Standardisation of Copper Tubes.—The Birmingham and District Branch of the National Association of Master Heating and Domestic Engineers have drawn up a scale of tables of standardisation for light, medium, and heavy copper tubes, which has been submitted for consideration to a joint committee of the National Association and of the Institution of Heating and Ventilating Engineers. The tables are also receiving the consideration of the Engineering Standards Committee.

TESTS FOR MOULDING SANDS.

A LECTURE on "The Testing of Moulding Sands" was recently delivered to the members of the Sheffield and District branch of the British Foundrymen's Association at Sheffield by Mr. Richard Mather, B.Met. (London). The lecturer pointed out the rapid introduction that had taken place during the last 20 or 30 years in the iron and steel industry of processes for testing the qualities and properties of the materials used. This was almost equally true of every section of the iron trade but the foundry; and even here the use of exact tests for pig iron, coke, &c., was growing rapidly. Moulding sand, however, one of the foundryman's most important materials, had been left almost unaffected by these changes. Yet after pig iron, this material was used in larger quantities than any other in most foundries. The utility of a reliable series of tests needed no emphasis among those who recollected how many sources of wasters and trouble might be caused by bad sand. Natural aqueous deposits were never of quite reliable quality, and in the case of moulding sands the variations were frequently of such a nature as to pass undetected by the old tests. At the same time, the old tests had been and were useful, and pronouncements based on them were more often right than wrong. But most foundrymen admitted that too often for good practice these tests failed to reveal important facts.

It could not just be said that the inadequacy of the present methods of testing moulding sands was due entirely to indifference or opposition to new methods among foundrymen. Many of them looked with hope to the advent of the chemist with his ultimate analysis of a sand into silica, alumina, combined water, and so on, but now every judicious chemist saw that such a test, though of value in one or two respects, did not yield a reliable indication of the qualities of the sand as a whole. The foundryman's difficulty had been to find satisfactory and reliable new methods to supplement the old, and he had not here, as in the case of testing iron, had the help of the steel works and blast furnace people. Nevertheless, a good deal of preliminary work had been done, and while it was not yet practical to give definite specifications for moulding sand, the day for that might come.

Mr. Mather described in detail the result of the enquiries of a large number of investigators in this country, America, and Europe, and the various tests that are used to discover the fineness, porosity, permeability, and bonding strength of sand. What he wanted, he said, was a thorough scheme, very carefully planned and carried out, for investigating the reliability and usefulness of the tests with the object of weeding out those which were unnecessary. When the tests were standardised, the foundry industry would be in a position as regarded its sands to say exactly what it needed, and to see that it got it. The investigation, he suggested, might be organised by an association of that kind.

Mr. Herbert Pilkington, who presided, said that a good many of the members of the Council strongly favoured the adoption of an organised method to establish some sort of standard tests. Mr. Thomas Firth said that renovation of sand would, no doubt, effect a very big saving. Dealing with this point Mr. Mather said it might be found that the amount of colloids in the sand was of more importance than the amount of water in the clay, and if so they might grind the colloids into the sand and get satisfactory results, but that was a matter for the future.

Fatal Explosion of a Steamer.— An explosion occurred last month in the stokehold of the steamer "City of Lincoln," whilst in harbour at Adelaide, resulting in the deaths of the third engineer and five firemen.

Miner Electrocuted. — A fatal accident occurred on the 22nd ult. in Bardykes Colliery, Cambuslang. A miner was at work with a coal-cutting machine, and was left alone for about five minutes. On the return of another miner the unfortunate man was found to have been electrocuted. The current was stopped immediately, and efforts were made to restore animation, but without effect.

A LARGE BORING AND TURNING MILL.

THE boring and turning mill illustrated in Figs. 1 and 2 has just been completed by Messrs. George Richards & Co., Ltd., Broadheath, near Manchester. The machine is of the extension type. It is capable of dealing with work up to 24ft. diam., and will admit work 10ft. deep under the tools. A central boring reach is fitted to the machine to enable boring operations to be carried on when the uprights are moved back to their extreme position, and the machine is dealing with work of the maximum capacity. The machine is of massive proportions throughout, and capable of taking heavy cuts with high-speed steels. The table is 15ft. diam., and driven by a spur gear having 200 teeth, $1\frac{1}{4}$ diametral pitch. Three motors are attached to the machine for the various operations, the main driving motor being of 50 h.p., and giving a full range of speeds to the table varying from ·238 of a revolution to 10·27 r.p.m. A 10 h.p. motor is mounted on the cross girth, which serves the double function of raising and lowering the cross slide, and providing the quick power traverse to the saddles, rams, and centre boring reach. The third motor, also of 10 h.p., which is mounted on the cross bed at the back of the machine, is for the sliding of the uprights along the side beds. The tool bars, which are octagonal in section, are of steel, and have quick power traverse in all directions, those on the main cross slide having 80in. of down feed, and that to the boring reach 40in. of down feed. The rams are balanced by the makers' patent spring - balance arrangement, which does away entirely with the objectionable feature of chains and loose balance weights. Twelve rates of feed are given to the machine, varying from ·0301in. to 1in. per rev. of table. Almost the whole of the feed gearing is of steel, and slipping clutches are provided to prevent breakage in the event of jamming. In connection with the driving mechanism, which is placed between the side beds, an interlocking device is provided to prevent the direct and reduction gearing being put into operation at the same time. The table is supported by a large annular surface of white metal when on ordinary speeds and cuts, but it is so arranged that when it becomes necessary to run the table at high speeds, the weight can be put on to a heavy ball bearing underneath the spindle. This is accomplished by the movement of a hand-wheel placed in a convenient position at the front of the base, and which is given a gear ratio, such that a man can easily raise the entire weight of table, spindle, and gear ring when it is necessary to bring the ball bearing into operation. This arrangement is clearly shown on Fig. 2. It will also be observed that the spindle bearings are adjustable by means of large bushes and adjusting rings as shown. The entire weight of the finished machine is about 150 tons.

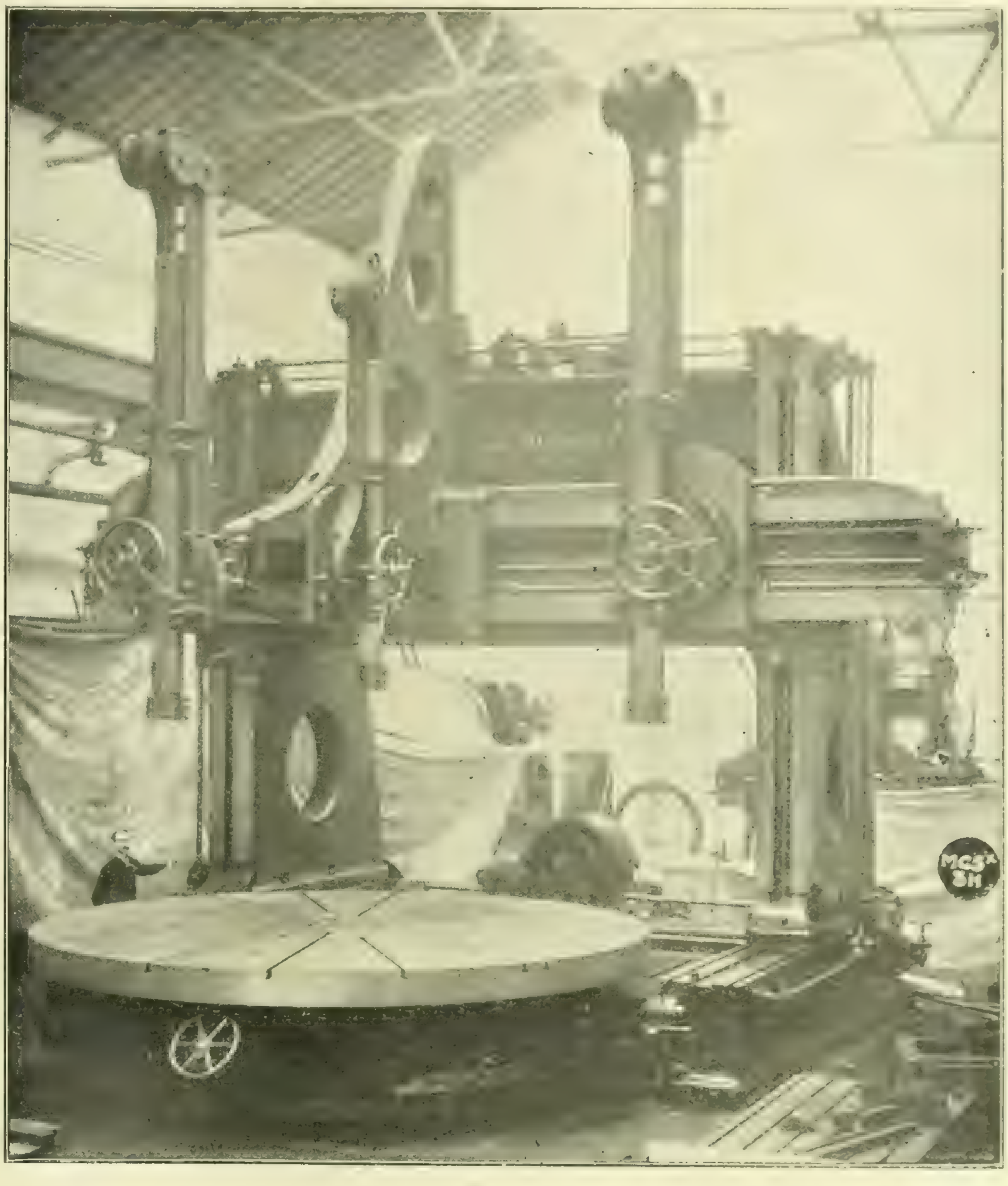


FIG. 1.—A LARGE BORING AND TURNING MILL.
Constructed by Messrs. George Richards & Co., Ltd., Broadheath, near Manchester.

Fatal Carbide Cylinder Explosion.— While the Rev. Stephen de Courcy was fixing up a lime light for a magic lantern entertainment at Branscombe, near Stroud, Gloucestershire, on Boxing Day, the cylinder exploded and killed him instantly.

DESIGN OF OIL-FIRED OPEN-HEARTH FURNACES.

BY W. MACGREGOR.

IT is a well-understood fact among engineers that the design of a furnace, to get the best efficiency from the fuel, depends entirely upon the nature of the fuel to be burned. Obviously, as we are to deal in high temperatures, we are, therefore, to pick out a fuel high in heat value and design our furnace to suit the combustion of this fuel.

In order to get the highest heat, our furnace body should be of such proportions that we can burn the necessary amount of fuel in the smallest possible space, and in order to burn a large amount of combustible in a small space, a short flame is necessary.

The factors governing the short flame, according to the fuel experts of the United States Navy, are: (1) A pure carbon fuel; (2) initial heating of the air which furnishes the oxygen for combustion; (3) intimate mixture of the oxygen with the fuel or diffusion; (4) large surface of the fuel presented for impact of this oxygen.

The first factor, the nature of the fuel, is settled for us, as we have decided upon fuel oil with a probable analysis as follows: Carbon, 83·26 per cent.; hydrogen, 12·41 per cent.; sulphur, 0·50 per cent.; oxygen, 3·83 per cent., with a specific gravity at 60° Fah. of 0·926.

The heat value of this fuel, according to Du Long's formulæ, would be 19,481 B.T.U.'s per pound. From this analysis we can easily compute the quantity of air required for com-

bustion and the products of combustion for any amount of fuel burned.

As a representative size of the small open-hearth furnace we will choose a five-ton furnace as an example, and discuss the conditions that will determine the proper furnace proportions. We are to melt and reduce five tons of metal, and the time from charging the heat until the time of charging the following heat we will assume to be four hours. As the oil consumed varies so much in different furnaces, we will assume as an average fuel consumption 48 galls. of oil per ton of steel melted in this time, or one gallon per minute.

Considering 12lbs. of air required for burning 1lb. of carbon and 34·78lbs. of air required for burning 1lb. of hydrogen, we have from the analysis of the fuel:

9·9912lbs. of air to burn the total carbon in fuel.
4·2161lbs. of air to burn the total hydrogen in fuel.

14·2073
·16 Correction for oxygen in fuel.
14·0473lbs. of air for complete combustion of 1lb. of liquid fuel.

With fuel oil of 7·72lbs. per gallon, we have $14·047 \times 7·72 = 108·37$lbs. of air required per gallon of oil.

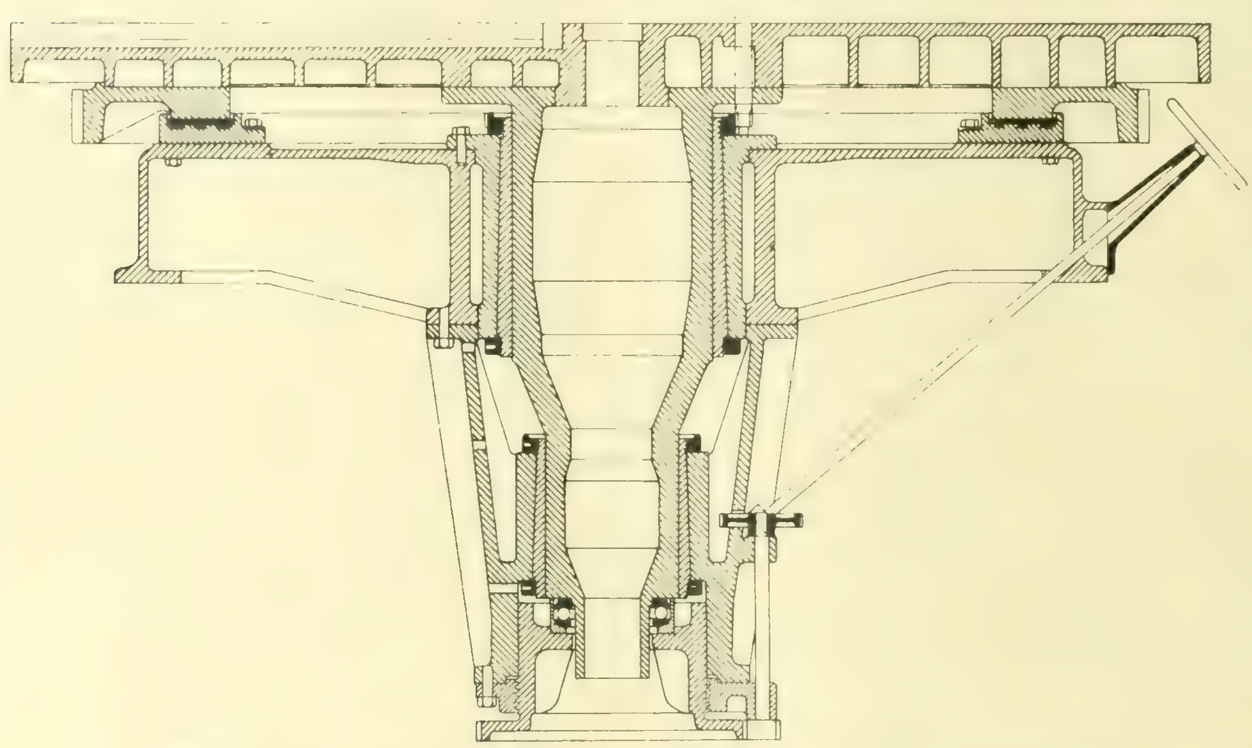


FIG. 2. A LARGE BORING AND TURNING MILL. ARRANGEMENT OF TABLE. (See page 5.)

With air at 13·14 cub. ft. per pound we have $108·37 \times 13·14 = 1{,}424·11$ cub. ft. of air required to burn one gallon of fuel oil.

Hence, to burn one gallon we must admit, theoretically, 1,424 cub. ft. of air per minute into the furnace. To this we must add the amount of air required in reducing the carbon and silicon in the metal.

We have a 10,000lbs. charge, of which $12\frac{1}{2}$ per cent. is pig iron, and about $2\frac{1}{2}$ per cent. carbon, and the rest steel scrap and billets of about 0·30 per cent. carbon, to be reduced to about 0·18 carbon at the time of tapping. From this we get the total carbon content of the bath, 56·5lbs., to be reduced to 18lbs. of carbon, or $56·5 - 18 = 38·5$lbs. of carbon, to be burned out in about two hours of reducing the charge. As 157·6 cub. ft. of air are required to burn 1lb. of carbon, we will require $157·6 \times 38·5 = 6{,}070$ cub. ft. air in two hours, or 50 cub. ft. per minute. All of this passes off with the products of combustion. In the same way we can determine the amount of air required in eliminating the silicon, which will run about 42 cub. ft. per minute. A certain amount of oxygen is also taken up by the manganese, but this is so small as to be negligible.

With the total theoretical amount of air required, 1,424 + 50 + 42 = 1,512 cub. ft. per minute, we are in a position to determine the proper furnace proportions with due regard to the second circumstance in producing the short flame.

The volume of air is figured at a temperature of 72° Fah., which will be about the temperature of air entering the valve. The increase in volume of air at different points along its travel due to its increase in temperature must be the governing factor in designing the ports, flue openings, &c., and as the volume of this air increases in direct ratio to the absolute temperature, it follows that the volume occupied at any point may be computed when the temperature at that point is known.

In the case of the air valve, due to the reversing feature of the furnace, this should be figured rather to accommodate the products of combustion than the entering air, as these are at a higher temperature and will, therefore, require a greater area of flue.

The temperature of the valve is a vital point in the problem of design, for any heat beyond this point toward the stack is lost, as far as the furnace is directly concerned, and can only be used in the field of economisers. In determining the size of the valve, we will first have to determine the velocity of the products of combustion through the valve due to the draught of the stack, and this, in consequence, gives as our starting point—the design of the stack—which we would naturally consider as our finishing point.

A number of eminent authorities on chimney design have chosen 600° Fah. as the most economical stack temperature, and Rankine has spent considerable time in trying to prove it in his work on "Steam Engines." I have never seen an open-hearth stack with so low a temperature, and will, therefore, base my calculation on a temperature of 1,000° Fah. as being more nearly uniform with current practice. In my experience with small furnaces, I find that the most satisfactory stack draught to be maintained is about 1in. of water. This is a function of the height of the stack and the difference in temperature inside and outside the stack. With this difference in temperature and a draught of 1in. of water, we would get a stack 110ft. high, and hence we will assume this as the minimum height to be desired. The velocity of gas due to the pressure head corresponding to this height of stack and temperature, allowing a 25 per cent. friction factor, is a little less than 15ft. per second, which is recommended by a number of authorities as good practice.

We have based our calculation so far on the theoretical amount of air required for combustion, but will design our stack and flues as in the case of power plant design, for an excess capacity of 100 per cent., which would be 3,000 cub. ft. of gas per minute, or 50 cub. ft. per second. This divided by the velocity of 15ft. per second would give a sectional area of stack of $3\frac{1}{3}$ft., or a trifle over 2ft. diam., and we will assume 27in. diam. of stack as best suited to this furnace, and plenty large enough to permit of any crowding of the furnace. This, then, will also be the size of the valve and flues leading to the valve from the checker chambers.

The second factor governing the short flame, "The initial heating of the air," is introduced by means of the reversing feature of the furnace through the checker chambers, and these chambers should be so designed as to slow up the travel of the products of combustion in order that they may give up the major part of their heat to the checker brick, or that part of the heat which is not required to produce the stack draught. The cubical contents of these chambers should not be less than 75 cub. ft. per ton of steel melted per heat, and preferably in the neighbourhood of 100 cub. ft. per ton

These chambers should be located behind the furnace, and not immediately under the furnace. This point is quite as important in small furnaces as in large ones, as they operate at a higher temperature, and we should get the benefit of a good circulation of outside air under the hearth of the furnace. These chambers should be long and narrow or deep, in oil-burning furnaces, giving a very long travel to the products of combustion before they reach the valve, as on account of the highly volatile nature of the fuel and the slowness with which many of the hydrocarbons mix with oxygen, a great deal of the fuel will be out in the stack before it has undergone complete combustion.

The methods of gas analysis as applied to steam boiler practice will show some very interesting relations in this regard. In a five-ton furnace which I have been operating, a flue gas analysis will show the following:—

	CO_2 per cent.	CO per cent.	O per cent.
At the rear of the checker chambers, 24ft. back of the centre line of furnace	6·4	3·1	0·2
In the air valve, 9ft. further back..	8·8	0·3	8·0
In the stack, 16ft. further back ..	9·4	0·3	9·0

With a decrease in temperature between the first and last point from 1,750° Fah. in the rear of the chambers to 930° Fah. in the stack.

In case all the fuel were burned before it reached the stack, the sum of the oxygen components of the flue gas would be 21 per cent., as there is 21 per cent. by volume of oxygen in all the air admitted to the furnace, the volume of the carbon element being so small as to be considered zero. As a matter of fact, however, the sum of the oxygen components at the valve is only 17·1 per cent., and even out in the stack it is only 18·7 per cent., which shows that there is some form of hydrocarbon gas occupying the other 4 per cent. which is getting past the valve unburned, and is being wasted out in the stack. This, I think, shows very conclusively the necessity of having long chambers and flues in oil-burning furnaces, to ensure complete combustion of the gaseous fuel before reaching the reversing valve.

These figures are based on atomising the fuel with compressed air instead of with steam, as with steam the hydrocarbons are slower in taking up oxygen, and a gas analysis at the valve will show a higher percentage of hydrocarbon gas unburned at the valve, and a corresponding increase in stack temperature. A sample of gas at the base of the stack when steam was used for atomising purposes, showed the following analysis: CO_2, 7·5 per cent.; CO, 0·4 per cent.; and oxygen, 9·5 per cent.; or a total of 17·4 per cent. of oxygen components out in the stack, which is 5½ per cent. less than shown at the base of the same stack with air, and, therefore, a less perfect combustion.

The third condition governing the short flame, "Intimate mixture of oxygen with the fuel or diffusion" bears directly on the size and arrangements of the air ports and the furnace body. The size of the ports depends upon the size of the reversing valve, or vice versa, and the relation between the two is in a direct ratio to the absolute temperature at the two points, these temperatures being 1,490° Fah. at the valve, and 2,800° Fah. at the ports, or in a ratio of 1 to 2. The ports, therefore, should have an area of twice the area of the reversing valve. We will, therefore, have a total port area at one end of the furnace of about 7ft. These ports should be carried out the full width of the furnace to prevent any short circuit of air through the furnace body, as the travel of gas through the furnace body should have the same velocity at all points to get the proper diffusion. These air ports should come well up above the hole in the monkey wall through which the oil burner enters the furnace, so that the air must come down on top of the flame rather than underneath it. This is a very important factor in designing a hot working furnace.

The space to be allowed for hearth in small furnaces should not be under 10 sq. ft. per ton of charge, and the shape should approach more nearly a square than the oblong shapes in general use, as this tends to give a better effect of the radiation of the walls and roof, and by widening the furnace we lessen the cutting action of the flame on the side walls and keep down the repair bills.

As to the length of the furnace body, this should be governed by the length of the oil flame, for the hottest part of the flame should be about the centre of the furnace. In my experience I have not been able to get a flame that was intense enough to melt down a charge of metal any less than about 8ft. from the tip of the burner to the hottest part of the flame, and as the tip of the burner should pass clear through the monkey wall, which will extend 9in. beyond the ports of the furnace at least, we will get as a minimum furnace length twice the length of the flame previously mentioned, plus twice the width of the ports, plus twice the thickness of the end walls, plus twice the 9in. extension of the monkey wall beyond the ports, or a total of about 22ft. as the minimum length of the outside of the furnace body.

The fourth factor governing the short flame, "Large surface of fuel presented for impact of oxygen," is a matter of oil burners and atomising agents, and has furnished inspiration to thousands of inventors. The problem of atomising this fuel oil is one of overcoming the surface tension of the oil and breaking it up into very fine particles, so that it will present a greater surface for contact with the oxygen, and the two methods in use, superheated steam and compressed air, give a low mechanical efficiency.

There is a great deal of discussion at the present time on the needless waste of using compressed air for atomising purposes when superheated steam will answer, but in the small casting business one of the main difficulties is getting the metal hot enough to run the thin sections in the moulds, and, since by its very nature compressed air while atomising the oil furnishes at the same time oxygen for combustion, and that, too, very intimately mixed with the oil, it is quite evident that by using air we would get quicker combustion, a shorter flame, and a somewhat hotter furnace.

In conclusion, I will say that in operating a furnace designed along these lines, it will not be a difficult matter to get out six five-ton heats in 24 hours, and still have the metal hot enough to pour many castings weighing a fraction of a pound each. With a five-ton heat it is not uncommon to pour as high as 175 moulds, consuming about 50 minutes in pouring. The metal must, therefore, be extremely hot at the time of tapping the heat.

DENSITY AND EXPANSION OF ALUMINIUM.

AT a recent meeting of the Faraday Society, Dr. F. J. Brislee presented a paper, entitled "A Redetermination of the Density and Coefficient of Lineal Expansion of Aluminium." The earlier determinations of the physical constants of aluminium were, he said, made upon specimens of doubtful purity and unknown composition. In view, therefore, of the high state of purity of the metal now on the market redeterminations of these constants became desirable. The metals used were carefully analysed, and were found to consist of about 99½ per cent. aluminium, and about ¼ per cent. each of iron and silicon. The density determinations were made upon the cast metal, hard-drawn rod, and soft-annealed rod, and both the ordinary method of weighing in air and water and the displacement method were employed. The results obtained averaged 2·708 for cast metal, and 2·705 for hard rod. The density of re-melted aluminium was about 2°68. These values differ from published results. The coefficient of linear expansion was measured directly by determining the increase in length of a metal rod when heated from 10° to 100° C. The apparatus used was illustrated and described fully in the paper. From the measurements made the variations in length of a rod could be calculated from the formulæ:—

Hard-drawn Aluminium

$$L_t - L\ (1 - 0{\cdot}00002432t).$$

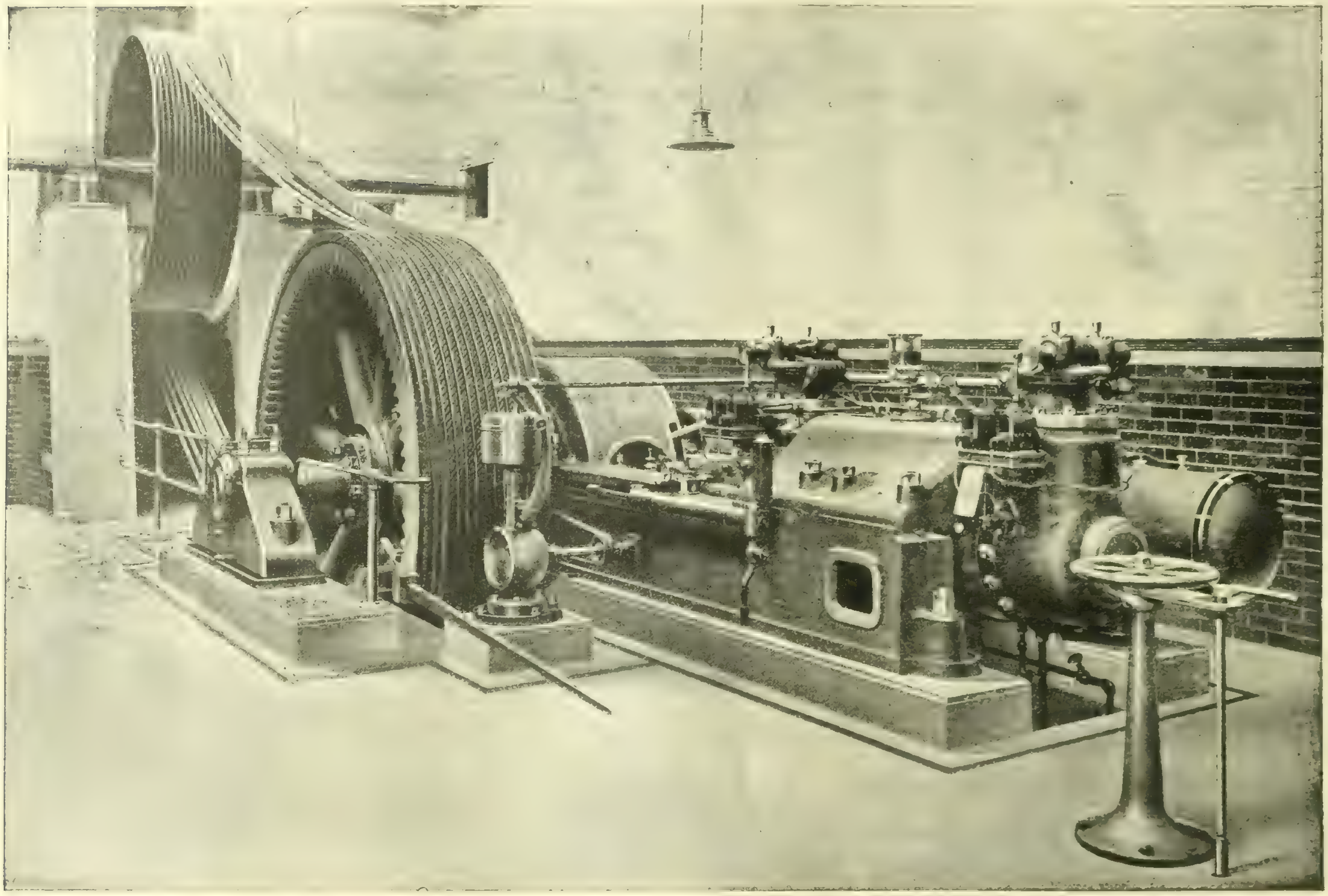
Annealed Aluminium—

$$L_t - L\ (1 - 0{\cdot}00002454t).$$

The paper concluded with a short discussion of the sources of error in the determinations.

A LARGE TWO-CYCLE GAS ENGINE AND SUCTION GAS PLANT.

MESSRS. MATHER & PLATT, LTD., SALFORD IRONWORKS, MANCHESTER.



AT a recent visit to Messrs. Mather & Platt's Salford Ironworks, Manchester, we had the pleasure of witnessing a test under load of a large two-cycle gas engine, which the firm are supplying to a firm in South America. By the courtesy of the firm we are able to give a few interesting notes and illustrations of the installation. The plant will consist of two engines of the firm's patent standard slow-speed two-cycle horizontal type of 400 i.h.p. each. The general design of the engine has been already fully described in our columns*, and its main features are shown in the general view and section through the cylinders on pages 8 and 9.

The engine will be operated with a suction gas plant arranged to use wood—obtained in the locality—as fuel for generating the gas required, the gas-producing apparatus being supplied by the Power Gas Corporation, of Stockton-on-Tees.

The engines will be used for driving both a spinning mill and a dye-house plant, and their lay-out, shown on page 10, is such that either engine may operate either of the drives, or run singly at night.

The flexibility of this arrangement, whilst seldom necessary in power installations in this country, is obviously of very great advantage in distant countries like South America or where continuity of service is imperative under all conditions. The dye-house plant will be driven electrically from an alternator shown on the plan, and, as stated, the gearing to give the maximum flexibility is interchangeable for each engine, though normally the two engines will drive the electric generator and the spinning mill together.

The suitability of a two-cycle gas engine for mill work has, the firm state, been amply proved by their extended experience under all conditions, and as will be seen from the Moscrop diagram obtained, and which we reproduce herewith, the uniformity of speed is equal to that obtained from the best steam engine.

The great simplicity of the engine, its solidity, slow speed, and general similarity in design to the well tried steam engine, which is one of its most prominent constructive features, has rendered it peculiarly suitable for the installation and country to which in this case it is being dispatched.

By virtue of the two-cycle arrangement, no exhaust valves are required, and the equality of running so necessary for mill driving, and which is a conspicuous attribute of the engine, largely results from the fact that every stroke is a "driving stroke."

The gas plant, as stated, is of the standard design for using wood as fuel but the grate is so arranged as to be also suitable for using coke or anthracite, should occasion demand; and the cleaning plant is ample to meet the conditions under which it has to work.

In obtaining the necessary experience to successfully drive a mill by a gas engine, troubles and failure have, undoubtedly, been experienced by all large gas-engine makers, and, unfortunately, have hung like a cloud over the merits of this type of prime mover, and, to a large extent, prevented their undoubtedly economical advantage being made use of. This state of affairs, however, it is to be hoped, is rapidly ceasing to exist, now the gas engine has been clearly shown to rank as a reliable prime mover for mill driving.

* See "Mechanical Engineer," March 3rd, 1911, page 258, Vol. XXVII.

All-steel Railroad Cars in the States.—At the beginning of this year there were about 3,000 passenger cars in service in the United States built of all-steel construction. The total number of passenger coaches is about 54,600, so that the number of steel cars is about 5·3 per cent. of the total

PROBLEM OF MACHINE TOOL STANDARDISATION.

BY L. P. ALFORD.

STANDARDISATION of product is a necessity in manufacturing. It is the starting point in every attempt to produce great quantities of parts cheaply and uniformly. The advantages are readily recognised. There are similar advantages in the standardisation of processes and tools used in manufacturing, and this broad fact is the reason for this paper. The problem of standardising machine tools is very important. I propose to treat it in a manner to establish the principles which should be followed to obtain the desired uniformity in details, rather than to go very far into the details themselves, except by way of illustration.

But turning to the machines, there are six important principles in standardisation, which I have formulated as follows:—

1. Standardise corresponding designations and capacities and establish a method of power rating.
2. Standardise devices for holding cutting tools.
3. Standardise devices for holding work and fixtures.
4. Standardise operating movements.
5. Standardise parts concerned in the setting-up of machines with reference to the permanent shop equipment.
6. Accept the geometric progression as a fundamental requisite in designing feeds and speeds.

The application of none of these principles will introduce a radical change in design. The first principle aims at a standardisation of corresponding machine designations and capacities, and the establishing of a method of power rating. In 1903, action was taken by a number of milling machine manufacturers establishing the maximum feed travels for various sizes of knee-and-column milling machines. For example, the maximum feed travels for a No. 2 universal machine were fixed as follows: Longitudinal, 25in.; cross, 8in.; vertical, 18in. This was a start toward standardising designations and capacities. The resulting uniformity is of advantage to the buyer in comparing the various makes of machines designated as Nos. 1, 2, 3, 4, &c.

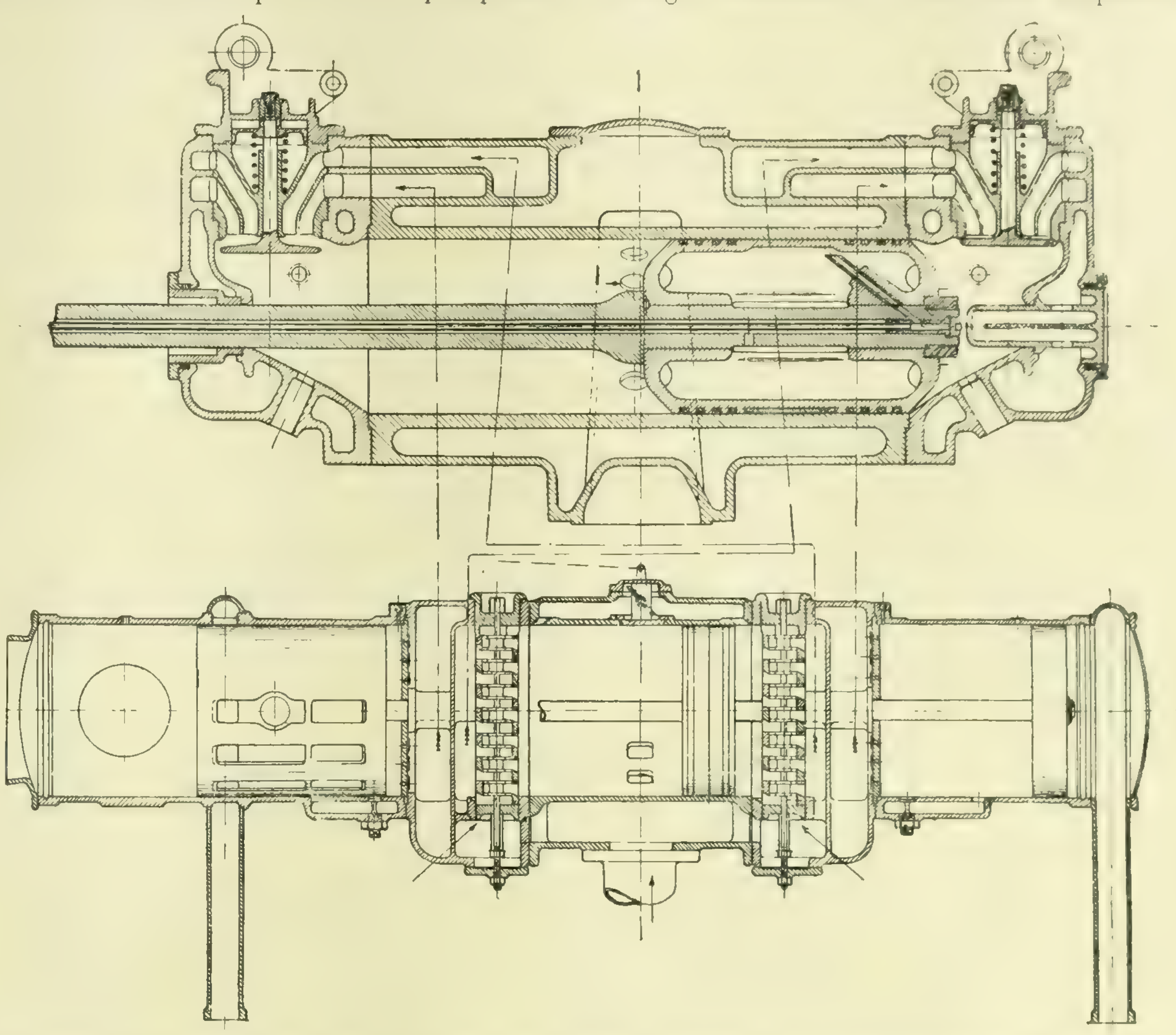
But this is only a beginning. To develop the point let me ask what is a 14in., 6ft. bed engine lathe? To answer my own question, I don't know. From data that has been prepared comparing some of the dimensions of a number of 14in., 6ft. bed engine lathes, it is found that the diametrical swing over the bed ranges from $14\frac{1}{8}$in. to $16\frac{1}{8}$in.; the swing over the plain carriage from $7\frac{1}{2}$in. to $10\frac{3}{4}$in. and the maximum distance between centres from 1ft. 6in. to 3ft. 3in.

From the user's standpoint, it is as important to know the diameter that can be swung and turned over the carriage as it is to know the maximum diameter that can be swung over the ways. And the length of the bed is of no more interest than the height of the lathe hand that operates it. A similar argument can be presented for other kinds of machines, but would only serve to unnecessarily lengthen this discussion. Is there not an opportunity to bring about reasonable uniformity of corresponding designation and capacity, making these descriptive?

Turning to the question of power rating, the user should have some means of distinguishing between the relative capacity for removing metal and mechanical efficiency of machines of the same dimensional capacity. If he asks for bids on a 20in. 10ft. engine lathe, and in one case is quoted £120 and in another £90, he should have some means of knowing that the difference in price represents a difference in metal-removing capacity of the tool. Let me call attention to the phraseology that I have used in connection with this point; that is, to establish a method of rating—not to establish or standardise ratings themselves. Development is giving us light-powered and heavy-powered machines; each kind has its field, but there should be some way to differentiate them except by name.

The second principle refers to standardisation of devices for holding cutting tools. The small tool equipment of a shop represents a large investment. The more adaptable this equipment is, the fewer pieces there need to be in use; the greater the number of hours each small tool can be at work, and, therefore, the greater the operating efficiency of the shop. The interchangeability of lathe tools and tool holders throughout the tool posts of all lathes of a given size, the interchangeability of milling cutters and their collets among machines of different makes, the interchangeability of drill chucks throughout all the drilling machines of a given department, and so on, represents a real increase in efficiency which is so apparent, merely to need mention to be recognised. To show that this principle has already influenced design, I have but to refer to the taper of the hole in the spindles of milling machines. For the No. 2 milling machines, whose dimensions were tabulated, all had the hole in the spindle conforming to Brown & Sharpe's No. 10 taper. Similarly, for the No. 3 milling machines, the spindle taper was found to be uniformly Brown & Sharpe's No. 11. Again, the Morse taper is extensively used in drilling-machine spindles; in the 10 14in. engine lathes investigated, the majority of the tools' post slots were found to be made for $\frac{1}{2}$in. by $1\frac{1}{4}$in. tools.

The third principle proposes to standardise devices for holding work and fixtures. The arguments presented in favour of standardising the devices for holding cutting tools apply here with even greater force, for the devices and fixtures for holding work are more expensive as individuals

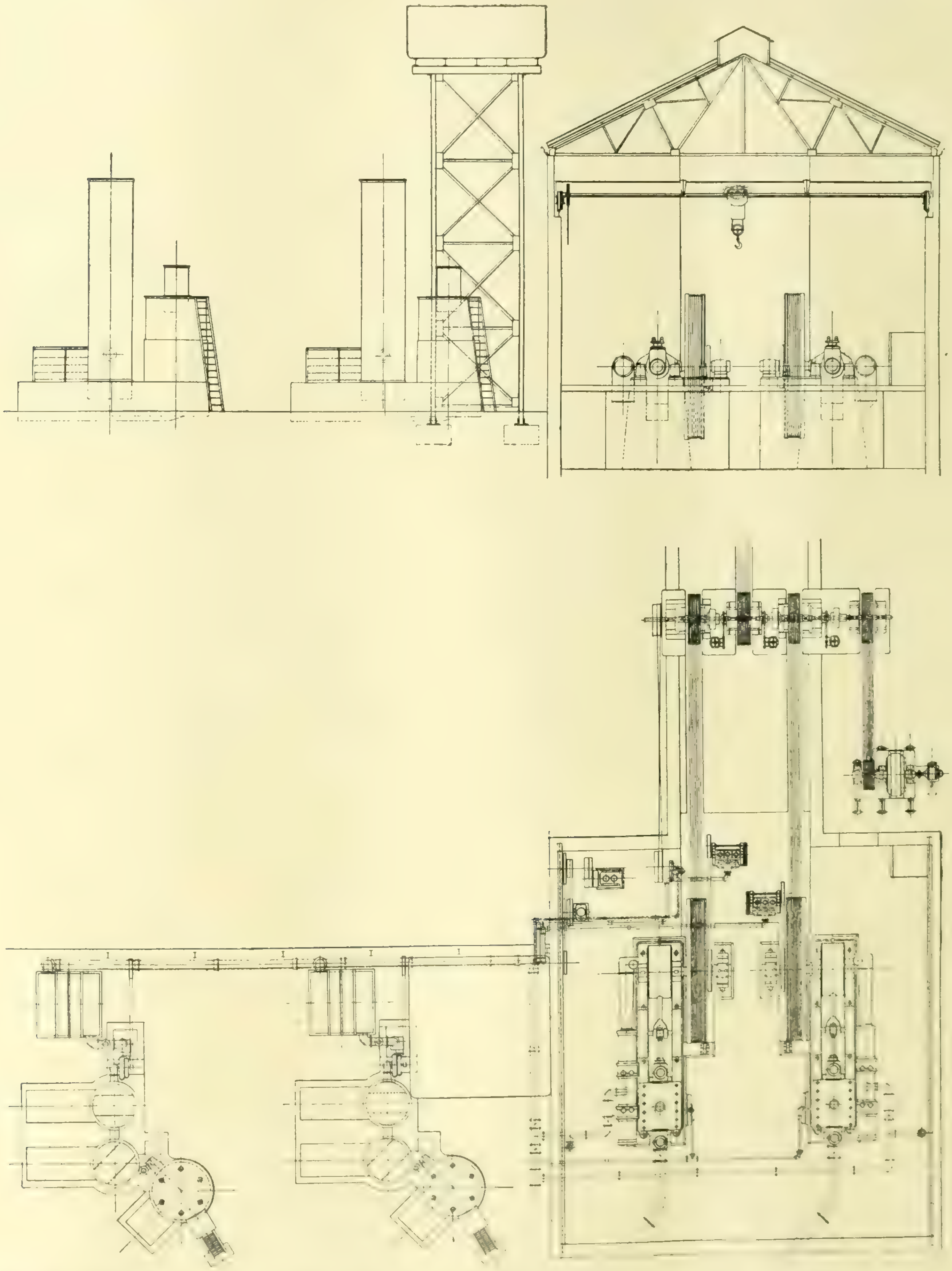


MATHER & PLATT'S PATENT TWO-CYCLE HORIZONTAL GAS ENGINE. Longitudinal Section through Cylinder. (See pages.)

* Abstract of paper presented at the New York meeting of the National Machine Tool Builders' Association.

than are separate cutting tools. Consider the advantages of having chucks interchangeable throughout all of the lathes of a given size in a lathe department, or consider the advantage of uniform T-slots throughout all kinds of machine tools of relative, similar sizes. A milling fixture can then be used on any milling machine of a given number, holding-down bolts can be standardised as regards the sizes of heads, with the full assurance that they can be used on a milling machines. Of the milling machines investigated, the table slots were uniformly $\frac{5}{8}$in.

The fourth principle refers to the standardisation of operating movements. Rapid repetition work depends very largely upon the sense of touch of the operator. Frequently repeated movements become, to a great degree, involuntary. It, therefore, follows that a standardisation of the operating movements of machine tools will contribute to an operator's



[illegible] Two-cycle Suction Gas Engine Plant, operated with Wood Fuel, for South America, by Messrs. Mather & Platt, Ltd., Salford Iron Works, Manchester. Plan and Elevation, showing general arrangement of Engine and Gas Plant. (See page 8.)

machine, or drilling machine, or planing machine, or lathe, as the case may be. In addition to the enormous saving in original investment and increased flexibility of the equipment, there is an attendant saving in the time required on the part of the workmen to find devices that can be used. To show that something has been done in recognition of this principle, I have but to refer to the table slots of milling speed by making his motions, to an extent, involuntary and permitting him to change from one make of machine to another without any disturbance to the habits that he has formed. On all standard lathes, the same direction of motion of the foot stock handle should advance the spindle toward the head. Similarly, a definite direction of motion of the hand wheel on the carriage should advance the carriage

toward the head, and so on, for the other hand-operated movements. To show that this principle has been recognised, in the engine lathes investigated the direction of motion of the operating handles was uniform to produce a corresponding movement of the operating parts.

The fifth principle sets forth the standardisation of parts concerned with the setting-up of machines with reference to permanent shop equipment. There are only a few points to be considered here, such as the spread of the bolt holes in the feet of the countershaft hangers, the drop of the shipper rod, and for motor-driven tools the dimensions of the motor-feed pads. I need not dwell upon the advantage to the user in being able to buy a machine that meets his needs from a machine tool builder, and a motor adapted to the machine from an electrical machinery manufacturer, and assemble them himself with every knowledge that they will fit.

The sixth principle refers to an acceptation of the geometric progression as a fundamental requisite in determining relations throughout the chosen ranges for feeds and for speeds. I have reason to believe that this principle is very generally recognised, especially among those producing milling machines. But there seems to be a wide difference in the ratios aimed at. Personally, I am not in a position to make any definite recommendation along these lines, other than to state the general principle.

To make my argument complete, it is evidently necessary to prove that a lack of uniformity exists in connection with the features covered by the principles outlined above, and at the same time that these differences are of such a nature as to indicate that uniformity can be established. To meet this requirement one of my associates has prepared the accompanying four tables. Two refer to lathes and two to milling machines, and give, respectively, an analysis of many of the features capable of being standardised for 14in. and 20in. lathes, No. 2 and No. 3 milling machines.

The following lists of features to be considered for standardisation are for the four fundamental machines—lathes, planers, drilling machines, and milling machines. This does not imply that standardisation cannot be carried on in connection with some other machines, but the limit of time prevented a consideration of them. However, the principles laid down are of such a nature that they can and should be applied to all classes of machine tools that are of a fixed type and made by a number of builders. The real work of determining dimensions is a long, tedious task, and cannot be done in a weak-kneed, faltering manner. Personal experience in the work of standardisation has taught me that the difficulties in the way are always magnified. The way is easily found if there is a will to do. What follows is suggestive only.

Designations and capacities might be linked together by giving three dimensions: First, the swing over the ways; second, the swing over the plain carriage; third, the maximum distance between centres. Thus, a 14in. 6ft. bed engine lathe would become, say a 14in. by 8in. by 3ft. engine lathe. The maximum swing over the ways should be fixed for each nominal swing; the other dimensions to be exact.

As a suggestion merely, is it necessary to have so many nominal sizes of lathes as are now built and listed? As now arranged, these sizes roughly form an arithmetical progression, having a common difference of 2in. Has anyone considered arranging these sizes in a geometric progression with the direct purpose of reducing their number? If anyone is interested in this speculation, let him start a progression with 10in. and apply the ratio of 1·2.

A standard method of power rating might be to give the horse-power of the driving belt for the machine; this power to be figured by means of a determined formula with determined factors for single, double, and triple belts. This same rating could apply whether the machine was belt-driven or motor-driven, for a given type and size of machine is usually built for both methods of applying power. This will permit a careful designer to develop a design and have a proper relation between power and rigidity. It will also permit the user to compare mechanical efficiencies.

For each nominal size of lathe the following details of designs should be standardised: The diameter, thread, and length of spindle nose; taper of hole in spindle; diameter of hole through spindle; taper of the centres; hole, keyway, face, pitch and kind of teeth of change gears for the ordinary screw-cutting type; number of threads per inch of the lead screw; size of T-slots in wings of carriage, direction of motion of operating handles, controlling movements of footstock spindle, carriage, tool block, and compound rest.

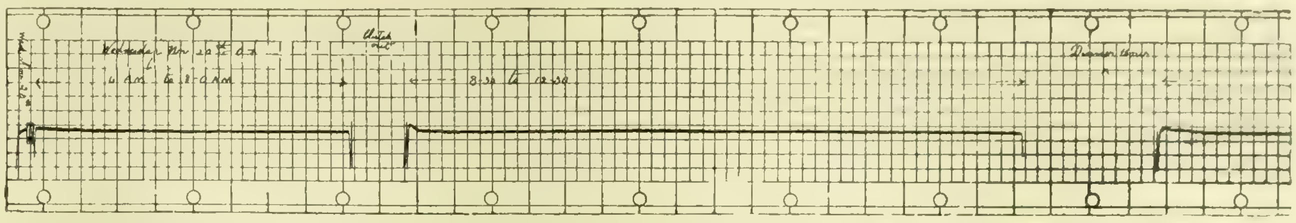
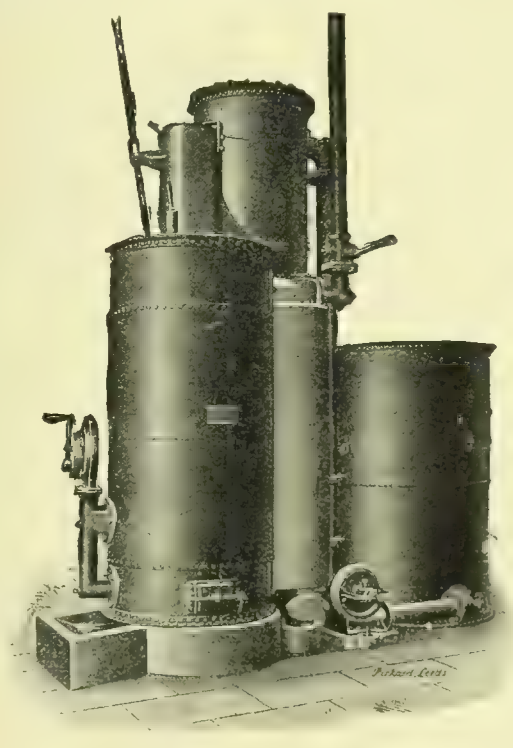


DIAGRAM FROM MOSCROP RECORDER, SHOWING REGULARITY OF TURNING OF MESSRS. MATHER & PLATT'S PATENT TWO-CYCLE GAS ENGINE. (See page 8.)

Features of vertical drilling machines that should be standardised for each nominal size are: Dimensions of a table and of finished surface of base; distance from centre of spindle to face of column; method of power rating; dimensions of the spindle nose, taper of the hole in the spindle; number, arrangement, and size of T-slots in the table and base, maximum distance from spindle to table and from spindle to base; direction of motion of operating handles.

The features to be standardised in connection with planers are: A method of rating; method of stating capacity; number and size of T-slots in the platen, and dimensions of reamed holes in platen and direction of motion of operating handles.

In the planing machine, drilling machine, shaping machine, and lathe, we have a precedent for a form of designation that of itself indicates capacity. Is there any good reason why milling machines should not be styled in similar manner? To illustrate, is not a designation a 25in. by 8in. by 18in. universal milling machine better from the viewpoint of conveying information, than to say a No. 2 universal milling machine?



SUCTION-GAS PLANT, USING WOOD FUEL, FOR 100 H.P. PATENT TWO-CYCLE GAS ENGINE, BY MESSRS. MATHER & PLATT, LTD., SALFORD IRONWORKS, MANCHESTER. (See page 8.)

Features to be standardised in connection with milling machines are: Designation and capacity; a method of rating; a length and width of working face of table; maximum distance from centre of spindle to table; thread on nose of spindle; diameter of nose; taper of hole; width of slot in clutch end; diameter of clutch end and distance from face

Dimensions of Six No. 3 Milling Machines.

SPINDLE DETAILS.											COLUMN DETAILS.					
Thread on nose.	Taper hole in spindle.	Width of slot in end of spindle, inches.	Distance column face to spindle end, inches.	Thread on drawing bolt.	Working surface of table, inches.	Number of T-slots.	Size of T-slots, inch	Spacing centre to centre of T slots, inches.	Telescopic screw.	Outboard bearing, diam., inches.	Width of face of column, inches.	Angle of V on column, degrees.	Distance column angle goes above spindle centres, inches.	Over arm diameter, inches.	Circumferential speed of pulleys, r.p.m.	Weight, pounds.
3¼in. diam., 3½ threads per inch L. H., U. S. S.	11	1½	1⅞	none, bolt not furnished	53 × 12¼	3	⅝	3	yes	2⅛	11½	50	6¼	4¼	760 600	4,350
2½in. diam., 6 threads, U. S. S.	11	none	3	⅝-11 threads	52 long 12 wide	3	⅝	2⅝	yes	2⅜	10⅞	45	2⅛	4½	765 1,225	4,350
3¾in. diam., U. S. S., 4 per inch, L. H.	12	1½	3⅛	¾-10 U. S. S.	48½ × 13	3	⅝	3½	yes	1⅞ 2⅛	12	50	4 below	4½	1,640 1,640	6,700
Five per inch	11	$1\frac{9}{16}$	3¾	12 threads per inch	13½ × 58¼ 63 over all	3	⅝	2½	yes	$1\frac{1}{16}$	12	45	4½	4¾	660 800	4,200
2⅝in. × 12	11	none	1½	⅝-No. 11	49 × 12	3	⅝	3½	yes	$1\frac{1}{16}$ $1\frac{13}{16}$	10½	40	6½	4½	715 1 080	4,200
3¼in. diam., 1⅔ lead, ⅓ pitch, U. S. S.		$1\frac{35}{64}$	3¼	⅝-11 threads	55¾ long 13½ wide	3	⅝	2⅞	yes	2⅜	11¾	45	2¾	4½		

Dimensions of Ten 14-inch Lathes.

SWING.			SPINDLE DETAILS							
Swing over bed.	Swing over carriage.	Swing between centres.	Spindle nose.	Taper of hole.	Centres.	Hole in spindle.	Weight, 6ft. bed, pounds.	Lead screw.	Belt speed.	Size of tool, inches.
—	8½	—	2¼ × 6	Morse 4	M 2	1	1,715	6	285–362	½ × 1
14⅛	8⅜	—	2⅛ × 6	–	M 3	1¼	—	4	645–785	½ × 1
15¼	9½	3′ 3″	—	—	—	$1\frac{5}{16}$	—	8	950	—
16	10½	3′	2¼ × 8	–	– –	$\frac{15}{16}$	1,600	5	475	½ × 1
15¼	10¾	–	1⅞ × 8	–	–	¾	—	6	375	–
15¼	9⅝	3′ 4″	2⅛ × 5	–	M 3	$1\frac{3}{16}$	1,650	—	350–475	⅝ × 1
14¼	7½	2′ 11″	2¼ × 7	–	—	1⅛	1,550	– –	585	—
15¼	8½	2′ 6″	2⅜ × 7	–	M 3	1¼	1,825	—	380–485	½ × 1
14⅞	8⅜	3′ 1″	2 × 7	⅝ per ft.	M 2	$1\frac{3}{64}$	1,600	6	375	½ × 1
16⅛	—	3′	$2\frac{5}{16}$ × 6	⅝ per ft.	M 3	1⅜	1,850	6	525–660	⅝ × 1

Dimensions of Six No. 2 Milling Machines.

SPINDLE DETAILS.					TABLE DETAILS.						COLUMN DETAILS.					
Thread on nose.	Taper hole in spindle	Width of slot in end of spindle, inches	Distance column face to spindle end, inches	Thread of draw-in bolt.	Working surface of table, inches	Number of T-slots	Size of T-slots, inches.	Spacing centre to centre of T-slots, inches.	Telescoping screw.	Width of face of column, inches.	Angle of V on column, degrees	Distance column angle goes above spindle centre, inches.	Over arm diameter, inches.	Outboard bearing diameter, inches	Circ. speeds of pulleys, r.p.m.	Weight, pounds.
2½in. diam., 4 threads per inch L. H., U. S. S.	10	none	1⅜	None, bolt not furnished.	39¼ × 10¼	3	⅝	2½	yes	9⅛	50	5½	3½	$1\frac{13}{16}$	450 595	2,850
2in. diam., 8 threads, U. S. S	10	none	3¼	⅝in., 11 threads.	43¾in. long 10in. wide	3	⅝	$2\frac{5}{16}$	yes	10	45	2¾	4¼	2[illegible]	510 650	3,050
2½in. diam., U. S. S., 4 per inch. L. H.	10	none	3	⅝in., 11, U. S. S.	39 × 10½	3	⅝	3	yes	9¼	50	3½ below	3¼	1[illegible] 1[illegible]	420 470	2,600
Five per inch	10	$1\frac{5}{16}$	3⅞	12 threads per inch.	11¼ × 47¼ length over all 52	3	⅝	2½	yes	10⅛	45	2½	3¼	$1\frac{1}{16}$	580 785	2,460
2¼in. × 12	10	none	1⅜	⅝in., No. 11.	41 × 10	3	⅝	2¼	yes	9½	40	about even	4	$1\frac{1}{16}$	590 730	2,850
2½in. diam., 1¼ lead, ¼ pitch, U. S. S.		$1\frac{35}{64}$	3¼	⅝in., 11 thds.	47¼ long, 11 wide.	3	⅝	$2\frac{5}{16}$	yes	10[illegible]	45	2[illegible]	4¼	$1\frac{13}{16}$ 2[illegible]		

Dimensions of Ten 20-inch 10-foot Bed Engine Lathes.

SWING.			SPINDLE DETAILS.							
Swing over bed.	Swing over carriage	Swing between centres 10ft. bed.	Spindle nose.	Taper of hole.	Centres.	Hole in spindle.	Lead screw.	Weight, pounds.	Belt speed.	Size of tool inches.
—	12[illegible]	6′	3½ × 4	Morse 5	M 4	1½	—	3,800	375–500	[illegible] × 1¼
20[illegible]	12½	6′ 2″	3 × 6	—	M 4	1¾	—	4,000	660–843	
22[illegible]	14[illegible]	6′ 1″				1[illegible]	4	—	445	—
20[illegible]	12[illegible]	5′ 4″	—	—	1[illegible]	1[illegible]	—	4,600	880	—
22[illegible]	13¼	5′	3½ × 5	—	Morse	1[illegible]	4	4,200	660–825	[illegible] × 1[illegible]
21[illegible]	13[illegible]	5′ 5″	2[illegible] × 5	—	Morse	1[illegible]	—	4,490	807	
20[illegible]	13[illegible]	5′ 6″	2¼ × 5			1¼		3,300	600	[illegible] × 1¼
22	14[illegible]	5′ 9″			M 4	1½		4,200	330	
21[illegible]	12[illegible]	6′	2¼ × 6	—	—	1[illegible]	—	3,800	347–460	[illegible] × 1¼
20[illegible]	11¼	6′ 1″	3 × 6	—	—	1[illegible]	—	3,260	—	—

of column to end of spindle nose and taper of hole of spindle of vertical attachment and index head; diameter of over-arm; distance from centre of arm to centre of spindle; diameter of bore for outer arbor bearings; width of face of pillar and solid angle of edges; distance face extends above spindle centre; number, size, and spacing of table slots; diameter and thread on draw-in bolt; general position and direction of motion of operating handles.

Thus far my argument has been directed toward standardisation within the general limits of a given size of a given kind of machine. We must also consider the advantages of inter-class standardisation. But this discussion cannot be carried very far until detail dimensions have been tentatively determined upon for the various sizes of the various classes.

The establishing of a standard method of power rating has been touched upon. It is evident that such a method would apply to all sizes and all classes of machines.

Turning to details of design, a ⅝in. T-slot should have the same dimensions whether it is in a milling machine table, a drilling machine base, a planing machine platen, the wings of an engine lathe carriage or the table of a shaping machine.

If there is an advantage in being able to exchange chucks throughout the individual machines of a lathe department, is there not an added advantage if these same chucks can be used on certain sizes of milling machines? To put it a little more concretely, why should not the spindle noses of 16in. engine lathes and No. 2 milling machines be identical, and again, why should not the noses of No. 3 milling machines and 20in. engine lathes be the same?

Turning to our fourth principle of standardisation, should not the general position and direction of motion of the operating handles of a 14in. lathe correspond with those of a 20in. lathe? Should there not be similar uniformity between a No. 2 milling machine and a No. 3 milling machine, and so on?

Referring to our fifth principle of standardisation, should not the space of the holes in the feet of countershaft hangers for countershafts of approximately the same weight and subjected to the same stresses, be uniform without reference to the machines they are used with? The advantage of such standardisation in aiding the locating, spacing, and setting-up of countershaft stringers is apparent. Again, should not the pads for the feet of a 3 h.p. motor to be applied to a lathe be identical with those for a similar 3 h.p. motor to be used on a milling machine?

As another general point, no screw or other part should be tolerated that has a travel of such a length that a hole must be cut in the floor to accommodate it. Machine users cannot countenance the cutting of holes in shop floors, particularly in buildings where the materials of construction are fire resisting.

It may seem to you that I have mentioned many points where uniformity already exists. If such is the case, the work of standardisation is made all the easier, for all that is necessary is for your association to adopt them formally as your standard.

Finally, I wish I could make you feel the enthusiasm with which this matter has been received by all the machine users with whom I have discussed it. From the viewpoints taken, it has been evident that the advantages of such uniformity will be felt not only in large manufacturing departments of machine shops, but likewise in the tool-making room and in the job shop. Its advantages in all three of these places have been emphasized to me.

Another Oil-Engine-driven Boat.—The German Petroleum Company has, we learn, placed a contract for the building of a twin-screw oil-carrying boat with J. Frerichs & Co., Ltd., Osterholz-Scharmbeck and Einswarden (Oldenburg), which is to be propelled by crude-oil motors. The vessel will have a length of 312ft. between perpendiculars, 44ft. beam, and a moulded depth of 26·2ft. Her total freight capacity is to be 4,000 tons. The engines, which are to be installed at the aft end, will consist of two of Prof. Junker's type of reversible crude-oil marine motors, of approximately 1,500 h.p., giving the ship a speed of 10 knots. An auxiliary boiler will be fitted for heating and other purposes.

BRITISH STANDARD SPECIFICATIONS FOR MATERIAL USED IN RAILWAY ROLLING STOCK.

FROM the Engineering Standards Committee we have received a copy of the British Standard Specifications for Material used in the Construction of Railway Rolling Stock (Report No. 24, Revised 1911), which has just been published.

Since the issue of the first revision in June, 1907, the Committees on Locomotives and Railway Rolling Stock Underframes have from time to time had brought before them points which have arisen in connection with the use of the standard specifications, and the present issue of Report No. 24 embodies the committee's decisions in regard to these. Some of the more important modifications to the specifications are as follows:—

1. The prohibition of a re-test in the case of failure under the falling weight test for axles.
2. The option of a bend test in the specification for carriage and wagon axles (without analysis) if there is any question in the mind of the engineer as to the axle having satisfactorily passed the falling-weight test.
3. The deletion of the specification (without analysis) for locomotive tyres.
4. The deletion of Class B tyres (42-48 tons per square inch) from the specification (with analysis) for locomotive tyres.
5. The addition of Class C tyres (50-55 tons per square inch) to the specification (without analysis) for carriage and wagon tyres.
6. The deletion of Class A tyres (35-40 tons per square inch) from the specification (without analysis) for carriage and wagon tyres.
7. The insertion in the tyre specifications of a formula for the deflection under the falling-weight test based upon the thickness and internal diameter of the tyre in place of that previously employed which was based upon the internal diameter only.
8. The division of the specifications for laminated springs and spring steel into separate specifications, dealing respectively with spring steel and with the finished springs. With a view of restricting the tensile stress on the plates of the finished spring under the scragging test to a figure somewhat below 70 tons per square inch, a definite deflection, depending upon the length of the top plate of the spring and thickness of the thickest plate, is now specified, and a table of the required deflections is inserted in the specification.
9. The addition of a further class of forgings (Class E) to the forging specification.
10. The reduction of the tensile strength of rivet bars to 24-28 tons per square inch.

The committee have had representations made to them with regard to the use of the term "elastic limit" in the axle and forging specifications, and this term has now been altered to "yield point," a definition of this latter term being added as a note to the specifications in which this term is employed.

The committee recommend that in specifying materials to any of the specifications contained in this report, both the specification number and the number of the report be quoted, in order to obviate confusion with other reports of the committee.

The report in its present form was approved by the sectional committees concerned in October, 1911, and by the main committee on December 6th, 1911.

Prizes for Military Aeroplanes.—The following are the prizes to be offered by the War Office for a competition to fulfil the requirements of the specification for a military aeroplane: A first prize of £4,000 and a second of £2,000 for aeroplanes made in any country, and a first prize of £1,500, two second prizes of £1,000, and three third prizes of £500 for British subjects with aeroplanes manufactured wholly in Great Britain except the engines. The War Office have the option of purchasing for £1,000 any machine awarded a prize.

BALL BEARINGS FOR HEAVY LOADS.*

BY H. GANSSLEN.

As presented to the practising engineer, the problem of friction in bearings is one connected principally with the question of economy in the operation of machinery. It is a problem, however, that has a broader meaning as well. Reduction in friction brings about saving in fuel. The conservation of our fuel resources is an important part of the movement towards the conservation of all natural resources that is attracting so much public attention.

The economies being obtained by the generation of power in central stations have eliminated a large number of small

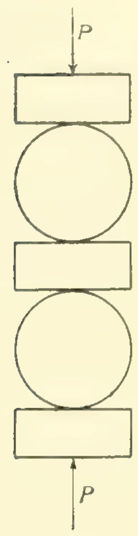


FIG. 1.

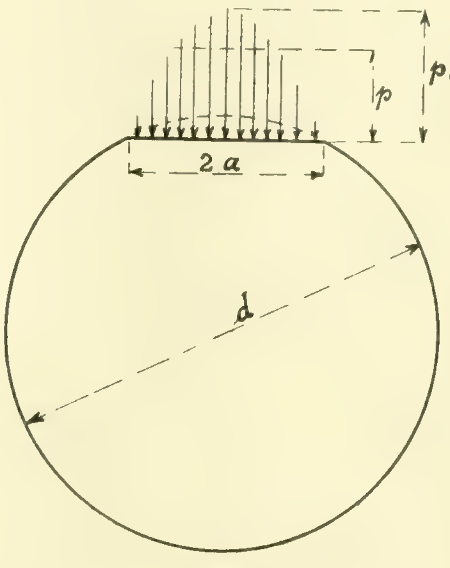


FIG. 2.

individual power plants. This, while unfortunate in that it works hardships on the small producer, is undoubtedly a development along logical lines. But, in the most economical steam power plant, there is only about 12 per cent. of the energy of the coal made available for driving machinery. Out of this amount from 15 per cent. to 60 per cent. is lost by friction in transmitting the power from the engine to the individual machines and tools of the plant. Furthermore, there are friction losses in the various machine tools, the magnitude of which is often unknown to the designer; in fact, in many cases these losses are not even considered, as we have grown to look upon them as a necessary evil. The element of machine design, which is the most important factor in the way of power losses by friction, is that of shaft bearings.

The writer has spent considerable time in engineering testing and research work connected with bearing friction, and the subject matter of this paper is largely the result of tests made by the writer under the direction of Prof. Stribeck, at the engineering laboratory of Neu-Babelsberg, near Berlin. This laboratory, erected about 14 years ago by an association of German manufacturers, was designed to provide a central institution where engineering investigations having a commercial end in view could be conducted thoroughly and economically. The writer is indebted to Mr. Henry Hess, of the Hess-Bright Manufacturing Company, for some of the illustrations and for a portion of the information given in this paper.

As early as the time of Aristotle some thought was being given to the question of friction in bearings. In his work, entitled "Mechanical Problems," Aristotle treats this question in discussing rollers and wagon wheels. In the writings of Leonardo da Vinci it is shown that the angle and coefficient of friction are independent of the size of the sliding surfaces. Various later writers have treated this question, but there has been much difference of opinion on important points, and many contradictory statements have been made, and only in recent years has it been possible to establish principles and methods of an authoritative nature, based on scientific deduction.

About 1[illegible] years ago the German Small Arms Company began manufacturing steel balls, and at the same time tried to [illegible] the demand for them, especially for the larger [illegible]. The ultimate was an attempt to build ball bearings for any desired load. At that time no theory of design existed other than certain empirical rules derived from experience in the manufacture of ball bearings for bicycles. This firm turned the matter over to the above-named laboratory for investigation. These investigations, extending over several years, were made and general principles were established. This work resulted almost immediately in the adoption of the ball bearing for automobiles, and for other engineering purposes. Tests were made at the same time on representative types of roller and plain bearings with a view to determining their friction at different loads and speeds, their permissible loads, and other features and merits.

The Ball Bearing. — Prior to this time there was no engineering basis for designing ball bearings, except a few formulas on the "Contact of Elastic Bodies" by Hertz, and other formulas by Auerbach. These, in some respects, contradicted each other. Manufacturers of steel balls stated that the permissible load on a ball in a bearing was 9.940 d^2 lbs. where d was the diameter of the ball in inches. They arrived at this figure by breaking a ball between two hardened steel plates in a testing machine and taking one-eighth of the breaking load as being the permissible load. To-day, it is known that the permissible load on a ball in a bearing is about one-fourth or less of the one then given. This fact accounts for many failures in the past. We know further that the breaking load of a ball cannot give any information as to the permissible load in service and that to arrive at the latter we must consider the occurrences at the places of contact between the balls and ball races, or balls and plates. See Fig. 1.

After several years of investigation, the following principle was established: In hardened steel balls under pressure the average stress p, Fig. 2, as well as the maximum stress p_o, in the flat surface of contact, is equal for balls of any size if the loads are proportional to the square of the diameter d of the balls; or, to formulate, $p = kd^2$, where k is a coefficient determined by the kind of material used and the shape of the supporting surface, whether plane or curved.

The balls used for the early tests reached their elastic limit with a load of 71 d^2 lbs. After passing that load, the sets appeared very slowly, so that at a load of 568 d^2 lbs. the set was only about one-fiftieth of the elastic compression. If a hollow support is used having a radius of two-thirds d in place of the flat plate, the load sustained is about $3\frac{1}{2}$ times that of the previous case.

The material used for the balls and races was, aside from the design of the bearing, the most important factor in the matter of success or failure.

Tests. — The regular tests of the material comprise the hardness, toughness, and fracture tests, the latter being

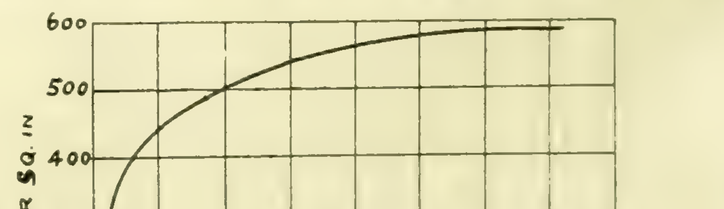


FIG. 3.—HARDNESS OF WELL-HARDENED [illegible] BALLS.

mainly for the purpose of getting information of the structure or grain of the material. Later on, a vibration test was added, and all these tests were checked, so to speak, by a running test of the complete bearing at different loads and speeds: this not only furnished frictional data, but often was severe enough to cause destruction of the bearing.

Hardness. — If two balls of the same material are pressed together with a load P, there is formed a circular plane surface of contact of radius a. The area of this surface increases at first with increasing load at the ratio of $\sqrt{P}$, and the average stress $p = \frac{P}{\pi a^2}$ increases at the ratio $\sqrt{P}$

*Paper presented before the Western Society of Engineers, September 13th, 1911.

Shortly after passing the limit of proportionality of the material, the area of contact grows faster and the stresses slower than at first, until finally a point is reached where the area ka^2 increases in the same ratio as the load, and where, consequently, the stress remains constant up to the breaking point of the ball. This stress, which indeed is a very noteworthy point, is called the hardness of the ball (see Fig. 3). Good balls of any size have a hardness of from 1,107,000lbs. to 1,206,000lbs. per square inch. Small balls have usually

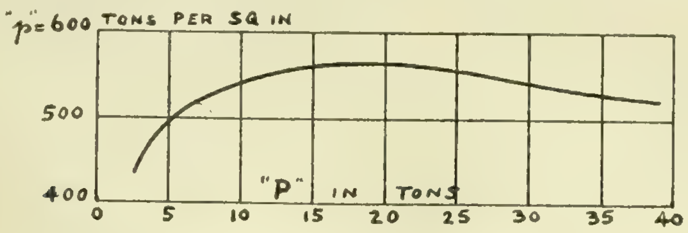


FIG. 4.—HARDNESS OF POORLY-HARDENED $\frac{7}{8}$IN. BALLS.

the greater and large balls the lesser hardness. Balls that are not thoroughly hardened clear through, but have a hard outer shell only, show a decrease of hardness after the latter has reached a maximum, as indicated in the diagram, Fig. 4.

Toughness.— If the load on two balls is gradually increased, a stage is reached where fine local cracks become visible at or near the circumference of the circle of contact. The first of these cracks follows that circumference exactly, and at its very inception is visible only under the microscope and after the surface of the ball has been treated with an acid. This load is still far below the breaking load. The larger the load and the compression at the moment when this first surface crack appears, the tougher is the ball. Toughness is defined as the mechanical work necessary, per unit of the cubic contents of the ball, to compress the ball between two other balls of the same size up to the point where the first surface crack appears. Good balls must have a toughness of not less than 3·56 ft.-lbs. per cubic inches, which corresponds to a load of about 6,675 d^2 lbs. (d in inches). This refers to balls of any size. Exceptionally good ones have a toughness of as much as 11·86ft.-lbs. per cubic inch.

Breaking Test.—This test is made to get the breaking load and especially to get fresh and clean surfaces to show the grain or structure of the material. From the appearance of the surface in case of hardened steel, important conclusions are drawn: it shows whether the ball was overheated in forging, annealing, or hardening; whether it is hard clear through, as is to be expected of a good ball, or whether it

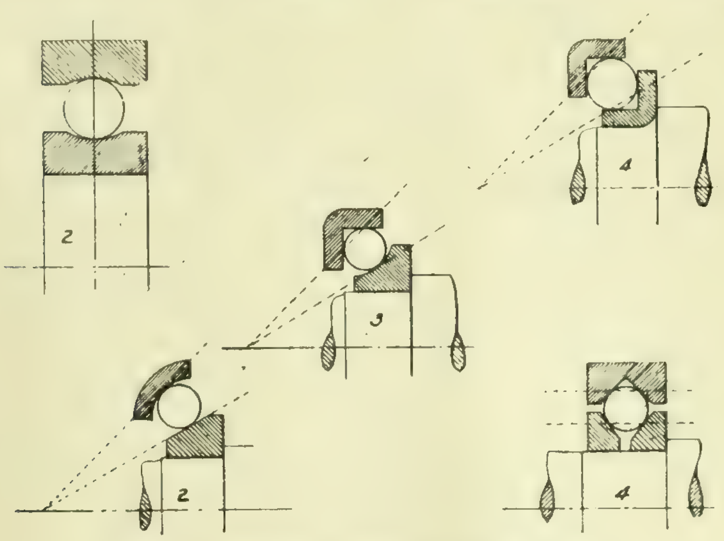


FIG. 5.—DIFFERENT FORMS OF BALL BEARING.

has only a hardened shell; and in the latter case, whether the hardness diminishes gradually or suddenly toward the centre. The ball under test is usually put in the testing machine between two other balls, as it then splits along a plane through the centre. The load at the breaking point is of no importance, as there is no relationship between that load and the admissible load on a ball in a bearing. The latter is better determined by the previously-described tests. Two extreme cases show this lack of relationship: a $\frac{7}{8}$in. ball showed the first crack at 7,820 d^2 lbs., and broke at 113,500 d^2 lbs.; a $1\frac{1}{4}$in. ball showed the first crack at 14,200 d^2 lbs., and broke at 49,700 d^2 lbs.

Sundry Tests.—Recently there has come into use a bending or rather a vibration test of the material entering into the manufacture of ball bearings. A piece of rod of the material to be tested is subjected to a series of rapid light blows, and the number of blows given before certain defects appear on the surface gives a criterion as to the suitability of the material. A convenient means of testing the hardness of a ball race without having to waste it, is the *scleroscope*. A minute weight with a diamond point is dropped from a certain height on to the object to be tested, and from the rebound comparative conclusions are drawn as to fitness of the material for the purpose in view. Of two ball races of the same hardness (as tested by the use of a file), one will show a smaller rebound than the other, which may have been burned and was thereby rendered useless, or at least inferior in quality.

The Bearing.— We now turn to the bearing itself; in Fig. 5 are shown a number of types that were tested. These are of the 2, 3, and 4 point contact type. The first one was adopted as the standard of the radial bearing on account of its lowest possible coefficient of friction combined with its relatively highest admissible load. All the other types are of the built-up type, and are therefore provided with an adjustment; thus making them possible or even probable of destruction by inexperienced attendants.

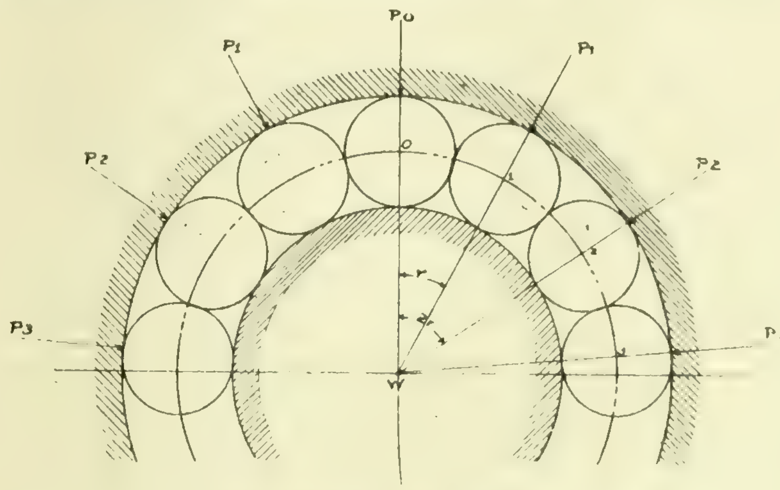


FIG. 6.—TYPICAL BALL BEARING.

The fewer the balls used, or in other words, the larger the diameter of the balls, the less will be the friction in the bearing. In the standard bearing, from 6 to 20 balls are generally used. Referring to that case we have Fig. 6:—

$p_o z = 5P$ for the whole bearing unit, and

$p_o = kd^2$ for the maximum load on any one ball.

P is the total load on the bearing, and z is the number of balls; k is a coefficient explained above.

From these two equations the following equation for the design of the standard bearing is derived: $P = \frac{kd^2 z}{5}$. Where P is given in lbs. and d in units of $\frac{1}{8}$in., and the radius of curvative of the race is two-thirds, then $k = 33$ for those alloy steels that have proved most satisfactory for the purpose. The constant 5 was deduced mathematically. More accurately it should be given as 4·37, assuming that there is no play between the balls and races, and that the latter cannot get out of shape when under load. In using this constant it might appear as though one-fifth of all the balls participated equally in carrying the load. In reality, of course, only the one ball directly in line with the direction of the load has to carry the maximum load p_o.

In Fig. 7 is shown a friction test diagram of the standard radial bearing, giving the relation between load and coefficient of friction. The latter is practically constant for widely-varying loads, so that at one-tenth of the rated load the coefficient of friction increases only from 0·0015 to 0·0030. This coefficient refers to the diameter of the shaft so as to make it directly comparable to the one given in the same figure for plain bearings. The shaft diameter used for all tests was $2\frac{3}{4}$in. Any ball bearing which under its rated load has a coefficient materially larger than 0·0015 is inadmissible because it has an undue amount of sliding friction and its life will consequently be short. There is no change in the coefficient of friction owing to speed: and the kind of lubricant, whether thin or heavy, is also without effect. This,

however, does not mean that the bearing can run successfully without oil, or with oil containing acids often found in certain lubricants; such conditions are disastrous to the bearing.

The radial bearing, Fig. 8, can also be used in places where there are moderate axial or thrust loads not exceeding one-third of the radial load; as the races are uninterrupted, the balls being inserted to fill only part of the annular space: the clearances are then filled by distant pieces which also act as oil carriers. For larger thrust loads it is necessary to use

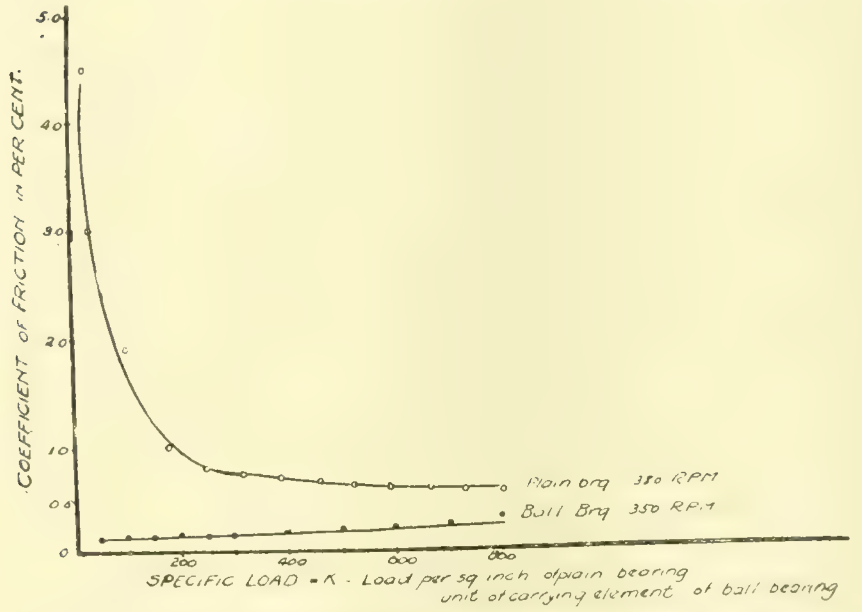


FIG. 7.—FRICTION TEST DIAGRAM, COMPARISON OF A PLAIN AND BALL BEARING.

a regular thrust bearing, as shown in Fig. 9. Without going into details, it may be said that the admissible load of this bearing decreases with increasing speed. This fact would indicate that there is a certain amount of sliding friction prevailing, owing to centrifugal action, in contradistinction to the standard radial bearing. The distribution of the load over all the balls is of the greatest importance, and the illustration shows the means employed to that end. The successful ball bearing must comply with the following requirements:—

Design: The carrying surfaces of the races should be at right angles to the load direction and be curved with a radius somewhat greater than half *d* to get the maximum carrying capacity. The races should be uninterrupted; that is, filler openings for the balls should be omitted.

Material: Material must be uniform in hardness and toughness not only as to the different parts of a bearing, but also as to the particles of each individual part. The elastic limit, hardness, and toughness must be high to the best obtainable degree.

Workmanship: The running surfaces must be true as to shape and size. The balls in one and the same bearing must not vary in diameter more than 0·0001in., both individually and collectively. The running surfaces must be ground perfectly, and when examined under a microscope of low power there must be no scratches visible. Ball-bearing and ball-making machinery have been perfected to such a degree that the radial clearance of an assembled radial bearing is less than 0·0001in., and the axial clearance ranges from 0·006in. to 0·0006in. according to the size of the bearing. Ordinary commercial balls, as a rule, do not fulfil these exacting requirements, and no one but a specialist can make a ball bearing comply with them and guarantee results. Their manufacture requires the closest supervision, and the price cannot be expected to be as low as that of a plain bearing. Engineers, of course, have to look to the question of cost.

Recent shop practice has demonstrated the commercial outcome of the above theories and tests by the adoption of ball bearings under almost all conditions of loads and speeds. The earliest and most important use was on automobiles, where power economy is an all-important factor. Hundreds of thousands of ball bearings have been used for this purpose, as in the actual construction of grinding machinery, cranes, mine hoists, paper machinery, gun carriages, electrical machinery, marine appliances, line shafts, &c.

It is a well demonstrated fact that in the average manufacturing plant there is wasted in the line and countershaft bearings from 20 per cent. to 60 per cent. of all the power consumed. A few years ago the author was called upon to investigate the advisability of using ball bearings in place of the ordinary plain bearings for the line and countershafting, in a new can-making plant, where about 135 hangers for $1\frac{15}{16}$in. and $2\frac{3}{16}$ in. shafts were to be used. The excess cost of ball bearings over plain hangers was considerable. It was estimated that it would take about five years to make the calculated power saving pay for the excess in first cost. It was decided not to incur this expense, especially since power cost was a small item in the total cost of production. The assumptions as to the loads on the bearings were weak, because they were based on the friction of individual bearings as tested in the laboratory. In the meantime, more accurate tests were made as to the total friction on line shafts (see Transactions A.S.M.E., 1908). These tests show that the actual line shaft friction is very much larger than was figured on in the above case, and that the saving, therefore, as estimated was too small. Furthermore, the ball bearing to-day is lower priced than at that time, and in the average case now it is a well-paying proposition. The results of the tests point to a saving of 37 per cent. annually as a return on the extra investment. In view of the fact that ball-bearing line shafts can be run at higher speeds than plain ones without danger of overheating, it is even possible, under certain local conditions, to get the first cost of the total equipment as low as with plain bearings, or lower. This is partly due to the use of smaller belts, pulleys, shafts, &c., incidental to the higher speed. On account of the low friction there is no overheating possible, and line shafts in flour, saw, cotton, powder, and other mills should be equipped with ball bearings because of the lessened danger from fire and lower insurance rates.

Plain Bearings. — In Fig. 7 is shown two curves referring to tests with plain and ball bearings In a similar manner as they demonstrate graphically the dependence of the coefficient of friction upon the specific load, it has also been proved that the speed, the temperature, the lubricant, and the occurrences during the dangerous period of the running-in are all affecting the coefficient of friction in a large measure. Under the best obtainable conditions of load, speed, &c., during such a laboratory test, the coefficient of friction is not vastly different from that of the roller and ball bearing, but such conditions do not prevail in practice. The friction of repose, also at starting and slow speeds, is

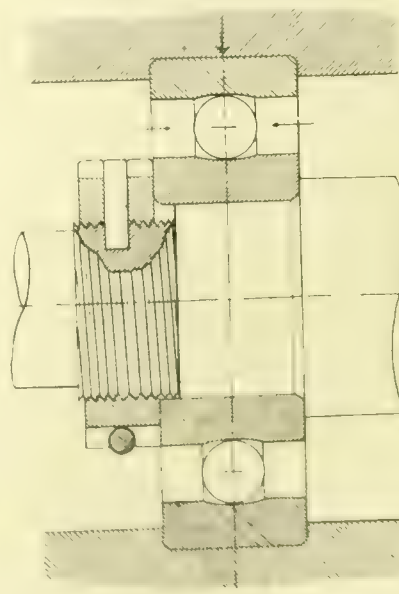


FIG. 8.—COMBINED RADIAL AND THRUST BALL BEARING.

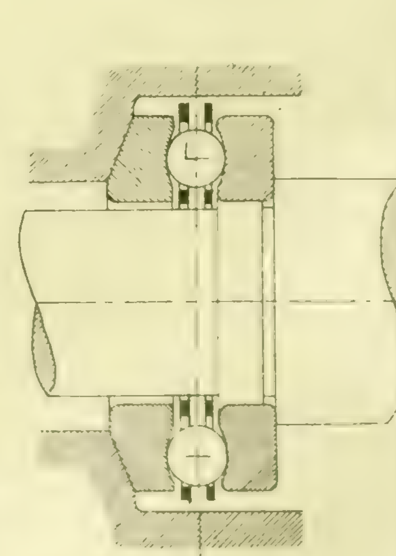


FIG. 9.—THRUST BEARING.

especially high on the plain bearing, and for these conditions the saving of the ball bearing is particularly apparent.

Roller Bearing. — Theoretically this bearing should have the same low friction as the ball bearing: but the theoretical requirements set forth above cannot be met. The materials and workmanship, as well as the accuracy of the present commercial roller bearing, are far below the requirements, and consequently the coefficient of friction is larger than that of ball bearings, as indicated in the diagram. Fig 10. In relation to load and speed, this diagram shows points of

similarity to the plain-bearing diagrams already shown. On account of the relatively soft materials that it has been found practicable to use, this bearing is principally used for light loads. This sounds rather strange in view of the common reasoning of the mechanic as to the larger line contact of a roller over the point contact of a ball. The roller bearing is proportioned in a manner analogous to the ball bearing: the formula used is $P = \frac{k\,l\,d\,z}{5}$, l being the length of the roller, and the other symbols having the same meaning as in the ball-bearing formula. The coefficient k must be small, as the rollers are relatively soft. For this reason the bearing is practically as long as an ordinary plain bearing of the same capacity. On the other hand, the ball bearing is no wider than the hanger itself, thus making available valuable space for pulleys on line shafting, for instance.

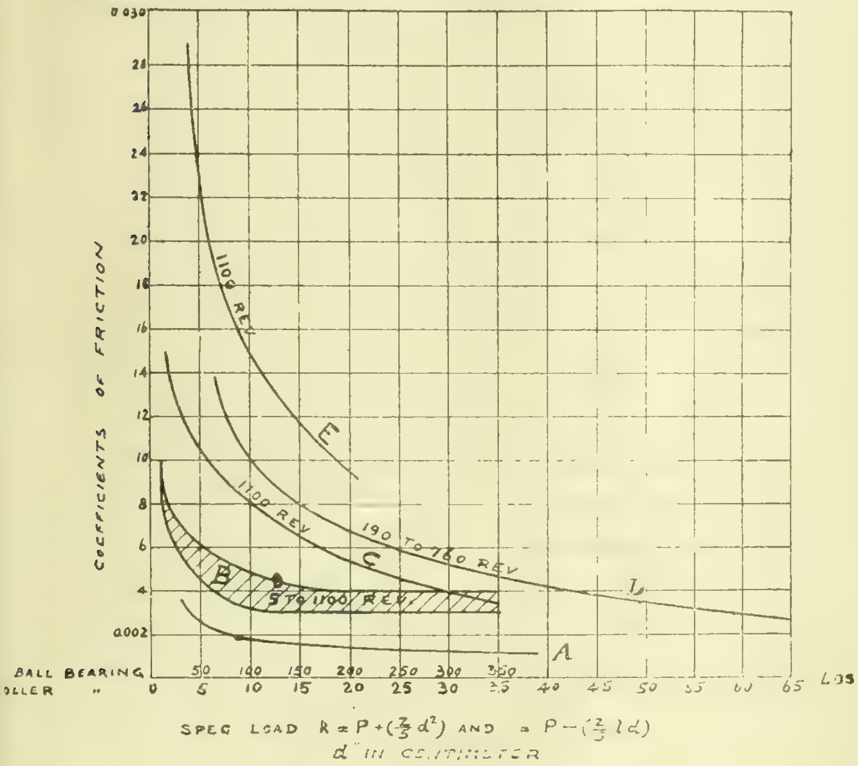


FIG. 10.—FRICTION DIAGRAMS.
A, Ball Bearing with 14 balls; B, Hyatt Roller Bearing; C, Kynoch Roller Bearing; D, Roller Bearing, Hollow Cylinders on pins; E, Mossberg & Granville Roller Bearing.

Conclusion. — It would appear that to-day there are very few conditions under which the ball bearing cannot be used successfully, assuming that the requirements and conditions are clearly understood by the maker, and that the bearings are properly mounted. The troubles incidental to the running-in of the plain bearing are avoided; the friction is as low the first day as it will be after years, and there is no wear. Any visible wear means destruction.

The item of saving power is in most cases so important as to pay for the bearing in a reasonable time, 90 per cent. of the friction of plain bearing being often saved by the ball bearing. Ball bearings require very little space on the shaft for any speed or load as compared with plain or roller bearings. As the ball bearing does not heat, there is no fire danger due to hot boxes.

There were many failures in the early stages of development. Most of them were due to the fact that there was little or nothing in the way of scientific basis for design. Some failures occurred when mechanics tried to make ball bearings for their own use without the necessary knowledge or appliances. Failures have been caused by insufficient allowance for belt pull. The bearing would seem to be sufficient if figured on the customary basis of 40lbs. to 60lbs. of belt pull per inch of belt width; but experience has shown that belts are often made too tight, and the present practice is to figure on 350lbs. per inch of belt width.

The theoretical basis for the design of ball bearings is now well established: but the exacting requirements confine the manufacture to a few specialising firms. Standard radial bearings are made in units up to 15,000lbs., and thrust bearings, for slow speeds, as high as 300,000lbs. load. Special bearings for practically any load are feasible.

ELECTRIFICATION OF RAILWAYS.*

BY E. O'BRIEN

(*Concluded from page 803.*)

IT is not generally realised by those not intimately connected with railways that a large proportion of main line railway mileage lies in the neighbourhood of large towns, and, as a natural corollary to this, neither is the unremunerative expenditure realised which would have to be incurred in providing electrical equipment on the overhead system for long lengths of sidings and running loops which, though very necessary, are only in active use for a small proportion of the day; for instance, more than one-third of the total track mileage of the Lancashire and Yorkshire Railway consists of sidings, exclusive of loops; for it is to be presumed that any general electrification of a railway would include the operation of goods trains, as otherwise not only would a remunerative night load on the power house be lost, but extra cost would be incurred in maintaining both locomotive and electrical establishments.

This question of the nature of a railway's mileage has a profound influence on the choice of a system of electrification. It is not merely a question of whether the bulk of the track mileage is main line or suburban, but of whether the bulk of the train mileage is main line or suburban, passenger, or goods. If the London, Brighton, and South Coast Railway are satisfied that electrification of the whole of their main line is profitable and within measurable distance of attainment, then it is possible, considering the fact that the bulk of their services are branch passenger services, that they have done wisely in choosing the single-phase system for their suburban passenger services; but it would be very unwise to argue from the Brighton results that the single-phase system is applicable to the Lancashire and Yorkshire or inapplicable to the South-eastern Railway.

Taking definite figures, the cost of a straightforward piece of main line on the third-rail system may be taken at £800 per mile of single track, or £1,000 per mile with many junctions, section switches, &c. The cost of the overhead line of the Rotterdam-Hague-Scheveningen line is £1,200 per mile. This is a plain straightforward suburban line, free from complicated junctions, and in a level country. The cost of the London, Brighton, and South Coast Railway electrification has yet to be revealed.

A figure based on American practice works out at £1,130 per mile of single track. The more rigid requirements of this country, however, would increase the cost about 25 per cent., *i.e.*, the cost per mile of straightforward single track for overhead construction would be £1,200, or about £800 per mile of double track more than third-rail construction, and this is on the assumption that no structural alterations are required.

With a line properly sectioned with regard to the power required, the cost of feeders and transformers will be the same in both cases, and the power house equipment will also be the same, therefore there will be a surplus of £800 per mile in favour of the third-rail system. This would provide for a 200 kw. of rotary converter power and feeders, housed and connected up, per mile of double track, which is ample allowance for straightforward main line work. The Liverpool and Southport line has 300 kw. of rotary converters per mile of double track, but this is for a very heavy and frequent suburban service.

For main line work the systems are on a fairly equal footing, but when the work in the vicinity of, and in towns, and the sidings and loop work is considered, the cost per mile will be less for the third-rail system, but will be much greater for the overhead system on account of the physical difficulties already mentioned. It may be noted that in the case of heavy third and fourth rail construction, say using an 80lbs. rail, the cost of the working conductor material is about 60 per cent. of the cost of track electrification, but in the case of high-tension overhead construction it is only 15 per cent.; the third-rail construction therefore lends itself to economy in first cost in dealing with sidings and loops, referred to above, as the cost per mile can be readily reduced by using a

* Paper read before the Manchester Association of Engineers, November [illegible], 1911.

lighter conductor where traffic is light and high momentary electrical losses are permissible.

Anyone who has seen the admirable manner in which a single-phase electrification has been carried out by the Prussian Government on the Dessau-Bitterfeld line will admit the perfect suitability of the system chosen in this case both from the standpoint of prime cost and maintenance. The commercial soundness of electrifying such a line at all may be doubted, but not the wisdom of choosing the single-phase system.

The greatest difficulties, however, in English railway practice occur in operation. Two considerable advantages (assuming equal efficiency in all respects) are claimed for the single-phase overhead system as compared with the third-rail system.

(1) The working conductor is inaccessible to the public and the staff, and therefore safe.

(2) It is unnecessary to have sub-stations in the case of short lines, and with long lines the sub-stations can be fairly widely spaced, and do not require attendants permanently on duty. But on the other hand, in considering the electrification of such a line as the Lancashire and Yorkshire on the single-phase system, it is certain that as many sectionalising points would be required as sub-stations on the third-rail system. The signalman could hardly be expected to attend to the switches, so that permanent attendants would almost more easily dealt with than to the overhead conductor. The most likely sources of accidents to a overhead network will be defective insulators, broken wires, or disturbances to supporting poles due to derailed vehicles, instances of which have occurred on the London, Brighton, and South Coast Railway.

The work of repair involves at least the use of ladders, and probable use of lifting tackle. It is not always probable that such accidents will occur within a few yards of the station where platelayers or other help may be obtained, and the fact that trains are brought to a standstill in the section by the accident, and are blocking the line, will necessitate tedious manual transport of heavy train repair material to the scene of the trouble. On the other hand, a damaged third-rail insulator can be knocked out by the blow of a hammer, and an overturned rail can be set into position by any platelayer; in fact, by using a few boards to stand on, work can be safely done on the live rail at any time without interfering in the slightest with traffic. Further, the inspection and repairs on the overhead line offer difficulties which are unknown on a tramway system. The block system of signalling, the frequent train service, and the necessity for inspection and repairs being done from some arrangement like a tower wagon, will preclude all inspection except at night, and probably on the busiest section of the line where it is most needed the inspection will only be possible on Sundays. In addition to this the section under examination will be blocked

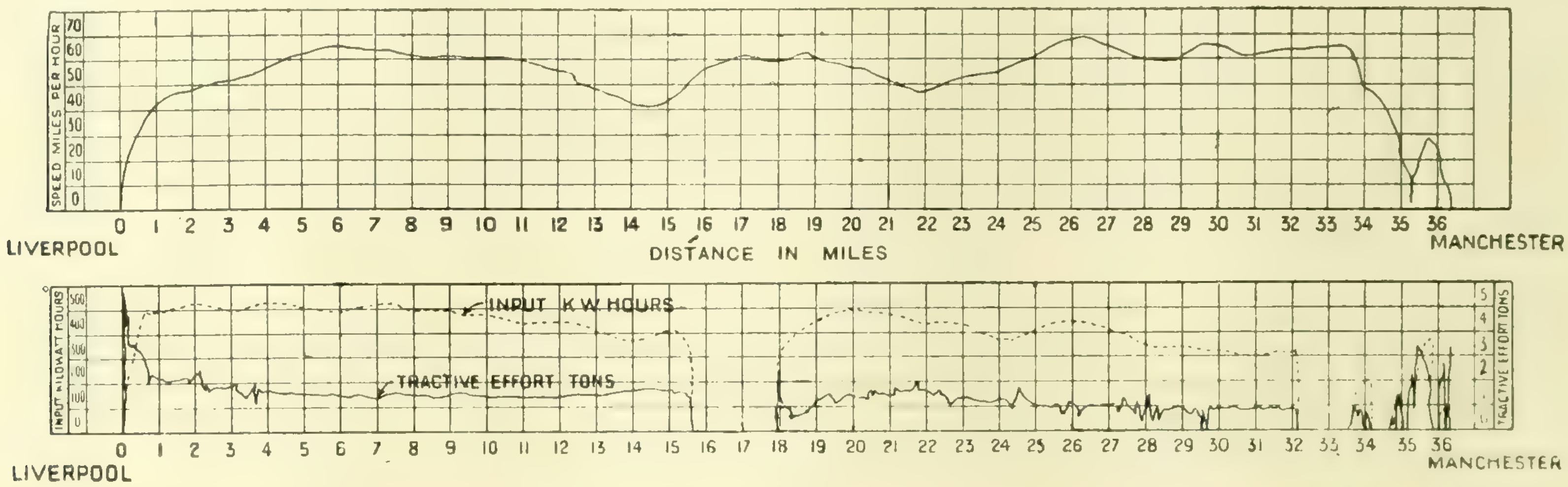


Fig. 12.

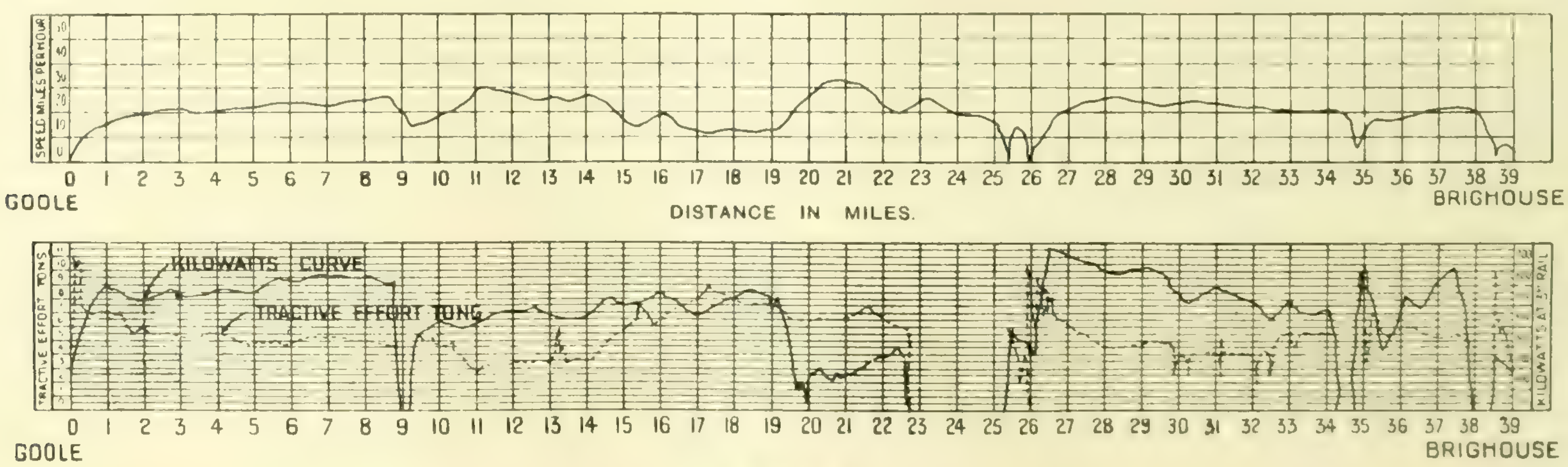


Fig. 13.

certainly be required. Reliability and safety are the first words in railway operation.

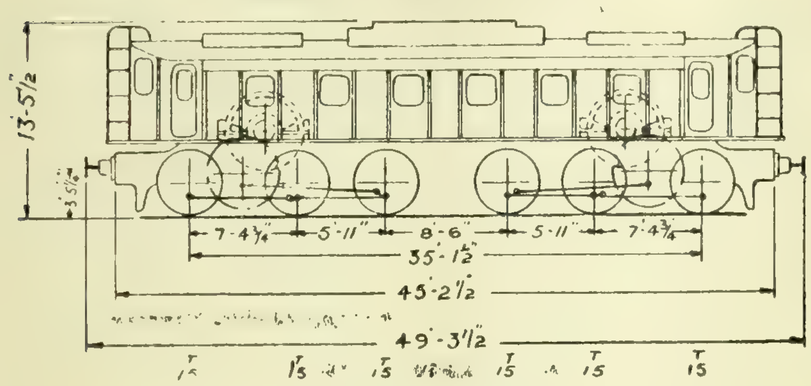
Third-rail dangers have been held up as a grave disadvantage of that system, but in reality these are very slight. The permanent way of a railway is no place for trespassers, whether the third rail is there or not, and the fact that practically no accidents have occurred to railway servants, and that all railway operations, such as relaying, &c., can be and are carried on without any special difficulty goes to prove that the third-rail danger has been very much magnified. Its protection, even with an over-running shoe, is easily and cheaply effected. Though fatalities to trespassers have occurred in the early stages of the direct-current third-rail system, no less than three fatal accidents to railway servants have already occurred on the short lengths of single-phase line in this country. Accidents to the third-rail are much and single line working necessitated. Here again the overhead system compares most unfavourably with the third-rail system, as on the latter inspection and repairs can be carried on without any appreciable delay to traffic. It may be noted here that these objections would not apply with the same force on lines devoted mainly to passenger traffic. A further point for consideration is the delay likely to occur in the repair and inspection gangs assuring themselves that the line is safe to work on. Again, the cost of maintaining the overhead girders and supporting poles, painting them, &c., is much more than with the third rail. Such difficulties as those outlined will, no doubt, be overcome at a cost, but there seems to be difficulties graver and less easy of solution than those which presented themselves to the designers of the pioneer third-rail system.

We may now consider to what extent economy would be

effected by operating main line goods and passenger trains electrically. The diagrams in Figs. 12 and 13 show the coal consumption of steam trains on actual run. The drawbar pull and speed have been converted to kilowatts, and the actual equivalent coal consumption calculated for electric traction.

Comparing current with coal, it will be seen that only with current at 0·4d. per unit at the third rail is electricity on an equal footing with steam for the passenger train. With the goods service the difference is more marked, due to the heavy load handled. As regards the other item, drivers' and guards' wages, repairs, &c., some little economy is effected, making the total cost of operation for express work about the

0-6-6-0 (TWO-MOTOR A.C.) ELECTRIC LOCO. FOR SWITZERLAND.
Diameter of Driving Wheels 4ft. 5in.



Maximum Speed 43 miles per hour. Normal Speed 18 miles per hour.
Normal total rated H.P. 2,000.
Maximum Draw Bar Pull 28,600 lbs. Normal Draw Bar Pull 22,000 lbs.
Weight of Mechanical Equipment including Brakes, 46 tons.
,, Electrical ,, ,, ,, 44 tons.

FIG. 14 (b).

same. The chief advantages to be reaped would be the possibility of pulling longer and heavier goods trains at a higher speed than is possible with the largest steam locomotive that can be designed under the British load gauge, and also the diminution of coal stand-by losses which are very high in goods-train services. On congested lines like the Lancashire and Yorkshire, in spite of the difficulty that would arise with couplings and traders' wagons, owing to the heavier haulage stresses, some considerable advantage might be obtained, and the express goods service so ardently desired by the public might be nearer attainment.

TABLE VI.
COSTS OF OPERATION.

EXPRESS PASSENGER TRAIN, LIVERPOOL TO MANCHESTER.

Total weight of train 142 tons. Total coal used 17 cwts.
Equivalent B.O.T. units 250.

STEAM.	s.	d.	ELECTRIC.	s.	d.
Coal, 1,900lbs.	8	6	Energy at ·625d. per unit	12	11
Driver and stoker at 1·85d. per train mile	5	6	Motor-man and guard at ·88d. per train mile	2	8
Maintenance at 2·72d. per train mile	8	5	Maintenance at 2·05d. per motor-car mile	6	0
	22	5		21	7

EXPRESS GOODS TRAIN, GOOLE TO BRIGHOUSE.

Total weight of train 801 tons. Total coal used 40 cwts.
Equivalent B.O.T. units 910.

STEAM.	s.	d.	ELECTRIC.	s.	d.
Coal	20	0	Energy at ·625d. per unit	47	5
Driver and stoker......	8	4	Motor-man & assistant	2	10
Maintenance	8	10	Maintenance	6	8
	37	2		56	11

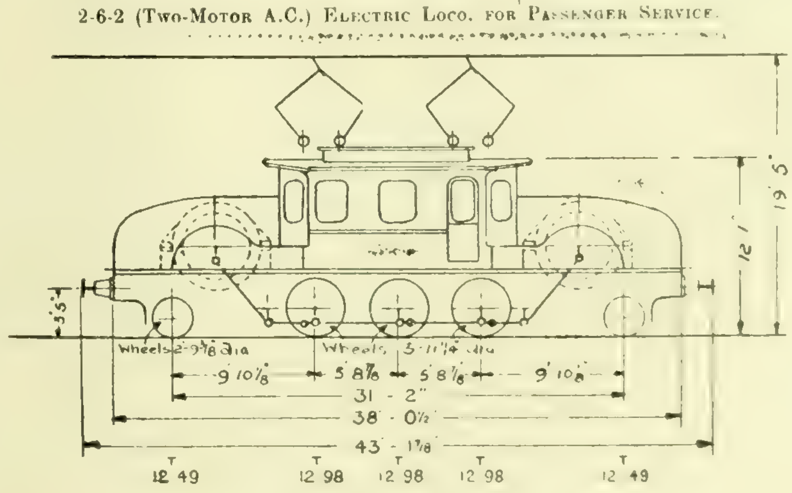
The electric locomotive, however, has, as indicated, possibilities in the way of providing a sustained hauling power unobtainable with a steam locomotive within the British loading gauge. The diagrams in Fig. 14 give some idea of what has been done in this direction. It is a striking sight to see the ease and silence with which heavy trains are hauled through the Simplon Tunnel by the powerful 3-phase locomotives employed there. Little as yet is known about the first cost and repair costs of these monster electric locomotives, but it is probable that there will be some appreciable economy as compared with the steam locomotives.

In connection with these diagrams it may be noted that Figs. 14 (e) (coal loco.) and 14 (f) show one advantage of single-phase traction, in that the method of control allows one motor to be used without the heavy rheostatic losses of direct current.

The fact is that under suitable conditions the steam locomotive is a very economical machine, not only to run but to keep in repair, and the application of superheated steam has done much not only to increase running economy, but to enable the boiler repairs, which are the most costly, to be reduced. A very cheap supply of electricity, at, say, ¼d. per unit, is a prime condition of successful main-line electrification. Such a supply is not an impossibility, but it is only likely to be obtainable in the coalfields or where water-borne coal can be obtained.

To sum up the conditions in the neighbourhood of large towns where electric traction would be most profitable preclude the adoption of overhead construction, or the single or 3-phase systems; it is therefore probable that the direct-current third-rail system will gradually be brought into use by the more progressive railway companies, where, as before stated, there is either a residential neighbourhood to develop or a slower means of transit to be competed with. The extent of such a system of suburban electric transit may become so large as to make it profitable to work the local goods service from the same power house as the passenger trains; further than this, two large towns fairly adjacent, such as Glasgow and Edinburgh, Newcastle and Darlington, Liverpool and Manchester may each have such a suburban goods and passenger electric system, and this may lead to the electrification of the main line between two such cities, and this in its turn to the electrification of an entire system. Probably a power station will feed about 25 to 30 miles as a maximum distance, *i.e.*, there will be about 60 miles between generating points; but cheap coal, water, and land will be principal deciding factors. Whether one phase or direct-current third rail is used batteries will be installed to a large capacity, probably sufficient to run any section of the line for an hour

2-6-2 (TWO-MOTOR A.C.) ELECTRIC LOCO. FOR PASSENGER SERVICE.



Maximum Speed 46 miles per hour. H.P. per Motor 390. Total 780 H.P.
Continuous Tractive Effort 6,610 lbs. at 46 miles per hour, and 8,820 lbs. for one hour at 37·9 miles per hour.
Initial Tractive Effort equals 17,640 lbs.

FIG. 14 (c).

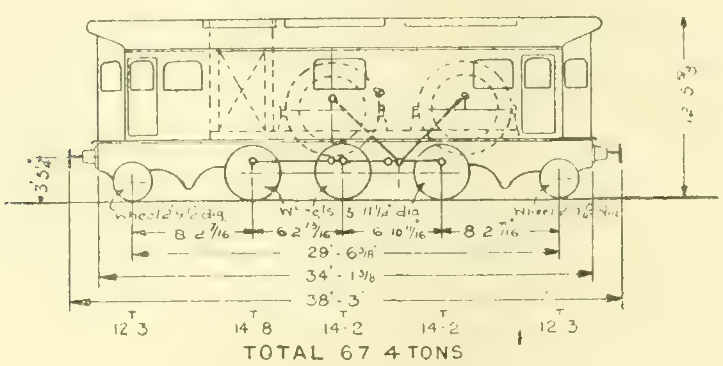
on a reduced schedule, thus acting both as load equalisers as well as a stand-by.

Thus the electrified railway of the future appears to be a continuous-current third-rail system for suburban and inter-urban lines, with possible stretches of straightforward main line, on the single-phase system. This, of course, precludes the movement of the suburban motor-coaches or shunt engine from one district to another; but this movement does not take place in practice, and this is no practical objection. Goods yards will only have their entrances electrified and will

be worked largely by storage battery locomotives. Only by this means can the prohibitive cost of overhead construction or the unnecessary use of the third rail and the comparatively useless electrification of sidings only used occasionally by a locomotive be avoided.

The financial difficulties, however, will be very great. To illustrate the matter, the cost of electrifying the whole Lancashire and Yorkshire Railway system might be considered. The average daily train mileage is about 48,000, or taking this

2 6 2 (TWO-MOTOR A.C.) ELECTRIC LOCO.



TOTAL 67 4 TONS

FIG. 11 (d).

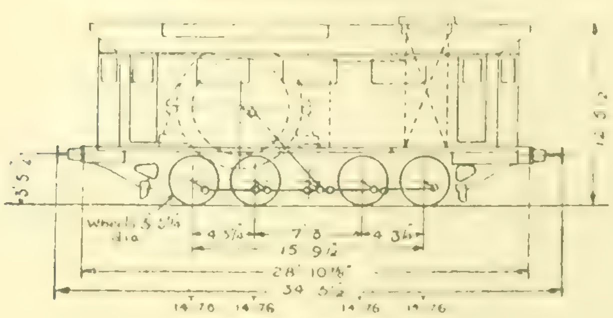
uniformly distributed over the day, about 2,000 train-miles per hour. Taking 10 kw. per train-mile, a fair figure in view of the heavy services, the mean demand will be for about 20,000 kw., and the maximum demand, say, 40,000 kw. This demand would be supplied from three power stations, serving respectively the eastern, western, and central districts, each containing about 20,000 kw. of plant, and about 60 sub-stations containing about 120,000 kw. of plant (about 100 kw. per mile of single track, including loops). The present locomotive stock would be replaced by about 1,000 electric locomotives (probably only two types would be used, one for goods and one for passenger work, and could be run 1, 2, or 3, in multiple unit at the head of the train); also about 100 storage-battery locomotives for goods yard work, and the cost would be about as follows:—

	£
Power stations, 60,000 kw. at £12 per kilowatt ..	720,000
Feeders, 300 miles at £1,200 per mile	360,000
Sub-stations, 120,000 kw. at £6	720,000
1,400 miles of track at £1,000 per mile	1,400,000
1,000 locomotives and motor-cars at £2,000 each	2,000,000
100 storage-battery locomotives at £2,000 each ..	200,000
Sundry Extras	250,000
	£5,650,000

Say £5,700,000 in round figures.

To pay 1 per cent. interest on this would take £228,000 per annum, or assuming that the cost of operation remained

8 WHEELED COUPLED (A.C. 1 MOTOR) ELECTRIC LOCO FOR GOODS SERVICE.



TOTAL 59 TONS

FIG. 11 (e).

the same, and the receipts were not increased, the dividend would fall by nearly 1¼ per cent. Certain economies, however, might be reckoned on, and certain expenses would be increased, otherwise operating costs would remain much the same. It would, therefore, be necessary as a result of the electrification to make certain of an immediate increase of about 5 per cent. (£300,000) in total receipts, as the bulk of the train service would be unaffected in speed or convenience by the change.

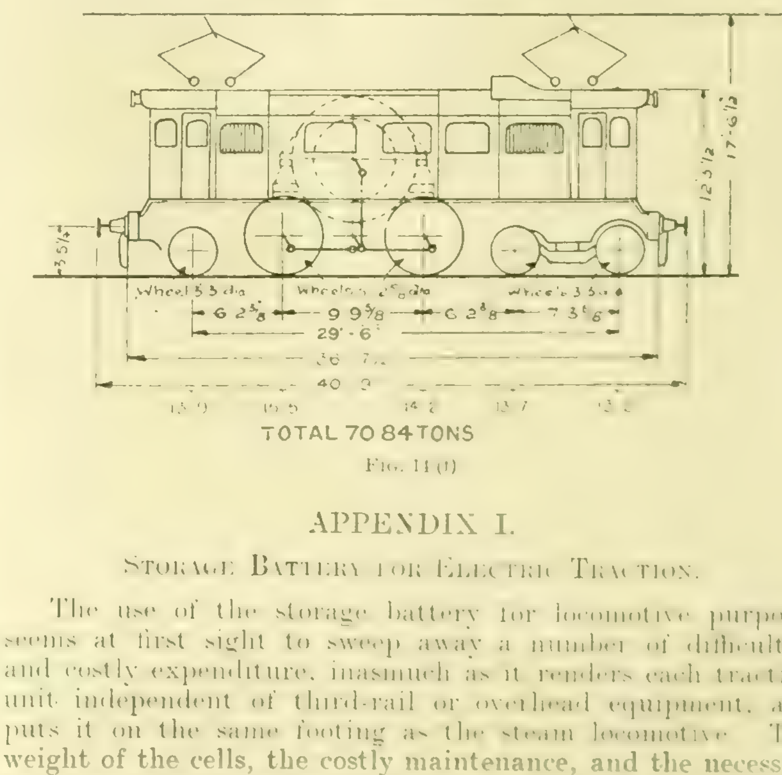
This increase would have to come mainly from the suburban areas, the electrification of which could be undertaken separately at a vastly lower cost. In fact, though pregnant in the possibilities, the electrification of an entire system would be a financial operation of stupendous magni-

	Increase.	Decrease.
Maintenance of way 25 per cent. on wages	£20,000	—
Locomotive power, coal 33 per cent. ..		£100,000
Working wages, 10 per cent.		30,000
Repairs	—	30,000
	£20,000	£160,000

tude for a company, and fraught with the possibility of disaster. If, on the other hand, the electrification brought with the absorption of all supply companies, municipal and otherwise, in the area, and the supply of electricity for power, light, and traction for the whole area, from, in the case of the Lancashire and Yorkshire, even six power stations, the possibilities of success of the operation would be very great. Undoubtedly the innate conservatism of the English character, and the fierce opposition which would be shown by existing undertakings and other vested interests, would involve parliamentary, and eventually statutory expenditure, which would cause the failure of any such scheme, profitable as it would be to the community if it could be carried out.

In conclusion, the author wishes to thank Mr. Barnes for his valuable assistance in the preparation of the paper.

2-4-4 (A.C. 1 MOTOR) ELECTRIC LOCO.



TOTAL 70 84 TONS

FIG. 11 (f).

APPENDIX I.

STORAGE BATTERY FOR ELECTRIC TRACTION.

The use of the storage battery for locomotive purposes seems at first sight to sweep away a number of difficulties and costly expenditure, inasmuch as it renders each traction unit independent of third-rail or overhead equipment, and puts it on the same footing as the steam locomotive. The weight of the cells, the costly maintenance, and the necessity for charging stations forbid their use, however, for anything except shunting and very light work.

A car, for instance, of a total weight of 33 tons would have 9 tons of cells, and 24 tons of motors and equipment, and would maintain an average speed of 17 m.p.h. The average watts per ton mile works out at 64·4 at the car, and with a battery efficiency of 66 per cent. this would be increased to 81 watt hours at the power house. A car with this equipment would run 30 miles between charges. The

TABLE VII.

	Storage Battery.	Third-rail System.
Weight of car for equal seating capacity ..	33 tons	26 tons
Average speed	17 M.P.H.	21 M.P.H.
Watt hours per ton-mile at the car ..	64·4	61
Watt hours per ton-mile at the power station..	81	75
Kilowatt hours per car-mile at power station.. ..	2·67	[illegible]

figures when compared with third-rail traction, as shown in Table VII., prove conclusively that the storage battery is not practicable for serious electric traction.

In addition the storage battery car will be standing idle a considerable portion of its time whilst the cells are recharging, the radius of operation is limited, and the maintenance per car-mile for the battery alone is as high as 2¾d. The storage battery locomotive, however, has a field for shunting purposes.

APPENDIX II.

Regenerative Control.

Referring again to diagrams 2 and 3, in all three cases a large portion of the energy imparted to the train is finally absorbed by the brakes in bringing the train to a stop. Not only is this energy lost as far as useful work is concerned, but a considerable wear takes place in the wheel tyres and brake blocks, which manifests itself in maintenance costs. Taking an actual case, a 5-car train, weighing 166 tons, required 14·12 units, or 19 h.p. hours, to accelerate it up to 40 m.p.h., the time taken being 98 seconds. The work done during acceleration is consequently 1,665 foot-tons.

The accumulated energy in the train at 40 m.p.h. is 887 foot-tons.

Therefore, work done against train resistance and lost in electrical resistance = 778 foot-tons.

Therefore, allowing 80 per cent. efficiency between shoe and car wheels work done at car wheels = 80 per cent. of 1,665 = 1,332 foot-tons, which represents the work done against train resistance and acceleration alone.

Therefore, work done against train resistance 445 foot-tons, and this is equivalent to 21·6lbs. per ton, which is a close check to figures obtained from tests.

The train is brought to rest in 600ft., and the time taken 20 seconds. The work absorbed by brakes and train resistance is the accumulated energy 887 foot-tons.

The work absorbed by the brakes (taking the figure of 21·6lbs. per ton for train resistance) is 776 foot-tons, which is equivalent to 6·6 units (8·8 h.p. hours), or 47 per cent. of the energy supplied.

This is for a one mile run at a schedule speed of 30 m.p.h. The figure decreases with the length of run, but in any case the loss at the power house with current at ·625d. per unit amounts to 5·2d. per stop. The saving of this by some method of regeneration by which the energy of the train could be reconverted into electrical energy and returned to the line, at the same time braking the train, has been a favourite problem amongst electrical engineers. Several schemes have been tried, but none of them, except in small street cars, are nearly satisfactory. The motor, which is invariably used for direct-current traction, is the series type. A more simple piece of mechanism, and one suited in every way for the severe conditions exposed, it would be hard to design. The single-phase motor is built on similar lines, but with some complications necessary because of the alternating current being used. Unfortunately the series motor does not lend itself to regeneration. In the systems which have been tried, one of them used a shunt motor with field regulation, and the other a combination of series and shunt motor with a sectionalised field, the sections being placed in parallel for series running (driving) and in series for shunt running (regenerating). The loss in adaptability, the numerous complications and consequent reduction of reliability, and the high cost of installation have lead to the abandonment of regenerative systems, because the saving from a reduced power consumption was not sufficiently great.

2-8 2 (Two-Motor A.C.) Electric Loco. for Goods Service

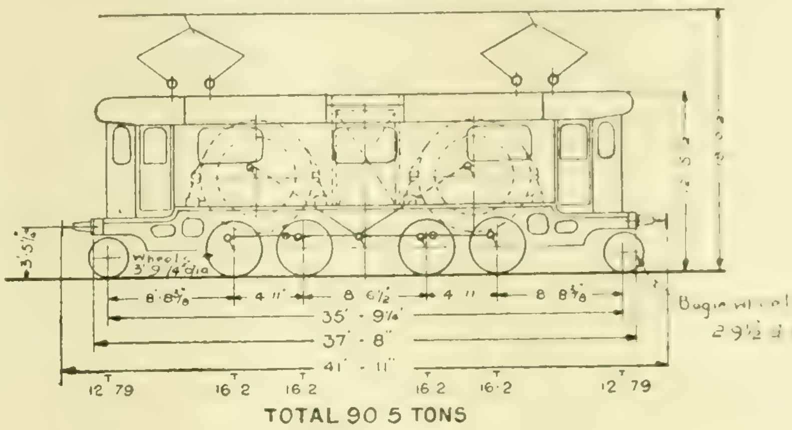


Fig. 11 (g)

With 3-phase system regeneration in a modified degree is possible. If a 3-phase induction motor is run over synchronous speed it will return energy to the line. In running down a gradient, therefore, if the speed increases sufficiently regeneration takes place and the speed of the train becomes a resultant of the braking due to the returned energy and the effect of the gradient. This is of rather great advantage in mountain railways. It cannot be made use of, however, in bringing the train to a stop.

To sum up, the real difficulty lies in the fact that the energy of the train is dissipated by means of the propelling motors. This means more capacity to radiate heat is required, and hence the motor equipments are heavier and more complicated, and what is gained in one direction is lost in another.

Appendix III.

Fig.	Maker.	Wheelbase Arrangement.	System.	Overall Length. Ft.	In.	Weight. Tons.	Tractive Effort.	No. of Motors.	H.P. of each Motor.	Driving Mechanism.	Type of Collector.	Service.
14 (b)	Oerlikon Co. (Lotchberg Ry.)	6-6 All drivers.	S.P.A.C.	49	3½	90	Max. 28,600lbs. Normal 22,000lbs.	2	1,000	3·25 : 1 gear and rods	Bow	—
14 (c)	Siemens	2-6-2	S.P.A.C.	43	2	64	6,610lbs. at 46 M.P.H.	2	390	Rods	Bow	Passenger
14 (d)	Siemens	2-6-2	S.P.A.C.	38	3	67·4	—	2	—	Rods	Bow	—
14 (e)	Siemens	8 All drivers	S.P.A.C.	31	5½	59	—	1	—	Rods	Bow	Goods
14 (f)	Siemens	2-4-4	S.P.A.C.	40	9	70·8		1	—	Rods	Bow	Passenger
14 (g)	Siemens	2-8-2	S.P.A.C.	41	11	90·5	·	2	—	Rods	Bow	Goods

Particulars of Electric Locomotives shown diagrammatically in Fig. 14 (b—g).

The Battleship "Orion."—The world's first super-Dreadnought "Orion" was commissioned at Portsmouth on Tuesday last. The "Orion" is a sister ship to the "Monarch"—now completing at Elswick—and to the "Conqueror" and "Thunderer." She is 545ft. long, 88·5ft. in beam, and displaces 22,500 tons. On her trials the turbine engines of 27,000 h.p. gave her a speed of 22·31 knots. The armament of the new ship consists of ten 13·5in. guns in five centre line turrets, with 24 4in. quick-firing guns for repelling torpedo craft. As each 13·5in. gun fires a shell of 1,250lbs., the weight of a single broadside is 12,500lbs. The "Orion's" main belt is 12in. thick. The full cost of the "Orion" is not yet available, but without her guns she cost £1,769,894. This works out to £78·7 per ton of displacement. She has been completed in 25 months, so that the average is 900 tons per month, or practically double the rate of building in 1904-7.

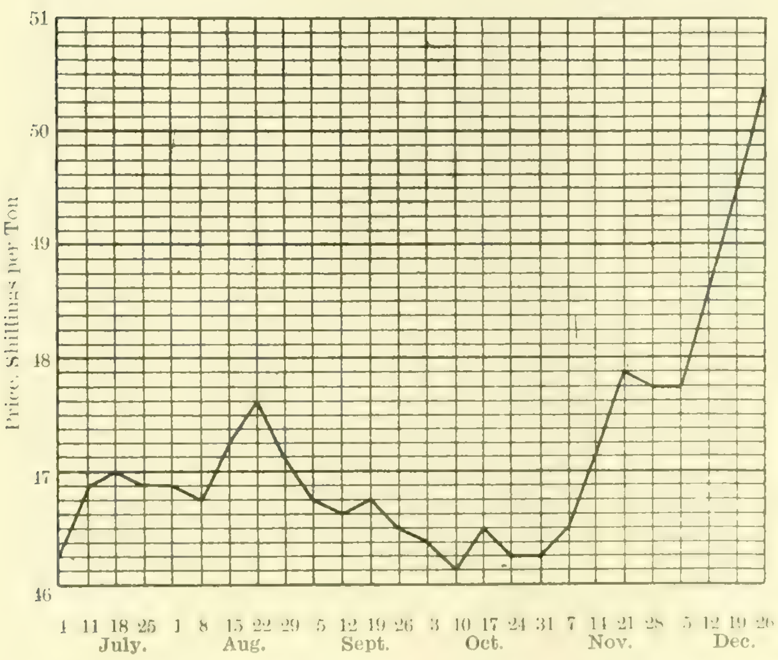
INDUSTRIAL AND TRADE NOTES.

Light Railway.—The Board of Trade have recently confirmed the under-mentioned Order made by the Light Railway Commissioners: Great Northern (Kirkstead and Little Steeping) Light Railway Order, 1911, authorising the construction of a light railway from Kirkstead to Little Steeping, in the parts of Lindsey, in the County of Lincoln.

United States Metallic Packing Company, Ltd.—We have received from this firm a beautiful and artistic wall calendar, a form of advertisement in which they appear to take a special pride and display great taste. The calendar, which represents a statue entitled "The Echo," is quite a work of art, and one of the best specimens of blocked colour printing we have seen. Its artistic merits, in fact, will, we imagine, in many cases, lead to its appropriation for decorative purposes in private drawing rooms rather than public offices.

Air Compressors and Rock Drills.—In connection with the Turin Exposition, which closed recently, we are informed that the Ingersoll Rand Company, of 165, Queen Victoria Street, London, were the only firm awarded a Grand Prix for their exhibit, consisting of air compressors, rock drills, hammer drills, and other pneumatic machinery for mining, quarrying, and metal working purposes. It may be added that the machines exhibited in the case of Turin were of standard design and workmanship, being taken from the firm's regular European stock.

Prices per Ton of Cleveland Iron, July to December, 1911.

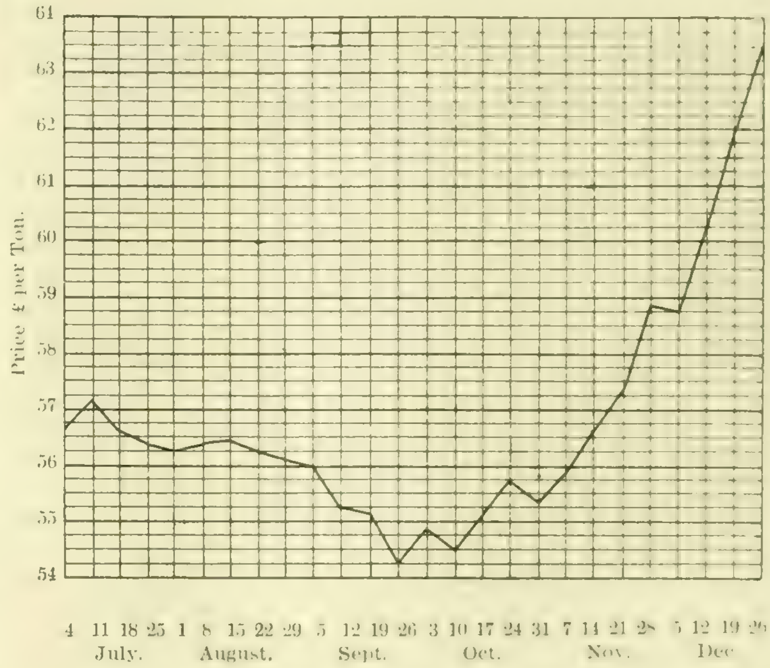


The American Zinc Industry.—An American Consular report states that the zinc smelting industry of the United States made a record output in 1910, the total tonnage of spelter amounting to 269,184. From foreign ore 16,705 tons were produced, and from domestic ore 252,479 tons. The total production of spelter in 1910 was equal to the output of 63,367 average retorts operating continuously throughout the year, or about 72 per cent. of the effective smelting capacity in 1910. The United States retained first place in the world's production of spelter, with 30·5 per cent. of the total output.

Messrs. G. Birch & Co., Islington Tool Works, Islington Grove, Salford, Manchester, has been incorporated as a private limited company, and the business in future will be carried on under the style of G. Birch & Co. Ltd. Mr. Ernest Hollings, who is a practical engineer with modern workshop experience as works manager for an eminent firm of engineers and machine tool makers, becomes the managing director, and the services of Mr. T. Fletcher Robinson, the manager of the old firm since the death of the founder, Mr. George Birch, 11 years ago, have been retained as chairman of directors.

Accidents in Shipyards.—At Greenock Sheriff Court on the 22nd ult., enquiries under the Fatal Accidents Enquiry (Scotland) Act, 1905, and the Fatal Accidents and Sudden Deaths Enquiry (Scotland) Act, 1906, were held by Sheriff Welsh and a jury into the circumstances attending a series of six fatal accidents which occurred in the district during the past few weeks. The deaths were all caused by falls of varying distances in vessels in Greenock and Port Glasgow, and took place, with one exception, in new vessels in course of construction or fitting out in the district. Mr. H. J. Wilson, H.M. Factory Inspector, Glasgow, said that he and other inspectors had visited shipbuilding yards in different parts of the country, in the investigation of the causes of such accidents, and the matter was under very careful consideration with a view to having legislation passed or regulations drawn up to prevent their occurrence. Sheriff Welsh said the jury would be glad to hear that, and the jury expressed their satisfaction that such steps were being taken. Directed by the Sheriff, the jury returned a formal verdict in each case.

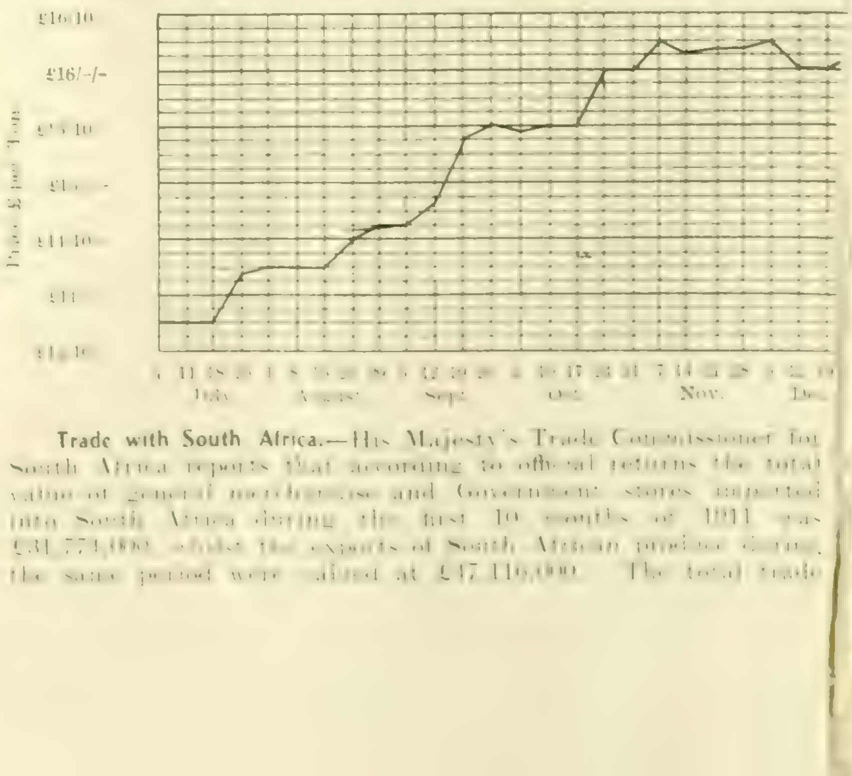
Prices per Ton of Standard Copper, July to December, 1911.



Hans Renold, Ltd.—For the purpose of getting into closer touch with their friends in Scotland, this firm have opened an office in Glasgow at 86, St. Vincent Street, and appointed Mr. F. M. Lawson, Assoc.M.Inst.C.E., A.M.I.Mech.E., as resident engineer for Scotland. Mr. Lawson has for some time held a leading position with the firm, and is therefore fully qualified to advise on all matters relating to chain driving. For the present the Glasgow office will deal more particularly with matters requiring personal attention, but when enquiries are urgent, they may be sent there. The Glasgow office will generally only concern itself with engineering matters, and not with cycle, motor, and mortise chains.

Shipbuilding Records on the Clyde and N.E. Coast.—A great increase in the figures of the previous year marks the shipbuilding returns for 1911, just issued, for both the Clyde and the North east Coast. The shipbuilding industry on the Clyde has had a record year. The total tonnage of the year's output on the Clyde is 640,000, representing 403 ships, as compared with the record of 619,919 tons in 1907, and with 392,000 tons last year. The output from the 11 yards on the lower reaches of the Clyde is 218,322 tons. Messrs. Russell & Co., Port Glasgow, head the list with a tonnage of 72,230, representing 14 vessels. On the North-east Coast one or two returns are yet to be made, but the great bulk are now known, and the figures for 1911 show an increase in output of 84 vessels and of 364,962 tons, as compared with last year's figures. In all, 30 firms have built 257 vessels, with a tonnage of 970,784 tons, and the complete returns will raise the tonnage to a million.

Prices per Ton of English Lead, July to December, 1911.



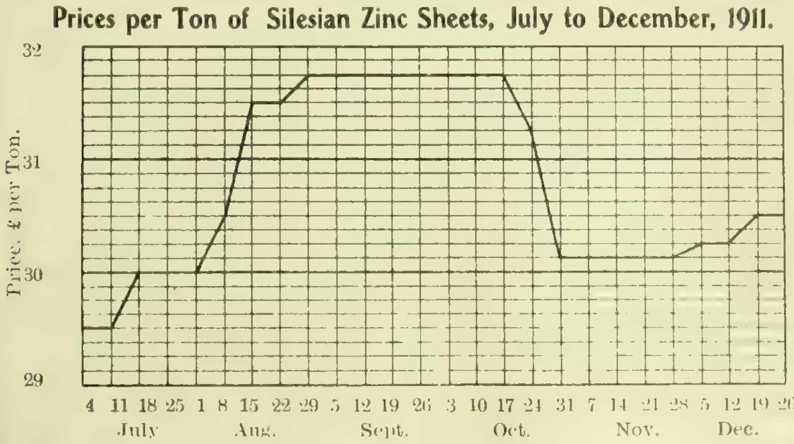
Trade with South Africa.—His Majesty's Trade Commissioner for South Africa reports that according to official returns the total value of general merchandise and Government stores imported into South Africa during the first 10 months of 1911 was £31,774,000, whilst the exports of South African produce during the same period were valued at £47,110,000. The total trade

in 1911 shows an increase, compared with 1910, of a little over 4 per cent. The trade with the United Kingdom is believed to have been adversely affected to some extent by the recent industrial disturbances in this country, as not only was the execution of orders delayed, but orders for machinery, &c., are in some instances said to have been placed elsewhere owing to the uncertain conditions which prevailed here. South Africa continues to offer an expanding market for British manufacturers. There was a falling-off in respect of mining and electrical machinery, but this would seem to be due to the recent completion of important mining works and electrical stations. The growth of the market for agricultural machinery deserves the careful attention of British manufacturers.

Prices per Ton of Block Tin, July to December, 1911.

Trade Circulars and Catalogues.—From the Pulsometer Engineering Company, Reading, we have received price list and catalogue of their various types of pumps, including not only their well known pulsometer, but also numerous designs of reciprocating and centrifugal pumps for every kind of service. T. Rowlands and Co., Stirling Chambers, Sheffield, send us particulars of some comparative tests carried out by the Boston and Maine Railroad on titanium, treated, plain open-hearth, and Bessemer steel rails. Alfred Herbert, Ltd., Coventry, send us an illustrated booklet descriptive of their various types of automatic turning lathes and of the kinds of work capable of being done by them, with cost of same. We have also received from them a wall calendar for 1912, copies of which, they inform us, they will be pleased to send to interested parties on request. The Sun Electric Company, Ltd., 118, Charing Cross Road, London, W.C., send us two catalogues, one of their "Kalkos" system of tinned brass

Prices per Ton of Silesian Zinc Sheets, July to December, 1911.



tubes and fittings for electrical connections, the other of various types of electric radiators for domestic and office use. The Armorduct Company, of Farringdon Avenue, send us catalogue and price list of the "Gral" metallic filament lamp. From W. Geipel & Co. we have received circulars relating to Okonite type and aluminium electric conductors. The Mirrlees Watson Company, Glasgow, send us particulars of combined hydraulic and steam turbine power plant at the Usine de Tuillere Dordogne in France, for which they have supplied the condensing plant. The same firm also send us particulars of the Mirrlees Leblanc air pump. Messrs. Babcock & Wilcox send us several circulars descriptive of some dock crane installations they have equipped. From W. H. Willcox & Co., Ltd., of 23, Southwark Street, London, E.C., and the Baldwin Locomotive Company, Philadelphia, we have received useful specimens of wall calendars.

Metal Trade Report.—In their annual review of the iron, steel, and kindred trades, Messrs. Bolling & Lowe of London, state that from the undeniable evidence of statistics, the actual results of last year's trading in the iron, steel, and kindred industries are not by any means satisfactory from the point of view of the exporter. An increase in the prices of many commodities, plenty of work in hand at most of the mills, and in some cases a difficulty in obtaining quick delivery, would, they continue, point to a highly satisfactory condition of things, but the consumption for shipbuilding and other requirements at home would appear to be mainly responsible for this. There has at no time been anything approaching a boom, but frequent reports of a prosperous state of trade have reached us, which we think are misleading. The coal market has been in a very unsettled state during the last several months. Prices have been abnormally high, and freights in most directions have also advanced considerably. As regards pig iron, prices were fairly level during the first nine months of the year, but during the last few weeks a sharp advance has taken place, and it seems probable that ultimately a higher range of values will be established and maintained. Until the closing weeks of the year, the copper market wore generally a somewhat dull and listless appearance, but towards the end of November there was a sudden sharp revival, arising from a recognition of the substantial strength underlying the situation. This impelled an enormous broadening of speculative interest, and with heavy stock reductions in the United States, the market swung sharply upwards. The tin market has been under highly speculative control all through the year. The situation of the article itself is certainly a remarkably strong one, but temporarily the outlook is somewhat complicated, as regards the speculative market, by the hostility shown by the controlling parties to the Standard tin contract.

CORRESPONDENCE.

Re the Vagaries of Corrosion: A Peculiar Failure.

To the Editor of "The Mechanical Engineer."

Sir,—That the corrosion of the plate round a combustion chamber stay in the steam trawler "Clyne Castle" should be regarded as uncommon or mysterious appears most remarkable to one accustomed to the inspection of marine boilers. It is a frequent occurrence at the bottom stays in combustion chambers. A dozen examples could be seen in vessels in this port. Generally it is accompanied by grooving of the stay. The remedy is to drill out and fit a larger stay, or, when it has gone too far before being discovered, to fit a small patch and the new stay through it.

Yours faithfully,

G. Pott.

Gloucester, December 28th, 1911.

[Our correspondent has missed the remarkable feature in the case referred to. Corrosion of stays is frequent enough, as he remarks, but it is quite unique, in our experience, for a single stay out of hundreds to be eaten away like the one in question, and for no trace of wasting to be found elsewhere in the boiler.—Ed., *M. E.*]

Balancing of Locomotives.

To the Editor of the "Mechanical Engineer."

Sir, With reference to your correspondent's letter in the issue of December 15th on the above subject. The paragraph in the "1912 Pocket Book" referred to is not intended to convey any such idea as suggested. The words "hammer blow" commonly used in this connection are understood to mean "shock" to the rail. Considering the balance weight merely as a mass moving in a cycloidal path relative to the rail or revolving round the wheel centre, the "blow" or "shock" is applied more gradually to the rail, by spreading the weight round the wheel, in crescent form, than would be the case if the same weight were concentrated at its centre of gravity. This, I believe, is generally conceded by locomotive designers, though certainly the attenuated crescent form looks better and lends itself to steel casting, but these are not the only reasons for such a shape. It is not contended that by making the balance weight extend well round the wheel, the amount of such weight can thereby be reduced, because the centrifugal effect is the same whatever its shape. While welcoming the criticism, I am sorry your correspondent should have thought it possible to read such a meaning into the words used. I hope, however, that he will forward his time-saving chart, which, I am sure, would interest all locomotive readers of your paper. Yours faithfully,

Jan. 1st, 1912. James Clayton

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1910.

Purifying and heating of boiler feed water. Hulsmeyer. 23561.
Rescue apparatus for mines. Kermode & Davis. 26106.
Compound levers. Gilbert. 28179.
Variable speed gear. Wethered. 28559.
Stand pipes for steam generators. Mills. 28630.
Safety appliance for mine cages and hoists. Golding & Edwards. 28632.
Means for the production of high temperature feed water for steam generators. Parr. 28619.
Alarm apparatus for preventing explosions and poisoning by gases. Von Pausinger. 28697.
Manufacture of water gas. Glasgow. 28855.
Weldless metal tubes. Astfalck. 28891.
Evaporating apparatus. Studer. 28925.
Conveyer belt. Wilson. 28932.
Water cooled exhaust silencers. Stroganoff. 28981.
Marine engine governors. Jackson & Ramsay. 29078.
Lathes for turning bevel gear blanks. Potter. 29158.
Water gauges for steam boilers. Lloyd & Davies. 29269.
Rotary pumps, condensers, or compressors. Rees. 29357
Bar bending machine. Hill. 29137.
Speed reducing gear. Barnes. 29145.
Apparatus for producing oil-gas. Burdon, Burdon, & Burdon. 29522.
Friction drive for power presses. Heaton & Hartley. 29628.

1911.

CO_2 recorder. Woodroffe. 199.
Cam actuated parts of fluid-pressure engines. De Veulle. 295.
Water level regulators for steam boilers. Kitchen & Storey. 381.
Regenerators used in the manufacture of gas. Mason. 382.
Apparatus for the regulation of steam boiler furnaces. McLean. 478.
Exhaust silencers for motor cars. Wolseley Tool and Motor car Company, and Remington. 631.
Carburetter for liquid fuel motors. Rotherham & Johnson. 1301.
Carburetters for internal combustion engines. Brown and Brown and Barlow, Ltd. 1412.
Speed indicators. Marks. 2237.
Means and apparatus for steam generation and feed water heating. Bone, Wilson, & McCourt. 2401.
Railway point levers. Vellere. 2849.
Vapour burning arrangements for steam generating systems. Shepherd. 3336.
Carburetters for internal combustion engines. C. Binks, Ltd., and Binks. 3468.
Construction of wheels and pulleys of malleable iron or steel. Dewar. 4415.
Machines for grinding rollers employed in roller bearings. Hoffmann Manufacturing Company, and Schmidt. 5046.
Shaft bearings. Hitchon. 5675.
Steam superheating and feed water heating. Owen. 6201.
Covers for vessels containing fluid under pressure. Galloways Ltd., and Pilling. 7296.
Lining of tube mills. Rigby & Birrell. 7801.
Grates for gas producers. Glasgow. 8537.
Forging presses. Witkowski & Schwarz. 9376.
Wick carburetter. Withers. 9395.
Variable hydraulic driving and reversing mechanism. Pittler Universal Rotary Machine Syndicate. 9519.
Reversing valves for compound oscillating cylinder engines. Ward. 9591.
Grates for boiler furnaces. Nielsen. 11642.
Apparatus for regulating the temperature of fluids. Darwin, Mason, and Cambridge Scientific Instrument Company. 12047.
Valve seat mountings for liquid piston explosion engine. Siemens Bros. Dynamo Works, Ltd., and Kieffer. 12152.
Regenerator for furnaces. Detoy. 12228.
Railway rail joints. Worunda. 13092.
Valve mechanism for use in reciprocating engine. Marks. 13171.
Power transmitting shafting. Maschinenbau Anstalt Humboldt. 13406.
Signal devices for speed indicators. Dahl & Martin. 13997.
Automatic recording apparatus for measuring ... fluid. Simon. 14218.
Elastic fluid turbines. De Ferranti. 14268.
Expansion joints for pipe lines. Opitz. 14530.
Propulsion of steamships. Plautz. 14609.
Apparatus for the manufacture of hollow cylindrical articles. Levi. 14705.
Tubular heat interchanging apparatus. Sandberg. 15890.
Steam generators. Steinmuller. 16436.
Cage rings for ball bearings. Schilling. 17356.
Governing mechanism for elastic fluid turbines. Vereinigte Dampfturbinen Ges. 17615.
Band conveyers. Prestwich. 18561.
Carburetters. Pearson & Pearson. 18703.
Service motor operated by liquid for controlling the parts of mechanism. Itala Fabbrica di Automobili. 19454.
Turning tools for cutting off lengths of metal bars. Taylor and Taylor. 20213.
Valve-control systems for elastic fluid turbines. Carroll. 20326.
Chain grates. Rademacher. 21358.
Gauge glasses. Moore, and Ambrose Shardlow & Co. 21562.
Device for feeding pneumatic conveyers. Thompson. 22387.
Safety appliance for pit and mine cages. Golding & Edwards. 26885.

ELECTRICAL, 1910.

Electric current regulators. Goodwin, Haslop, & Brown. 28613.
Electric transmission of power by polyphase currents. Siemens Bros. Dynamo Works, Ltd. 29168.
Iron clad, oil break, electric switches. Spagnoletti Ltd. and Joyce. 29270.
Electric signalling system. Mathys. 29296.
Printing telegraphs. Mathys. 29297.
Means for automatically operating electric switches. Jackson and Pearson. 29441.
Apparatus for duplex telegraphy. Heurtley & Gott. 30402.

1911.

Means for operating electric motors driving motor trains. Muller. 1209.
Electrically resistant material. Jones. 1459.
Electric incandescent lamp. Bloch. 1707.
Signalling apparatus for use with mono or polyphase current. Hardingham. 2120.
Wireless telegraphy and telephony. Shoemaker & Wilson. 2156.
Relays for automatic controllers for electric motors. Slater. 2530.
Electrical connecter. Harpin, and Walker Horrocks & Co. 3791.
Telephone systems. Rickets. 4282.
Electrical contact making devices. Day. 5412.
Electricity meters. Chamberlain & Hookham, Ltd., and James. 5654.
Electric switches. Page. 6129.
Electric switches. British Thomson Houston Company. 7104.
Electric flame arc lamps. Schuer & Hadfield. 8018.
Electric regulating arrangements. Lake. 9366.
Electrically driven pumps. Merryweather. 9717.
Arc lamps with parallel electrodes. James. 15217.
Electric switches. Thiel. 16078.
Circuit arrangements for automatic telephone exchanges. Siemens and Halske Akt. Ges. 19185.
Systems of electrically transmitting power to the screw shaft of vessels. Allmanna Svenska Elektriska Aktiebolaget. 19903.
Regulator for dynamos. Ferguson. 20586.
Trolley collectors for electric traction systems. Petter. 22295.

METAL QUOTATIONS.

TUESDAY, JANUARY 2nd

Aluminium ingot	63/- per cwt.
" wire, according to sizes, &c. ......from	102/- "
" sheets " " ...... "	120/- "
Antimony ...... £27/10/- to	£28/-/- per ton.
Brass, rolled	7¼d. per lb.
" tubes (brazed)	9¼d. "
" " (solid drawn)	8d. "
" " wire	7¾d. "
Copper, Standard	£62/17/6 per ton.
Iron, Cleveland	50/4½ "
" Scotch	56/4½ "
Lead, English	£16/-/- "
" Foreign (soft)	£15/12/6 "
Mica (in original cases), small	6d. to 2/- per lb.
" " " medium	2/6 to 4/- "
" " " large	4/6 to 8/6 "
Quicksilver	£7/15/- per bottle
Silver	25$\frac{5}{16}$d. per oz.
Spelter	£26/15/- per ton.
Tin, block	£204/-/- "
Tin plates	13/7½ "
Zinc sheets (Silesian)	£30/10/- "
" (Stettin; Vieille Montagne)	£30/15/- "

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Edited by
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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

The Work of the British Engineering Standards Committee.

AN interesting summary of the good work accomplished by the Engineering Standards Committee is given in the seventh report just issued for the year ending July, 1911. Originally started by the Institution of Civil Engineers to consider the advisability of standardising various kinds of iron and steel sections, the original committee became at once allied with the Mechanical Engineers, the Naval Architects, Iron and Steel Institute, and later with the Electrical Engineers, with the result that the scope and usefulness of the investigations were greatly enlarged, wider experience became available, and, thanks to the cordial co-operation of makers and users, reforms which a dozen years ago seemed hopeless of attainment, though universally admitted, are now accomplished facts. The work is a magnificent tribute to the virtue of self-help and of the efficiency of professional and business men when combined for a common object. Its range has been enlarged from time to time as the advantages have been realised, and questions relating to over 40 subjects have been or are under consideration. This has been rendered possible by the delegation of the main work of collecting and discussing data to numerous sub-committees comprised of prominent makers and users specially concerned in the materials or products dealt with, and therefore fully cognisant of the pros and cons of any standardisation proposed and of the extent to which it is likely to be successful in practice. Successive Governments have recognised to some extent the national character of the work by granting annual sums in aid, but, having regard to its important character, these sums have been comparatively small and inadequate to meet the costs entailed, and progress would have been seriously curtailed had it not been for the generous help of institutions and leading manufacturers. As it is, the committee has been driven to supplement its revenue by sales of its official reports, a procedure which restricts the publication of results which on other grounds should receive the widest publicity. The

value of the work done is testified in numerous ways officially. The Board of Trade, Lloyd's Register, and the Bureau Veritas have each amended their scales respecting ships and boilers in several particulars so to conform with British standard specifications for materials. The Railway Clearing House, which practically controls the construction of private owners' wagons, has adopted them as far as possible, as also has the Department of Iron Structures at the War Office and the London County Council in connection with steel-frame buildings. The influence of the committee on tramway rails, the sections of which not many years ago were at the whim of every local tramway engineer, is shown by the fact that no less than 70 per cent. of the total tonnage rolled were in accordance with the standard. Similar beneficial and wide-reaching effects have been brought into play in connection with locomotives, bridges, and railway rolling stock. Equally valuable and much-needed reforms have been secured in many engineering details bearing on the work of the engine builder and tool maker, and comparative order in such things as pipe flanges, screw threads, limit gauges now reigns where varied practice formerly led to endless annoyance and loss when repairs or the coupling of the outputs of different shops had to be effected. It is impossible to estimate the savings of one kind and another that have been brought about through the labours of the committee in various directions, but they must be enormous, not to mention the comfort secured to both makers and users by the knowledge that individual caprice in respect to choice of materials and proportioning of details has been so largely eliminated. The fear that standardisation might spell stagnation and crystallisation of ideas has been disproved by facts. The scope for real design has been in no way lessened, nor is there any likelihood it will be, so long as the various sub-committees maintain their present catholicity of composition. The work will inevitably require periodic revision, in view of the continued improvements in the manufacture and properties of materials and extended experience of their use, and evidence of this has been already afforded by the issue of several revised specifications, apart from which there are many questions calling for regulation which the little army of investigators have not yet been able to touch upon. The number of these in fact promises to increase rather than diminish with the growing demands of engineering science and the need for organised efforts to meet them. The Standard Committee has more than justified the expectations of those who urged its formation, and as a permanent institution of national importance deserves more generous public assistance. The Treasury voted a sum of £3,000 for the years 1903-4, and in the two following years gave a grant-in-aid equal to the amount subscribed by supporting institutions, manufacturers, and others, and have consented to continue this on a lower scale to the end of next year, but this sum is a mere pittance for work of such far reaching importance, and when the time for revision arrives, it is to be trusted the grant will not only be extended but enlarged. No similar public expenditure can show a more profitable return or one better calculated to secure the economic utilisation of raw materials and human efforts in shaping them.

Original Research in Mechanical Engineering. — The Institution of Mechanical Engineers call attention to the fact that the second award under the Bryan Donkin Fund will be made in February, 1913, and the amount available will be about £34. All applications received will be considered by a committee, who will make recommendations to the council upon the apportionment of the sum available. In the event of no grant being made, or the grants made amounting to less than the sum available, the surplus will be devoted to aiding the Research Committees of the Institution.

TESTS OF OIL CIRCUIT BREAKERS.

A PAPER describing some tests of oil circuit breakers was read by Mr. E. B. Merriam at a recent meeting of the American Institute of Electrical Engineers. The author stated that whenever an electrical circuit carrying considerable energy was opened in oil, gases were generated. These expanded, and rose and tended to force the oil out of the containing vessel. They also formed, with air, explosive mixtures, and either exploded or burnt for a considerable length of time when ignited. It was important, therefore, that oil circuit breakers be provided with strong oil-containing vessels in order to withstand the high initial stresses which were often present under certain conditions, and also that suitable provision be made for retaining the oil. In order to check tests made on moderate capacity circuits, and to study the operation of oil circuit breakers and current-limiting reactances on circuits of large capacity, under various conditions, arrangements were made, through the courtesy of the Commonwealth Edison Company, of Chicago, to use one of its generating units as a source of power for the tests. The tests were made at the Fisk Street Station, using a 3-phase 12,000 kw., 9,000 volt, 25 cycle turbo-alternator.

Practically all the tests were either 3-phase or single-phase short circuits, some to earth and some between phases. The short circuits were made by closing a triple pole circuit breaker, and the switch under test then automatically opened the circuit, being tripped by instantaneous relays operated from current transformers. About 150 tests were made in all.

In tests for the effect of short circuit on generator it had, the author stated, always been noted that the field current of the alternator rose when the armature was short-circuited. Values as high as ten times the field current at rated no load voltage of the alternator were observed during these tests. This phenomenon was dependent upon the interaction between the field and armature coils, and the maximum value which the field current attained was dependent upon the co-axial relation of the two circuits and their electrical constants. It was also noted during this series of tests that spits of fire came out of the alternator field. This was, in his opinion, due to the very high voltage induced in the alternator field windings when a short-circuit current was established in the alternator armature. Records showed that this voltage could be as high as seven times normal, although it might have been considerably higher, since only a few measurements were made. In some of the single-phase tests and also in some of the tests where the short-circuit was thrown on by three single-pole circuit-breakers, it was noticed that the voltage of the phase not short-circuited rose to a very high value, sometimes as high as two and a half times the normal. This was, he said, probably due to the very large current induced in the field, which, acting on the unloaded phase, produced a voltage rise. The end turns of the alternator did not move during any of these tests, a rigid inspection being made at frequent intervals to detect any such movement.

There was no appreciable drop in the speed of the alternator when the short circuits were thrown on, probably due to the current-limiting value of the reactances. In comparative short-circuit tests, made with the throttle of the turbine open and with the throttle closed, practically the same currents were produced in the test circuit. A number of tests were made by earthing one or all of the three phases of the circuit. In all such cases, the author noted that the effects, as instanced by the action of the oil circuit breaker under test, were very much more violent than when the short circuit was between phases. He also noted that when the water rheostats were connected to the test circuit as an initial load, their neutral point also being grounded, the effects were very much more violent than when this initial load was absent. At the completion of the tests, the generator was immediately placed in commercial service, and was still operating, none the worse for the severe service demanded of it throughout this series. This showed

the great value of current-limiting reactances in diminishing the jar on a generating equipment.

The current-limiting reactances used in these tests consisted of 76 turns of 1,000,000 cir. mil copper cable wound on a cement core and supported by a wooden framework. Each coil was made up in three layers. Terminals were brought out at the top and bottom. The result was a cement cored reactance having no iron in or about it. This construction was employed since the introduction of iron would not appreciably increase the current-limiting value of the device. The author found with the particular generator under test that the introduction of a 6 per cent. reactance in each phase halved the maximum instantaneous current and reduced the torque on the turbine shaft to about one-seventh of what it would have been without the reactance. The 6 per cent. reactance referred to the drop across the reactance, which, with rated load current through it at rated frequency, would be 6 per cent. of the rated phase voltage of the alternator. The reactances also maintained the terminal voltage of the alternator when a short-circuit was thrown on the system beyond the reactances, and permitted the generator to recover its normal voltage after a short-circuit had been removed much more rapidly than would have been the case had the short-circuit been placed directly across its terminals. This made them of great importance where a synchronous load was connected to a system, since one of the two features for holding a synchronous load was the maintenance of voltage.

As a result of the reduction of the torque on the turbine due to the introduction of reactances, there was practically no drop in speed when a short-circuit was thrown on it. Hence, the frequency of the system was maintained at practically normal value, and this, together with the maintenance of the alternator voltage, tended markedly to improve the operation of synchronous apparatus under abnormal conditions. Current-limiting reactances also changed the power factor of a short-circuit and distorted the wave form of the system. The stray fields of these reactances were not sufficient to distort the coils in any way and at a distance of several feet iron screens were not noticeably attracted nor were they appreciably heated.

During the tests, it was noted that at times some oil was thrown out of the oil vessels. By suitable baffling, the energy imparted to the oil by the expansion and explosion of the gases generated in the oil vessels was absorbed and the operation of the circuit-breaking device materially improved and its rupturing capacity increased. It was also found possible to separate the gases from the oil, thereby permitting the gases to escape into the air and the oil to be retained in the oil vessels. In a commonly-constructed design, a small distortion of the oil vessels permitted a considerable quantity of oil to be thrown out. This, however, could be readily prevented. It was very often found convenient to instal oil circuit-breakers in fire-resisting compartments. By means of external oil diverters, it was found possible to direct the gases and oil thrown out of the oil vessels to the lower parts of the cells. In reported cases on other systems, gases from oil circuit-breakers had been known to ignite, resulting in an explosion. Suitable baffles and diverters could be designed, however, to take care of these conditions.

In all the tests, the temperature of the oil was roughly noted, and in no case was it found to have been raised an appreciable amount after short-circuit was opened. This, the author thought, was due to the intensely local action of the oil circuit-breaker, for, when the contacts parted, the arc which was drawn produced gases which formed pockets in the oil. The larger oil vessels were of greater assistance in opening a circuit. The results showed that the stress developed in the 10in. diam. oil vessel was only from one-third to one-fifth of that developed in an 8in. diam. oil vessel. It was found that by diminishing the velocity with which the contacts parted, there was more disturbance, and the rupturing capacity of the device was greatly diminished. The length of break was directly connected with the velocity of moving contacts. A long break was very desirable, inasmuch as it gave a large factor of safety under normal operating conditions, and a much greater rupturing capacity in emergencies.

The tests showed that the oil circuit-breakers opened all the loads or short-circuits without producing any external disturbances or developing any undue pressures, and their ultimate rupturing capacity was not reached. The main current-carrying parts were well protected from burning by the arcing contacts, and these latter were not materially injured after opening and closing numerous short circuits. The temporary cell structure, although made of inflammable materials, was not injured in any way, and practically no stresses were developed in the cells. During some of the tests, a small quantity of oil came out of the oil vessels. It was found by actual measurements that only 5 per cent. of the oil had been lost. The repeated use of the oil in the oil vessels did not apreciably diminish its efficiency and the introduction of suitably-designed oil baffles and diverters overcame the tendency for the oil to come out of the oil vessels. The oil diverters and baffles experimented with could be readily applied to existing circuit-breakers at comparatively small expense and with practically no changes to the original installation.

METHODS OF DEALING WITH LOSSES IN STEAM PLANT DUE TO CONDENSATION.*

BY GEO. WILKINSON, M.I.M.E., AND J. RENDELL WILKINSON, B.SC.

THE object of the authors is to briefly outline methods of producing and using steam which offer advantages over the usual methods, such advantages varying in degree according to the type of plant in operation and the particular uses to which the steam is put. In steam plant, the losses due to condensation, which are common, to a greater or lesser extent, are often entirely neglected. We propose to discuss these, and also the methods of dealing with the resultant water of condensation.

Steam Traps.—The common method of removing water of condensation is by means of steam traps, which serve as an outlet to atmosphere for water, but automatically close against steam. The importance of keeping steam pipes and steam-using apparatus free from water is clear to all engineers versed in steam practice. The prevalent use of steam traps discharging water of condensation into the atmosphere cannot be too strongly condemned, as the water so discharged not only loses bulk by evaporation, but, more serious still, it loses by such evaporation a heavy percentage of its heat. This is shown by the following figures:—

Steam Pressure at	Sensible Temp. of Water.	Sensible Temp. of Water when discharged into atmosphere	Loss of Heat	
50 lbs.	298° Fah.	212° Fah.	86 Fah.	28·9%
100 lbs.	338° Fah.	212° Fah.	126 Fah.	37·3%
150 lbs.	368 Fah.	212 Fah.	154 Fah.	42·1%
200 lbs.	388 Fah.	212° Fah.	176 Fah.	45·4%

Often the steam-trap discharge is allowed to run to waste, when the whole of the heat is lost; in other cases the water with its reduced temperature and lessened bulk, is piped to the hot well, during which time it loses further heat, and also imbibes gases and scale-forming constituents from the atmosphere.

The selection of steam traps should always receive careful attention; too often traps are installed which are not well fitted to the duties they are called upon to perform. Numbers of British makers offer standard sizes and types of traps which may be admirable for use on high pressures, where the amount of water to be dealt with is small, and where it is discharged at a high terminal pressure. They are, however, often totally unfitted for use on lower pressure systems, especially where condensation is spasmodic, and where large amounts of steam are condensed during short periods which require to be ejected quickly and at a low pressure of emission.

It is a prevailing custom among makers to offer traps of the same size, type, and bore for all working pressures and

* Abstract of paper read before the Association of Engineers in Charge Wednesday, December 13th, 1911.

varieties of conditions, with no information as to size of valve or carrying capacity. Such a custom is to be condemned. The size of the inlet and outlet is no criterion of the discharging capacity of a steam trap; this, for any pressure of emission, is governed by the diameter and lift of the valve alone. The writer has bought traps of well-known makes, in which the valve seats were found to be exactly of the same diameter in both the ⅜in. and the ½in. traps. The only difference between the two was that the former had a larger body and was more costly; and he has frequently found it necessary, on low-pressure jobs, to bore the valve seatings out to four or five times the area of the standard size before the traps were fit to perform their duties.

Another feature which should be considered in selecting traps is the amount of heat-radiating surface presented by the trap body, and, other things being equal, the trap should be selected which presents the smallest surface of radiation, as this forms a serious item of loss.

Modern steam power houses are fitted with steam boilers working at pressures ranging from 120lbs. to 200lbs. per square inch. The boilers are normally fitted with superheaters, which add anything from 50° Fah. to 150° Fah. to the sensible temperature of the saturated steam, and the actual temperature of the steam delivered into the steam pipes ranges from 400° Fah. to 600° Fah.

Numbers of engineers have an idea that because they obtain a high superheat there is a negligible amount of condensation in the steam pipes, and that there is, therefore, little, if any, call for drainage. Moreover, the advent and extensive employment of steam turbines has tended to confirm this impression, because such prime movers will carry through the water of condensation at normal rates into the condensers without noise or much danger; but the reduced efficiency of operation, and the increased cost of fuel thereby entailed, is a heavy price to pay for this accommodation. For example, 1 per cent. of moisture in the steam will lower the efficiency of the turbine 2 per cent.

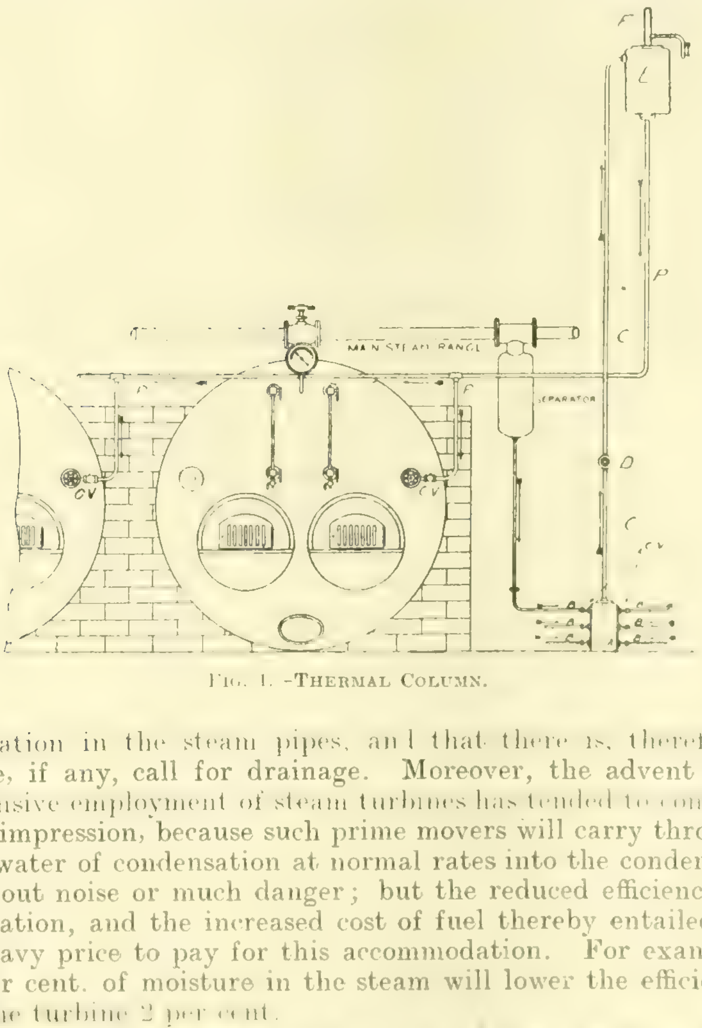


FIG. 1.—THERMAL COLUMN.

The authors are able to give the following data as to condensation in steam ranges:—

An electric power station in the Midlands with steam at 125lbs. pressure, and 50° Fah. of superheat, is fitted with steam pipes having a total area of 1,200 sq. ft., inclusive of flanges and valve bodies. The whole pipe range is housed in substantial buildings, and effectively covered by plastic asbestos to an average depth of 2in. The water of condensation discharged from the five points of drainage on November 11th, 1910, was 357 galls. in 24 hours.

An electric power station in the North of England, with steam at 140lbs., and 120° Fah. to 150° Fah. superheat, is equipped with a steam range having a total area of 1,384 sq. ft., including flanges, valve bodies, and separators. The whole pipe range is housed in substantial buildings, and effectively covered by magnesia to an average depth of 2in. During six successive days last April—the readings being taken regularly every three hours—the water of condensation from the range averaged 17·1 galls. per hour, or 410 galls. in the 24 hours.

In a large electric power house in Scotland, employing modern high-pressure boilers and superheaters, the water of condensation expelled from the steam range, when tested, was 1,198 galls. in the 24 hours.

It is found that the amount of condensation in the steam pipes is greatest in the winter time, and during the 24 hours it is heaviest when the lightest load is being carried by the station.

Taking the average for the three power houses abovementioned, the amount of condensation is 655 gals. a day, or 239,075 galls. a year. Assume an average steam pressure of 150lbs., or a sensible temperature of 366° Fah., say 310° Fah., in excess of the average temperature of the boiler feed water. The total useful heat represented by this water of condensation equals 741,132,500 B.Th.U.'s per annum. Should the water be discharged to the drains, which is the case in many instances, the whole of this heat is wasted.

In power houses where economy of operation is studied, the water of condensation is often entrained to the hot well, thus saving a large proportion of the water, and a certain proportion of the heat. This arrangement, while being in some cases better than allowing the hot water to run to waste, is not economical, for the following reasons:—

(1) The temperature of emission from the steam range carrying steam at 150lbs. pressure approximates to 366° Fah., while the maximum temperature of the water in the atmosphere cannot be above 212°. The additional cooling in transmission to the hot well and from thence to the feed pumps will further increase the loss indefinitely. However, taking the high figure of 180° Fah. as the temperature of the water passing to the pumps, and a feed temperature of 56°, the heat saved per pound of water is 124 B.Th.U.'s out of a possible (366—56) 310 B.Th.U.'s. In other words, about 60 per cent. of the heat is lost.

(2) Due to the rapid fall in temperature from 366° to 212°, approximately 16 per cent. of the water is lost in evaporation.

(3) As nearly all modern power houses are fitted with surface condensers and economisers, it is often wasteful practice to allow the high-temperature trap water into the hot well because of the heavy decrease in economiser efficiency which is involved.

This heavy continuous loss has largely escaped attention hitherto, and it is difficult to get data with regard to it. The following information will, however, indicate that the loss is more serious than is generally recognised:

Mr. J. R. Fish, of Bolton, in a recent communication, gave the results of two actual tests which show that economisers are far more efficient when supplied with feed water at a low temperature as compared with high temperature feed. The following table has been based upon the published figures given by Mr. Fish for the same economiser taking feed water at different temperatures:—

	[illegible]	[illegible]	[illegible]	[illegible]	B.Th.U.'s [illegible] from [illegible] lb. of water	[illegible] hour in [illegible]
No. 1	96 hrs.	800	60 Fah.	245 Fah.	185	8 cwt. 2 qrs.
No. 2	168 hrs.	800	120 Fah.	251 Fah.	131	8 cwt. 2 qrs.

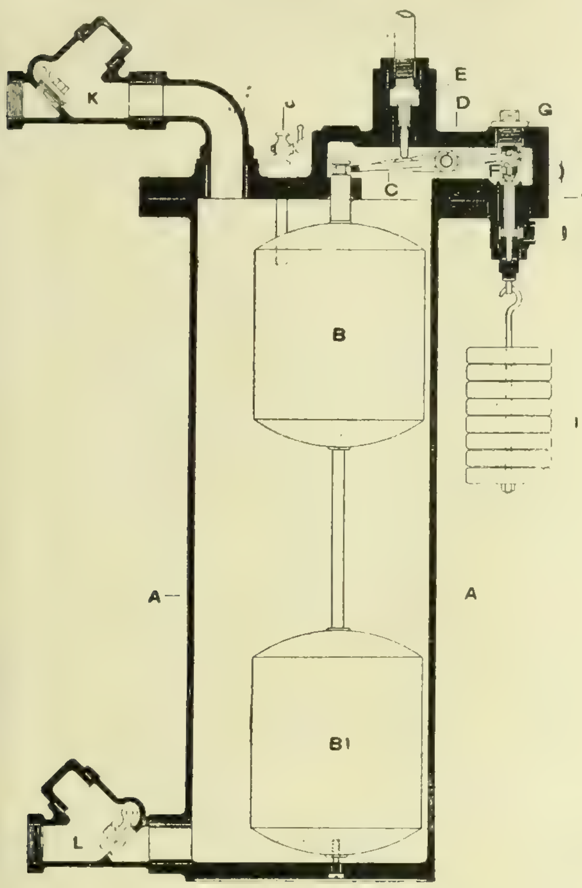
These figures show that 1,480,000 B.Th.U.'s were extracted from the spent furnace gases per hour in the case of the cool feed, against 1,048,000 with the higher temperature feed; a difference of 432,000 B.Th.U.'s in favour of the former or 41 per cent. gain in heat units, or a saving in fuel of 4 to 5 per cent.

The following figures, taken from a power station during a normal day's working, effectively demonstrate the point under discussion. The temperatures were taken after the conditions had been established for two hours, so that the thermometers had settled down to steady readings. Comparing feed at 50° Fah. and injector feed at 182° Fah., there is a difference of 10 per cent. efficiency due in favour of the former case.

It should be explained that the term "efficiency due to economiser" is here used in an approximate sense, based on

the rough assumption that every 10° Fah. added to the water is equivalent to an efficiency of 1 per cent.

In giving the above examples, the authors do not suggest that economisers, as at present made, should be fed with cold water, as sweating of the tubes and destructive corrosion would be set up; also, in cases where the furnace draught is feeble and the chimney inadequate, to extract so large an amount of heat from the gases might seriously reduce the draught and the furnace activity. There are, however, undoubtedly many steam plants, especially in cases where mechanical draught is employed, where such a modification could be readily introduced, and the result would be a substantial saving in the coal bill.



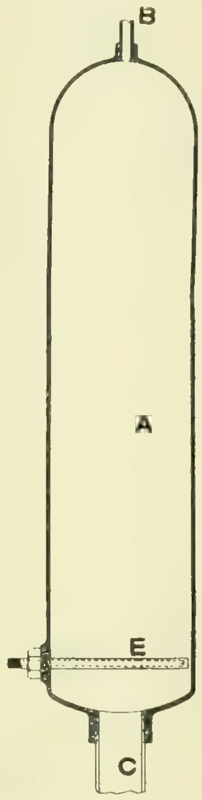


Fig. 2.—The Lifter. Fig. 3.—The Feeder.
Losles System of Drainage.

Further dependable evidence is furnished by the largest firm of economiser manufacturers in the kingdom, whose tests showed a difference in economiser efficiency, all other things being equal, between an initial feed temperature of 94° Fah. and 202° Fah., as no less than 26 per cent.

In 1910, when visiting one of the large power houses of the city of Glasgow, the writer took the opportunity of measuring the temperatures of the feed water, and found the temperature of the water discharged by the air pumps from the surface condensers varied from 110° Fah. to 120° Fah., and the discharge from the steam traps which entered the water duct at a point between the air-pump discharge and the hot well was lifting the temperature of the water to no less than 160° Fah., *i.e.*, it was adding 40° Fah. to a condenser discharge which was already 10° Fah. to 20° Fah. higher than was desirable for the economisers, and thus the economiser efficiency was very substantially lowered. The writer was fortunate enough to see the log sheets at the works and found that the temperatures taken accorded closely with the station records.

In view of the facts and figures given in the preceding paragraphs it is probable that if all the heat in the trap water had been allowed to run to waste the net result would have been a gain, due solely to the improved efficiency thereby realised in the economisers.

Incidentally, the authors may point out, as the foregoing facts prove, that exhaust-steam heaters are often connected up in an inefficient manner. If such heaters raise the feed water to a high temperature, they should not be put in series between the feed pumps and the economisers, but in parallel with the economisers, and the relative amount of water passed through each apparatus properly adjusted.

In cases where the normal temperature of the hot well is too low to prevent sweating and corrosion of the economiser tubes, it is far better practice to raise the initial temperature of the feed water by connecting a small pipe from the economiser discharge to the pump suction. The small amount of hot water which flows through this pipe raises the temperature of the feed water the required amount, and the whole of the heat in the feed water is thus derived from the spent furnace gases, while the economiser is maintained in operation continuously at its highest efficiency.

The authors trust that the foregoing observations demonstrate the necessity of better methods of dealing with water of condensation. Either to allow it to dribble through the prime movers to the condensers or to drain to the hot well is a method to be condemned.

The obvious and only efficient method of dealing with the problem is to return the steam temperature water to the boilers immediately condensation takes place. This can be done by simple and reliable methods; but, due to want of appreciation and enterprise, many engineers in this country are still content to continue the old and wasteful methods.

Between 30 and 40 years ago the first automatic method was invented in America and put upon the market under the name of "The Steam Loop," which automatically returns to the boiler any condensed water which may be formed in the steam pipes, without the aid of mechanism or complication of any kind.

Due to the limited capacity of the steam loop, and to the fact that a separate loop is required for every point of drainage, a further development of the device took place also in America, and was put upon the market under the name of "The Holly System." It was introduced in Great Britain many years ago, but has not succeeded in establishing itself in many power houses in the country.

In 1906 during extensions in the Harrogate Electric Power House it became necessary to improve the steam pipe drainage. After a series of experiments and investigations carried on under actual working conditions, the authors succeeded in evolving a simple automatic device, which is dependable under all working conditions. This device has since become known on the market as the "Wilkinson Thermal Column." This column is illustrated in Fig. 1, and it consists of two chambers A, the lower or sump (the standard pattern of which is fitted to take six entrainment pipes), and E, the upper chamber or receiver. The former is fixed in such a position that the water of condensation draining from the steam range, separators, steam jackets, &c., can

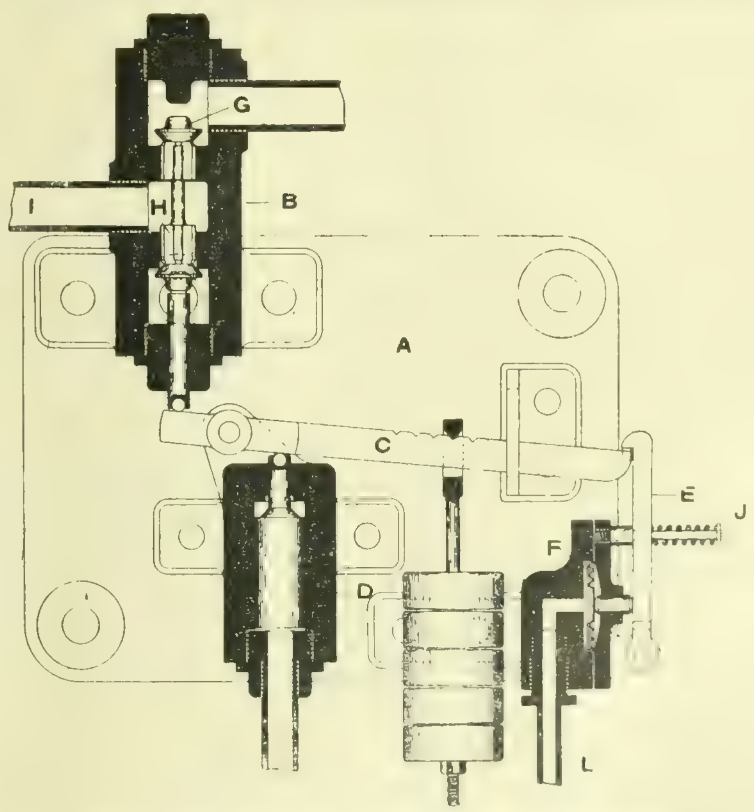


Fig. 4. The Controller. Losles System of Drainage.

freely flow thereto, by gravity, through entrainment pipes B and check valves *cv*. The sump is connected by a rising pipe C and valve *d* to the receiver E, which is fixed above the boilers, so that the water of condensation can quickly gravitate therefrom through the connecting pipe P and non-return valves *cv* back to the boilers.

The principle on which the thermal column works may

not be quite clear at first sight. Its operation is due to the fact that directly a body of steam is cut off from the source of supply it cools rapidly, and the pressure drops. For instance, steam at 150lbs. pressure has a sensible temperature of 366° Fah.; at 361° Fah. it has a pressure of 10lbs. less, which is sufficient to lift a column of water (in round figures) 20ft.

Bearing these facts in mind, it will be noted, on reference to Fig. 1, that when there is no water of condensation in the sump A, steam has free access up the rising pipe C. As the drainage water enters the sump through the check valves and inlets B, the bottom of the rising pipe C becomes immersed, and the rising pipe C and the receiver E are cut off from the source of steam supply. The steam in the receiver E instantly drops in pressure, and, due to the full steam pressure in the sump the water rises up the pipe C and drops over into the receiver E. Directly the water in the sump A has passed into the receiver E, steam follows up the rising pipe C, and establishes equilibrium of pressure between the receiver E and the boiler. The water is then free to gravitate through the pipe P and the check valves G into the boilers.

The receiver E is of such capacity that, notwithstanding the periods during which it is discharging its contents to the

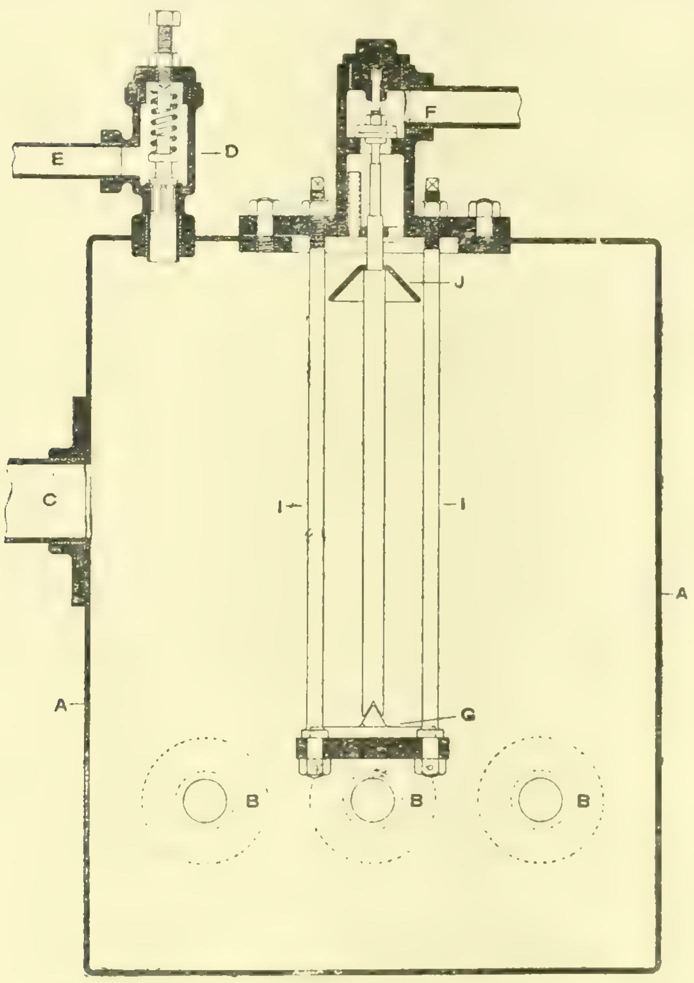


FIG. 5.—EQUI-SUMP. LOSLES SYSTEM OF DRAINAGE.

boiler, the normal amount of condensation water formed in the steam range during each cycle is incapable of filling it. In other words, the amount of water collected in the sump and entraining pipes during the period when the receiver is discharging to the boiler and being refilled is less than the receiving chamber will hold.

The apparatus is so sensitive that the heat radiation through good "non conducting" covering material is sufficient to ensure its effective working and the automatic return of the condensed steam direct to the boiler. The efficiency is so high that the condensed steam can be lifted from the sump and returned to the boilers with a maximum drop in temperature of less than one degree (Fah.) per foot of lift. In a well arranged high pressure plant the temperature loss is about half this amount. There is no outlet to atmosphere, and the whole of the water, at a temperature closely approximating to that of the steam, is within a very short time of its actual condensation in the steam range silently carried back direct to the boiler.

The cover of the receiver is fitted with an automatic air and relief valve F, which, while holding tight against steam, allows the small amount of air accumulating, to escape to atmosphere. The automatic valve F is designed so that should the receiver become flooded and the water rise into the inner tube of the automatic relief valve it causes the tube to contract slightly. This liberates a thin film of water, the kinetic energy of which water serves to throw the valve full open, and the discharge is then exceedingly rapid. The steam which follows after the excess water is discharged is unable to maintain the valve open, and it immediately snaps down upon its seat, and the flow of steam is stopped. This relief valve is called into operation only when there is an exceptional rush of water.

The thermal column may be left with confidence to discharge its functions continuously, provided the automatic relief valve on the overhead receiver is operated by hand for a few moments, say twice a week, to prevent its getting set fast. This is necessary, as the valve may not be called upon to operate more often than once in six months, or even longer. This apparatus is at work successfully dealing with all the water of condensation in power houses, having working pressures of from 25lbs. to 200lbs. per square inch.

Two objections have been advanced against the use of this system of drainage, and they have both proved groundless in practice. The first is that to keep the small entrainment pipes and joints tight will be a matter of some difficulty. The inconsistency of this contention is apparent when we consider the aggregate length of small piping used in superheaters, and the larger amount of comparatively weak cast-iron piping employed in economisers, the end boxes of which are kept watertight by the employment of circular back-tapered cast-iron discs. No trouble is incurred on the entrainment piping, provided it is built up in lengths and the socket connections are screwed dry and brazed. The various sections should be bolted together by means of flanges of substantial thickness, jointed with good mastic and corrugated metal jointing rings.

The second objection sometimes advanced is that, due to drop of steam pressure in various parts of the steam range on heavy loads, the drainage to a common sump will not be free and dependable. Experience under practical working conditions proves this objection to be groundless, as, while it is true that there are differences in pressure on a high-pressure steam range, such pressure variation within wide limits does not interfere with free drainage to a common sump.

It must not be forgotten that the steam is subject to rapid pulsations due to the spasmodic requirements of the prime mover and the action of the governors on the engines. Also, the steam piping is in a vibratory condition. These two elements are sufficient to ensure drainage from all points to the sump.

The greatest variation of steam pressure which has come under the authors' notice is upon a steam range working at 140lbs.; in this case a steam turbine of 1,000 kw. derives its supply from the extreme end of the steam ring, and a small auxiliary steam engine derives its steam supply from the remote side of this big plant. The drop of pressure on the auxiliary steam engine when the 1,000 kw. plant is in operation approximates to 8lbs. or 10lbs. per square inch. Nevertheless, the separator on the small plant drains freely, although there is a head of less than 18ins. between it and the sump.

Although losses due to condensation in the power house are serious, in the factory we find far heavier losses from this cause. The difficulty in dealing effectively and efficiently with the problem is also greater, due to: (1) The more extensive distribution of steam. (2) The widely and frequently varying pressures and temperatures at which the water of condensation is expelled at the numerous drainage points. (3) The constantly varying amount of condensation, the drainage system being often called upon to deal promptly with heavy condensation at irregular periods.

Like difficulties are also often found in workhouses, asylums, public institutions, and hotels. Such buildings, for the most part, have three steam ranges, from each of which considerable quantities of water of condensation are discharged. An average example is as follows:—

(a) Pressure in the steam boilers of, say, 80lbs. per square inch, used for driving machinery.

(b) A range at 30lbs. per square inch, supplied through a reducing valve, and used for heating, calorifiers for hot water, and the like.

(c) A third range at from 5lbs. to 10lbs. per square inch used in the kitchens for cooking purposes.

Many attempts have been made to produce apparatus to collect the water of condensation, and automatically deliver it to the boilers without exposure to the atmosphere. Few have survived, and the systems which are in use have found a limited field of application, as none of them meet all the conditions involved in the problem. The best-known systems are the Bundy or Morehead lifting pump steam trap, the Pratt return steam trap, and the automatically-controlled feed pump with superimposed receiver.

The disadvantages of existing return trap systems are that in the vast majority of cases, there is insufficient head available to lift the water above the boiler. The employment of two return traps then becomes necessary. The lower trap lifts the water to the upper one, which in turn discharges to the boiler. This arrangement appears satisfactory at first sight, but practice reveals an inherent disadvantage. In actual working, the two traps get out of phase. Imagine the top trap to be filled before the bottom one is quite empty. The lower trap remains standing while the upper one discharges to boiler. The latter then takes the remainder of the contents of the lower trap. In turn, the upper trap is then held up until the lower one has again filled, and become capable of completing the filling of the upper one. This out-of-phase effect very materially reduces the capacity of the return system. Again the "idle" period of the bottom trap occurs during its discharge stroke, *i.e*, when the trap contains live steam. The result is a soakage of heat into the trap and its contents, all of which is lost in the form of steam exhausted to atmosphere during the next filling stroke. This makes the "out-of-phase" filling stroke longer than the normal one, and so further loss of capacity is involved, in addition to the heat loss.

In the majority of cases in factory practice, the points drained are subjected to different and constantly-varying pressures of discharge. Nevertheless, in existing return trap systems a common closed sump is used, to which the drain pipes are connected. The inevitable result is a "backing up" of water in those parts of the steam plant which at the time have the lowest discharge pressures. This "backing up" effect is bad in three ways: (a) It is wasteful, for the apparatus in which it has taken place must be drained by running the water to waste. (b) There is also indirect waste due to the reduced efficiency of the flooded apparatus. (c) There is risk of positive damage due to water-hammer.

It is claimed that where the steam pressure is high enough to raise the water of condensation above the boilers, one return apparatus is sufficient. If, however, any part of the plant drained be out of use it is subject to the pernicious backing-up effect just described. It is impossible to keep all the check valves tight, and when a machine which has been out of use for a time is opened up it is often found to be full of cold water. Before commencing to work, this water must be run to waste, its heat being already dissipated. The remedy for this trouble is the use of a closed sump placed below the level of the lowest point drained. To obtain this result, however, it is necessary to have a sump which will automatically prevent a serious back pressure from being exerted on the drainage pipes.

The "Losles" system has been designed by the authors to overcome the several defects in existing return systems. The apparatus is illustrated in Figs. 2-5. The essential parts are: A bottom receiver or "Lifter" (Fig. 2); a top receiver or "Feeder" (Fig. 3); a "Controller" (Fig. 4); an "Equi-Sump" (Fig. 5).

Fig. 2 shows a sectional view of one type of "Lifter." It consists of a cylindrical chamber A of mild steel, in which hollow metal floats B and B_1 are suspended from the lever C carried in the cover D. As will be seen, the valves are of the mushroom type, and the spindle of the steam valve E abuts upon the lever C at a point between the float suspension and the fulcrum. The exhaust valve F is carried upon a hard steel ball G riding upon the other end of the lever C. Thus, the vertical motions of the valves are free, notwithstanding that they are both operated by a lever turning upon a centre pin. The general arrangement is such that all the parts can be withdrawn and replaced in a few moments by removing the end plate H without breaking the cover joint. The extension of the exhaust valve carries a balance weight I.

The adjustment is such that when the float B is submerged to the level corresponding with the bottom of the dip pipe J, it is sufficiently buoyant to force open the steam valve E until its upward movement is arrested by the exhaust valve F coming into contact with its seat. This admits steam, which forces the water at a great velocity into the feeder located above the boilers. When the water level has fallen, and the bottom float B_1 is partly denuded of water, the dual float becomes heavy enough to pull the exhaust valve F off its seat against the steam pressure, and at the same time allows the steam valve E to close. The steam in the lifter at once exhausts to atmosphere or into the feed tank through a silent heater, when the caloric is usefully absorbed by the feed water. The water enters the lifter clear of the dual float through the non-return valve K, and flows to the feeder through the non-return valve L. The floats have sufficient displacement to open large steam and exhaust valves while

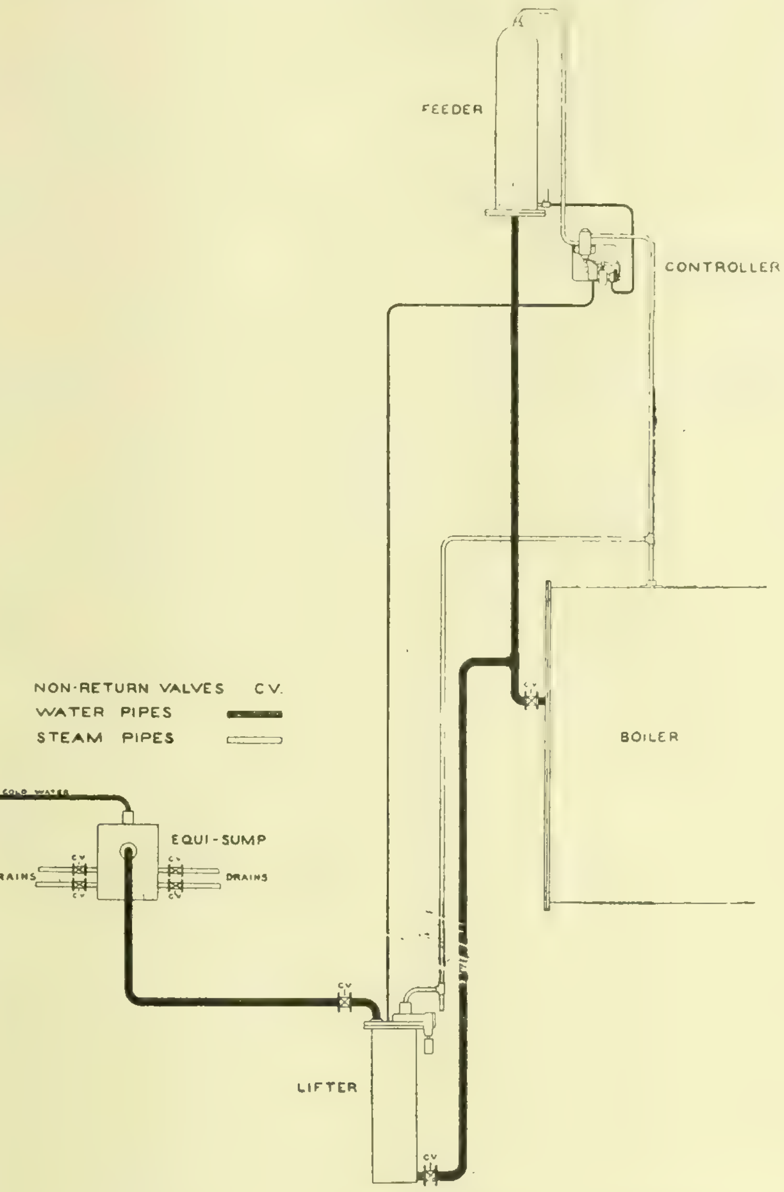


FIG. 6.—DIAGRAM OF CONNECTIONS. LOSLES SYSTEM OF DRAINAGE.

the inlet and outlet pipes are much bigger than hitherto used, the result being that a high duty is obtained.

The feeder consists of a steel chamber A, shown in Fig. 3. It contains no moving parts; it is fitted with a pipe B at its upper end, which serves alternately for the admission and discharge of boiler steam. At its lower end a larger pipe C is fitted, which serves alternately as the water inlet from the lifter, and the water discharge pipe to the boilers. The feeder is also fitted with a small horizontal pipe E, the inner end of which is closed. This pipe carries a core of metal of rather less diameter than the bore of the pipe and the intervening space contains water. The function of this pipe is described in connection with the valve box.

Fig. 4 shows the controller, which serves to deliver and exhaust steam to and from the feeder in synchronism with the lifter. This controller may be fixed in any convenient and accessible position. It consists of a back plate A, which may be bolted up in any convenient position. This plate carries the valve box B, the weighted lever C, the lifting cylinder B, the catch E, and the releasing diaphragm F. In

the valve box B is a steam valve G and an exhaust valve H. The pipe I enters between these two valves, and communicates with the top of the feeder (Fig. 3). This pipe serves to convey steam to or from the feeder, according as the steam valve G or exhaust valve H is open. The lifting cylinder D contains a plunger, and is connected by a small pipe with the lifter (Fig. 2). The catch E is controlled by the diaphragm F and the spring J. The diaphragm is connected by means of the pipe I to the pipe E in the feeder already mentioned. (See Fig. 3).

The function of the controller is to ensure the synchronous working of the lifter and feeder, which it does as follows: The weighted lever C is adjusted to keep the steam valve G open, and the exhaust valve H shut. This allows the feeder to deliver its contents to boiler. The feeder cannot fill with water until the lever C is lifted, allowing the steam valve G to shut and exhaust valve H to open. Two conditions must be satisfied before this can take place, if synchronism is to be obtained: (1) The lifter must be ready to fill the feeder. (2) The feeder must be sufficiently empty to take the lifter's contents.

The two conditions are satisfied by the action of the cylinders D and the diaphragm F respectively. When the lifter is ready to discharge to the feeder it communicates its steam pressure to the cylinder D, which will lift the lever C provided the catch E is also raised. When the feeder is sufficiently empty to take the contents of the lifter, the pipe E in the feeder (Fig. 3) is exposed to the steam, and the water it contains is evaporated. The pressure so generated is communicated to the diaphragm F, and raises the catch E against the spring J. This satisfies the second condition essential to synchronism. When the lifter has passed its contents to the feeder, it opens its exhaust valve. This drops the pressure in the cylinder D, and allows the lever C to drop back into its original position. The fresh charge of water in the receiver cools the pipe E (Fig. 3), condenses the steam therein, and the catch E is then able to return to its first position. The cycle then recommences.

In any particular case the speed of the operation is limited either by the filling head to the boiler or the filling head to the lifter. The former is proportional to the height of the feeder above the boiler; the latter to the minimum pressure of discharge in the drainage system.

Fig. 5 shows a sectional view of one type of the equi-sump, which allows the traps at points of differing pressures to drain into one common return system without waste of heat or loss by evaporation. It consists of a closed tank A, preferably covered by heat-insulating material, into which all the drainage pipes discharge at B, below the level of the pipe C, which conveys the contents to the lifter. Each drainage pipe is provided with a non return valve, and those which convey water of condensation at very high temperatures are preferably fitted with silent water heaters. A relief valve D in the cover of the feeder is set to maintain a pressure rather less than the minimum discharge pressure in the steam plant drained. The pipe E from this relief valve is terminated in the boiler feed tank below the level of the water. Should the return system be put out of action, the water of condensation, instead of backing up the drain pipes, finds a vent through the relief valve into the feed tank.

A cold water supply is connected with the equi-sump through the valve F, which is controlled by the automatic thermal regulator G. The drainage water, flowing into the sump may be so hot as to cause the temperature of the water within the sump to rise above that corresponding to the pressure at which the relief valve D will blow. Such a rise in temperature would mean a corresponding rise in pressure. In order to prevent this, the thermal regulator G is adjusted to open the valve F, admitting cold water, which absorbs the excessive heat. By means of the screws I the maximum temperature in the feeder is adjusted. The deflector J is to throw the cooling water clear of the thermal regulator G. In some cases, owing to the low emission pressure of the water of condensation, no pressure may be allowable in the equi-sump, and in that event the relief valve D is dispensed with, but air is prevented from entering the equi-sump by a water trap in the relief pipe or other equivalent device.

Fig. 12 shows, in diagrammatic form, the arrangement of a complete "Losles" system. If the steam pipe supplying the "Losles" apparatus is effectively drained, so that the water of condensation from the live steam supply pipe is passed into the lifter with the feed water instead of being allowed to find its way through the steam valve, the plant becomes a reliable meter-feed pump. When so used, a speed counter is fixed on the controller, and a sensitive reducing valve is fixed on the steam supply pipe to the lifter, so that the steam pressure upon the lifter may be uniform and independent of the usual fluctuations of steam pressure in the boilers. When so used, the ordinary feed-water tank takes the place of the equi-sump.

Economiser Efficiency on Low Loads with one 30ft. by 8ft. 6in. Lancashire Boiler Steaming.

Two Economisers in parallel, viz: No. 1, of 192 tubes, and No. 2, of 288 tubes.

Time.	Strokes of Pump.	Temp. of water entering Economiser.		Temp. of water leaving Economiser.		Aver. temp. of water leaving Econ	Heat Units added by Econ. per lb. of water.	Efficiency due to Econ.	Load H.P.	CO_2
		No. 1.	No. 2.	No. 1.	No. 2.					
10 a.m.	22	152° Fah.	152° Fah.	208° Fah.	210° Fah.	209° Fah.	57	5·7%	244	12%
12 a.m.	21	91° Fah.	91° Fah.	204° Fah.	200° Fah.	202° Fah.	111	11·1%	217	11·5%
2 p.m.	23	85° Fah.	85° Fah.	205° Fah.	198° Fah.	201½° Fah.	116	11·6%	244	11%
4 p.m.	Injector Feed.	182° Fah.	182° Fah.	200° Fah.	199° Fah.	199½° Fah.	18	1·8%	273	10%

THE PEEL-CONNER SYSTEM OF TELEPHONY.

LAST week the Postmaster-General afforded an opportunity to several Press representatives of inspecting the new "Avenue" telephone exchange in London. This exchange has been equipped by the Peel-Conner Telephone Works, Ltd., of Salford and London, on a plan which has been in use for some time in the United States, but has not been adopted previously in this country. The peculiar characteristic of the new method, which is known as the ancillary jack system, consists in the fact that each call from a subscriber is notified to three teams of operators instead of to one only, and any of these can respond, so that the opportunities for "getting through" quickly are tripled. This result is achieved in the following manner: Each subscriber's circuit is equipped with three (instead of one) call lamps and answering plug sockets or "jacks" located at widely separated points on the switchboard. One of the three jacks is the primary and the other two are ancillaries, being secondary and tertiary respectively. The primary jack corresponds to the single jack of the ordinary system and the call is normally responded to by the operator in whose position the jack occurs in the primary section. If this operator is busy and the operator at the position where the jack comes in the secondary set is disengaged, the latter operator responds; and similarly with the tertiary section. The second and third operaters, acting under their instructions, will wait long enough to give time for the primary jack to be used, and then if it is not brought into action one of the ancillaries will be employed. When two lamps glow simultaneously in front of a disengaged operator, one a primary lamp and the other an ancillary, she will answer the call of the primary lamp in preference to the other. The triple sets of jacks and lamps are arranged in parallel, and the insertion of the answering plug in any one of the three jacks extinguishes all three lamps. But if two, or even all three, were coupled up simultaneously no harm would result. Not only should this system lead to a more prompt response to calls, but the distribution of the traffic should be rendered more even and the work of the operators made more uniform. At night and during other slack times the work can be concentrated on to one third of the switchboard, the ancillary jacks and lamps in the section used being treated as primaries

INTERNAL-COMBUSTION ENGINE FOR HEAVY FUEL OILS.

In internal-combustion engines for burning crude and the heavier fuel oils, and in which the fuel is sprayed into the engine cylinder about the time that the piston arrives at the inner end of the compression stroke, a charge of air previously admitted into the cylinder being compressed during the aforesaid compression stroke to a very high degree of compression which raises the temperature of the air to a sufficient extent to ignite the fuel as soon as it is sprayed into the cylinder, it has been customary to introduce the fuel into an atomiser preparatory to its entrance to the cylinder, and to discharge the fuel from the atomiser by highly-compressed air which enters the atomiser from a storage tank connected with an air compressor.

In the arrangement illustrated, which has been designed and patented by James McKechnie, of Vickers, Ltd., Naval Construction Works, Barrow-in-Furness, the air compressor and storage tank are dispensed with, and a simple and efficient device for introducing the fuel into the cylinder in the form of spray substituted, which, it is claimed, materially simplifies the construction of the engine, and reduces the cost of manufacture.

Fig. 1 is a sectional elevation of the fuel-introducing apparatus, Fig. 2 is a detached view of a pneumatic arrangement for operating the fuel-introducing plunger, and Fig. 3 is a sectional elevation of a modified arrangement of fuel-introducing apparatus. A indicates the engine cylinder, B the piston, C the fuel-introducing plunger, and D a powerful coiled spring. As shown in Fig. 1, the spring D encircles a rod G which forms a continuation of the plunger C. This spring is confined between a disc H carried by the rod G and a cross piece that is connected to the plunger casing I by the bolts shown. The upper end of the rod G terminates in an open frame that carries a roller J for engagement with a cam K mounted upon a shaft that is driven from any convenient part of the engine. The charge of fuel to be forced into the cylinder A is admitted into a chamber L from a measuring pump E that is separated from the chamber by a non-return valve M. This pump comprises a plunger N that is operated from an eccentric O on a shaft P which is driven from any convenient part of the engine, the inlet valve Q of the pump being controlled from a stepped cam R that is slidably mounted upon a key on the shaft P and is provided with a number of lifting surfaces of unequal lengths for regulating the amount of time that the inlet valve is to remain open during the downward or delivery stroke of the plunger N. The chamber L is arranged in open communication with the cylinder A through a number of small apertures S, the arrangement being such that when the engine piston B is at or about the inner end of its compression stroke, the spring is released by the action of the cam, with the result that the plunger C forces the fuel under heavy pressure (for example from 2,000lbs. to 6,000lbs. per square inch) through the small apertures S in the form of a spray into the engine cylinder A, whereupon the compressed charge of air therein ignites the fuel in the usual manner.

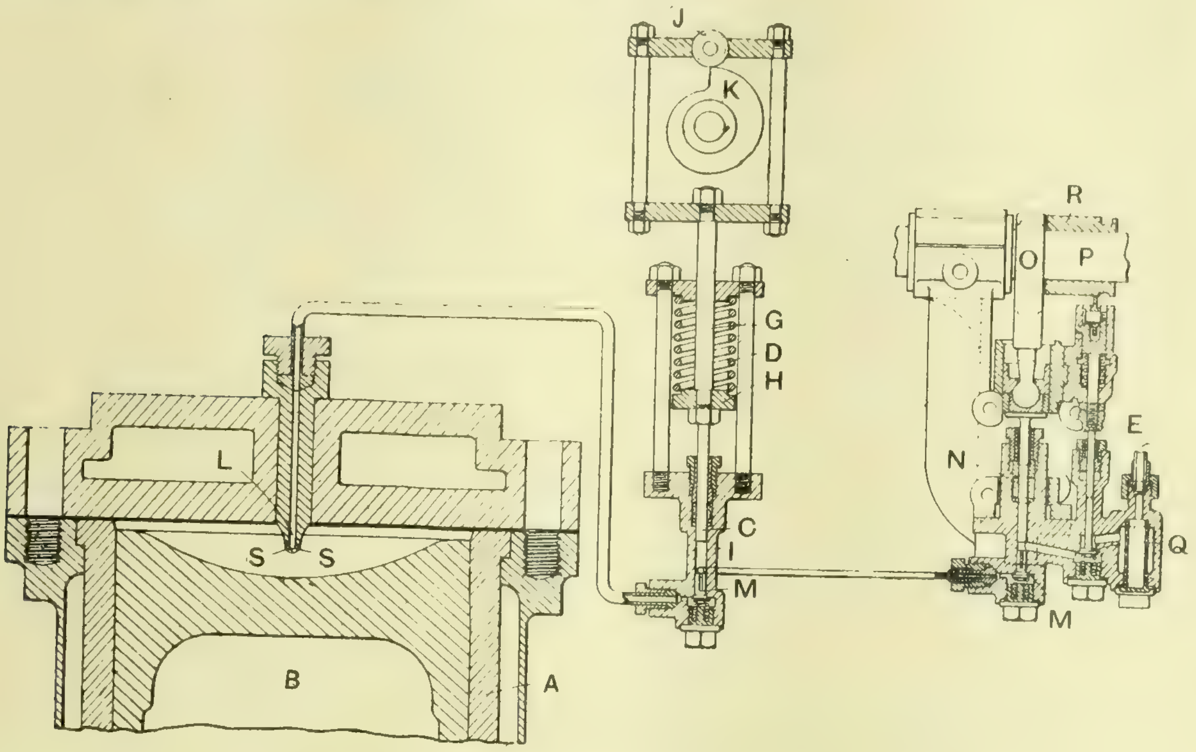


Fig. 1. INTERNAL-COMBUSTION ENGINE FOR HEAVY FUEL OILS.

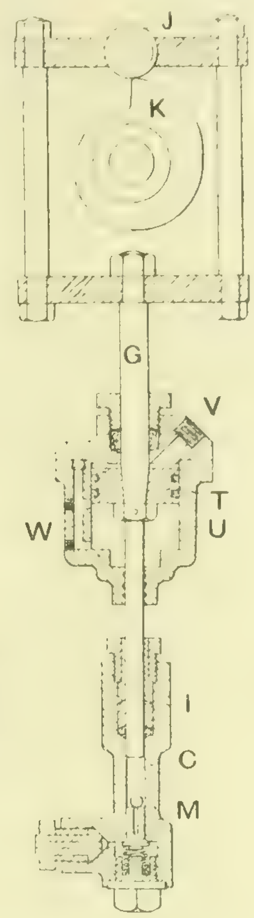


Fig. 2.

In the alternative arrangement shown in Fig. 2, a pneumatic spring is substituted for the metal spring shown in Fig. 1. For this purpose the rod G is fitted with a piston T that is enclosed within a cylinder U communicating through a pipe V and non-return valve with an air reservoir to which air is supplied under pressure by means of a pump. The action in this case is the same as that already described, the air admitted under pressure to the cylinder U being further compressed therein as the cam K raises the plunger C to the upper end of its stroke. As soon as the stepped portion of the cam clears the roller J, the compressed air in the cylinder U acting upon the piston T instantaneously forces the plunger C to the lower end of its stroke, with the result that the fuel admitted from the measuring pump E to the pump casing I below the plunger C is subjected to heavy pressure and suddenly ejected in the form of a spray into the engine

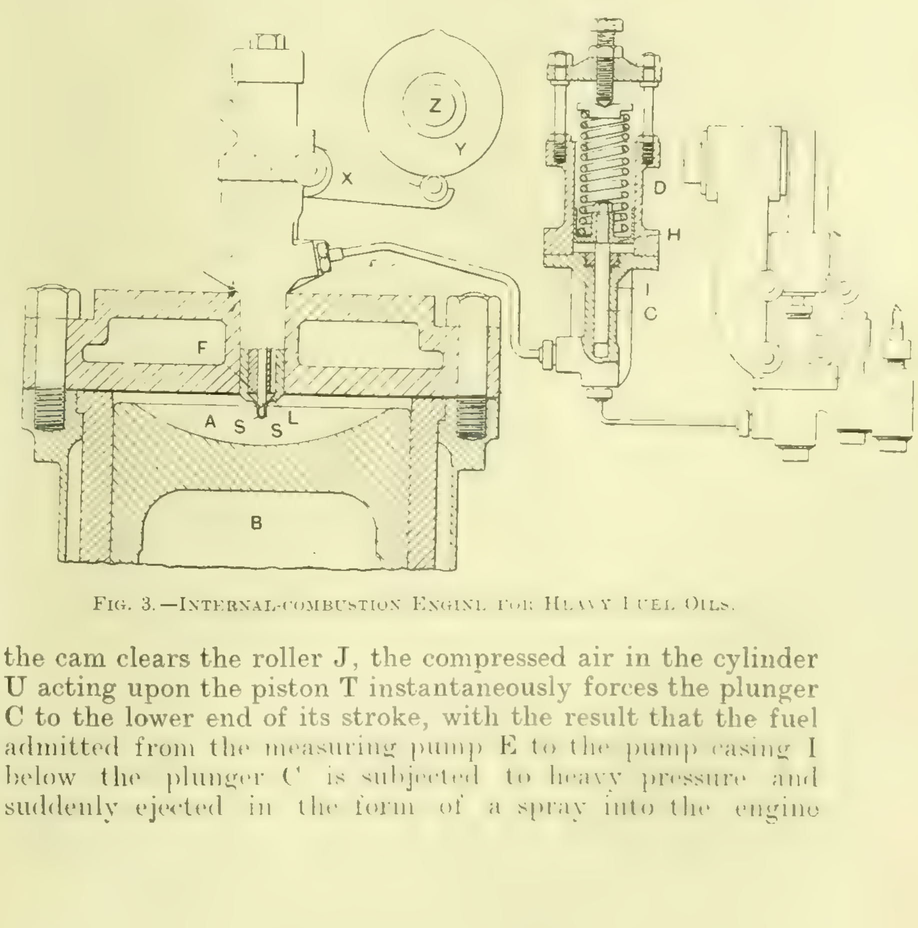


Fig. 3.—INTERNAL-COMBUSTION ENGINE FOR HEAVY FUEL OILS.

cylinder A through the apertures S. Any hammering action of the piston T upon the lower end of the cylinder U is prevented by a by-pass W which enables compressed air to pass from the upper portion of the cylinder to the lower portion, and thereby to form an air cushion for the piston as the latter reaches the lower end of its stroke.

In some cases it may be desirable to admit the fuel to the engine cylinder through a mechanically-operated needle or other appropriate valve. In the example shown in Fig. 3, F represents a valve that enters the chamber L and normally closes the outlet thereof to the engine cylinder. This valve is situated within a casing carried by the upper end of the engine cylinder and is connected with a lever X to which a rocking motion is imparted at the appointed time through the intervention of a cam Y fixed upon a shaft Z that is driven from any suitable part of the engine. The chamber L is placed in direct communication with the fuel-actuating plunger C, and such plunger is actuated by a coiled metal spring although a pneumatic spring may be substituted therefor if so desired. The mechanically-operated valve F takes the place of the cam for releasing the spring D and, owing to the fact that such valve closes the fuel passage to the engine cylinder, any fuel delivered by the plunger N of the fuel-measuring pump raises the fuel-actuating plunger C against the pressure of the spring D and itself becomes subject to heavy pressure. As soon as the valve F is opened, the spring D at once forces the plunger C to the lower end of its stroke, thereby discharging the fuel into the engine cylinder in the form of a spray through the apertures S. Any hammering between the disc H and the top of the plunger casing I is prevented by enclosing the disc in a cylinder, the air within the cylinder below the disc H acting as a cushion as the disc approaches the top of the casing I.

DEOXIDISERS FOR COPPER ALLOYS.

BY C. VICKERS.

WHEN copper is raised to a red heat it possesses such a powerful affinity for oxygen that an external coating of oxide or copper rust is formed. If the heating is continued and increased to the melting point of the copper, the coating of oxide may become so thick that the metal in the interior may become liquid and run out, leaving a shell the form of the original piece of metal. If the shell thus formed is stirred into the melted portion it will be absorbed and held in the metal, which thus becomes a mixture of dross and copper, greatly inferior in strength and other qualities to the original metal, and which will produce spongy castings.

To reduce oxidation to the minimum, the metal, whether copper, brass, or bronze, is never allowed, in well-regulated shops, to melt down without attention, but every effort is directed towards bringing it to a melted condition with the minimum amount of exposure to the atmosphere or furnace gases. Therefore, when melting commences, the metal is pushed down into the melted portion of the metal as soon as possible, and the surface of the bath is always kept covered with charcoal. Notwithstanding these precautions, however, enough oxygen is always absorbed by copper to make it impossible to obtain sound sand castings without some preliminary treatment of the metal. This treatment may consist of a reduction of the oxygen by poling or stirring with a stick of hard wood, or by the addition of zinc, phosphorus, silicon, magnesium, or other elements of similar effect.

Poling or stirring must generally be supplemented by the addition of some deoxidising element, such as silicon, &c., to eliminate porosity, although a smaller amount of the deoxidiser is required when the metal is so treated. The various elements which have been mentioned, and others, such as manganese, iron, sodium, &c., are known as deoxidisers, and their application in brass foundry practice is comparatively recent. By their use alloys have been greatly improved and adapted for many purposes for which they otherwise would have been unfitted. On the other hand, they are also responsible for many difficulties with which the modern brass founder has to contend, and in this article the effects of the various deoxidising elements on the external appearance of the castings will be dealt with, in order to give some idea of what may be the cause of the difficulty when trouble is encountered, due to some impurity which may have accidentally entered the metal. Phosphorus is probably the best known and the most generally used of all the deoxidisers. It was first used in copper and brass by Parkes, of Birmingham, Eng., who took out patents covering its use in 1849, but its value in copper and tin alloy was not understood until a much later date. Phosphor bronze was first made commercially in 1873, as a result of the investigations of Montefiore, Levi, and Kunzel, and since that time the use of phosphorus has been firmly established.

Phosphorus. — The external effects produced by phosphorus on castings vary according to the quantity used, but when the percentage of phosphorus is high the castings will be black in colour, and the metal so fluid that it will soak into the sand. Consequently, if some precautions are not taken to prevent this by making the mould impervious to the metal, or by pouring the metal near the congealing temperature, the castings will be so rough as to be often unrecognisable. When phosphor bronze is cast, the difficulties encountered, other than those arising from excessive fluidity, are due to the slag which is continually rising to the surface of the metal in the crucible, and is very difficult to skim off. Therefore, some form of skimming gate should be adopted, whenever possible, in pouring these alloys, to prevent the slag from entering the casting. In the case of very heavy castings, even after every precaution has been taken, defects may frequently be found on the upper parts of the castings, due to the formation of little slag pockets. This may be largely overcome by pouring as cool as possible and letting the bronze stand in the crucible until cooled to the proper temperature. This is preferred to cooling by the addition of gates, &c., so that as much slag as possible may rise to the surface before the metal is poured. Phosphorus in scrap metals may sometimes cause inconvenience, but it is by no means as harmful as some of the other deoxidisers.

Iron. — Iron is generally an accidental impurity in modern alloys, although sometimes it is used intentionally. It is not generally classed as a deoxidiser, although it can be used as such in the form of tin plate or yellow prussiate of potash. Its effect on brass castings is well known. It produces an unsightly black colour and undue shrinkage when used to excess. In this case prevention is better than cure, and the iron should be removed before the brass is melted, whether in the form of chips or scrap metals. When iron finds its way into the metal accidentally, the castings must be scrapped if much machine work must be done on them, or if fine finish is required. The metal can only be used by mixing it again with new metal or by running it into cheap castings.

Aluminium. — Bronze or composition castings contaminated with aluminium possess a disagreeable, bright, bluish white colour, and when this is removed by dipping or tumbling, dark spots are frequently faintly discernible, which, when machined, will often turn out to be blow-holes under the skin. The metal will be found more difficult to machine, as the effect of lead in the mixture to produce short chips is counteracted to a large extent and the castings will often be drossy and porous. In the case of yellow brass, aluminium is extensively used for the production of small, thin castings, such as saddlery hardware, refrigerater trimmings, plumbers' ferrules, &c., as it promotes fluidity, suppresses zinc oxide smoke, and permits the use of an increased quantity of zinc in the alloy, thus making it possible to use a cheaper metal with superior results.

To obtain these results only a small quantity of aluminium is required, and this generally amounts to a fraction of 1 per cent. Only sufficient aluminium is used to produce a bright, pale gold colour on the castings, and even this amount cannot be used if the castings are to withstand high pressures, as the aluminium will cause the castings to leak. It is liable, also, to cause drossing adjacent to the gate, especially if the castings are at all thick in section, so that the use of aluminium, even as a flux or deoxidiser in yellow brass, is limited. If used in larger quantities, and the alloy is leaded, the gold colour will be turned into a dark, bright blue, verging on purple in spots, and the metal will be so rotten that it can easily be broken, revealing large crystals when fractured. When this occurs, either by design or by accident, the metal cannot be brought back to its original con-

dition by re-melting, but must be used cautiously with new metal. Aluminised brass is very difficult to use in a satisfactory way, as heats of new metal are ruined by a very small percentage, and 10lbs. of yellow brass or manganese bronze containing one-half of 1 per cent. of aluminium is all that can be safely used in 100lbs. of red metal.

Aluminium, therefore, should be carefully excluded from all brass or bronze castings, with the exception of small, thin, yellow brass work, such as previously mentioned, otherwise much annoyance and loss may result. Accidents, however, will happen occasionally, and some of the ways by which this metal may be introduced into alloys, where it works harm, are by the use of scrap containing aluminium, such as manganese or aluminium bronze, which cannot readily be detected. Carelessness, however, is probably the most frequent cause of losses from aluminium in castings, and when aluminium castings are made together with brass and bronze in the same shop, the use of skimmers and furnace tools previously used for aluminium must be constantly guarded against, as the latter metal sticks to the tools in a thin film, which is sufficient to cause considerable trouble. Aluminium cannot be fluxed out of bronze or brass in the foundry, and the only way to use it is to proportion it with new metal.

Silicon. — Silicon is a product of the electric furnace, and is used in the brass foundry in the form of an alloy with copper, known as silicon-copper. It is extensively used as a deoxidiser for making copper castings, and is very effective, producing fine castings of a deep red colour, very soft and ductile, and of much higher conductivity than is possible with zinc or phosphorus.

In bronze, however, its range of usefulness is curtailed more than aluminium, as it cannot be used in alloys that contain lead, whether yellow brass or bronze. When no lead is present, however, both bronze and brass cast well, and silicon is occasionally used for making trolley wheels, either with copper or in combination with tin. The external appearance of yellow brass castings is similar to that produced by small percentages of aluminium, when lead is not used. The presence of lead, however, imparts to the castings a white coating when taken from the sand, and when this coating is removed by brushing or tumbling, the surface of the casting will be found to be pitted with innumerable holes filled with a white powder. The same effect is also produced on bronze when lead is present, and a very small quantity of silicon will cause this result. The percentage may even be so small that the castings fail to show the white coating, and merely leave a white impression behind them when removed from the sand. A closer inspection, however, will generally reveal superficial dirt spots on the surface of the castings, and these, when machined, will frequently turn out to be blow-holes.

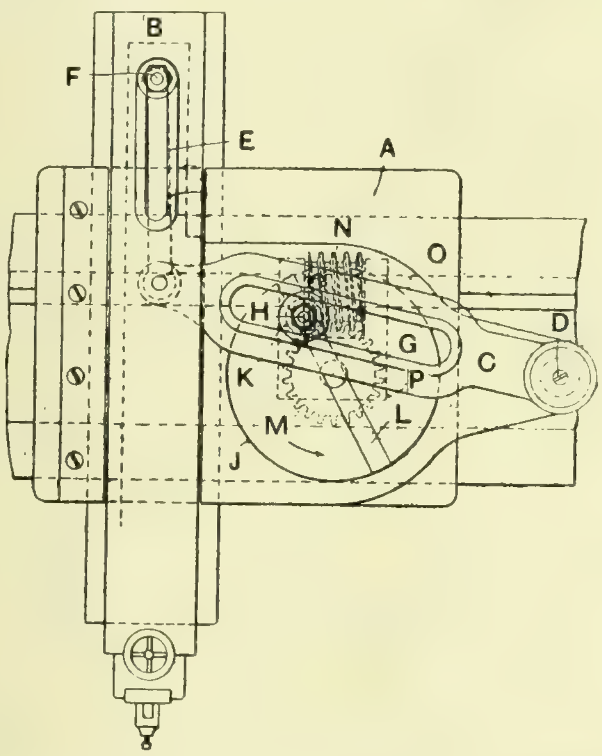
This difficulty is not as likely to occur accidentally as the difficulties caused by aluminium. When it does happen, the appearance of the metal when molten will be similar to that caused by the presence of aluminium, and the casting qualities as regards fluidity will be the same. When the castings are poured into sand moulds, aluminium will impart a lustrous, bluish white colour that can only be removed with difficulty by long tumbling or pickling with acids, while silicon produces a chalky coating that may be rubbed or brushed off, and in this way the trouble maker can be detected. Silicon, therefore, should never be added to scrap metal as a deoxidiser, as it is liable to cause trouble and loss, and its use should be confined to making strong, high zinc alloys, free from lead, and for making copper castings.

Manganese imparts a brown colour to castings, which will vary in depth according to the quantity of manganese used. It also interferes with the fluidity of the metal, so that the castings are filled with cold shuts. This may be corrected by the addition of a very small percentage of aluminium, or by phosphorising the metal. When scrap contains manganese no trouble results unless the percentage is sufficiently high to cause cold shut castings, and this is easily corrected by either aluminium or phosphorus.

Magnesium. — Magnesium, in large amounts, imparts a black colour to the castings, and so affects the fluidity that the alloy will not fill the mould. It is not found in scrap brass in sufficient quantity to cause any trouble, and when added as a deoxidiser must be used in small doses, otherwise its effects will be harmful.—" The Foundry."

ACTUATING MECHANISM FOR TOOL SLIDES OF SHAPING MACHINES.

In shaping machines wherein the tool is carried in the end of a reciprocating ram or slide mounted in a saddle adapted to travel to and fro along a bed in a direction at right angles to that of the reciprocation of the tool slide it is usual for the tool slide to have a slow forward or cutting motion and a quick return movement in the saddle, the latter being traversed along the bed by means of a rotary screwed spindle to impart the feed to the tool or cutter. A design of actuating mechanism for the tool slide has recently been patented by C. J. Fish, Polygon Works, Park Street, Wellingborough, and is shown in the illustration herewith. The bed is of ordinary construction and the saddle A fits and slides thereon by means of V slides. The tool slide B has the usual form of tool holder and is fitted into the saddle A and moves therein by means of V slides. The slide-actuating mechanism is arranged at the side of the tool slide B and is located in a horizontal position on the saddle as shown, this mechanism comprising an oscillating arm C pivoted at D to a part of the saddle A, the opposite end of the arm being connected by means of a pivoted link E with a bolt F. This bolt is, upon loosening its nut, adjustable to different positions along a slot in the slide B, and it may be fixed in any position by tightening the nut. This adjustment permits the position of the tool slide B to be varied in the saddle. The arm C has a slot G in which works a crank pin H on a rotary disc J. The crank pin has a roller K to engage the slot G and is adjustable to different positions along a slot L in the face of the disc J, so that its circle of rotation is either enlarged or reduced for the



ACTUATING MECHANISM FOR TOOL SLIDES OF SHAPING MACHINES.

purpose of increasing or decreasing the length of movement imparted to the tool slide B. The crank pin H fits and fastens within the slot L and may be tightened and released therein by the nut shown. The disc J is mounted upon a spindle and rotates in the direction shown by the arrow, so that when the crank pin H imparts the cutting stroke to the slide it is on that side of the disc furthest from the fulcrum D of the oscillating arm C, but when imparting the return stroke the crank pin engages the arm C nearer the fulcrum of the latter and consequently the return movement of the slide is accelerated.

Fixed on the spindle of the disc J is a worm wheel M located underneath the saddle A, and gearing with this wheel is a worm N mounted upon a shaft O. The worm is arranged between the sides of a bracket P carried by the saddle A and is slidable along but rotated by the shaft O. The worm is connected to the shaft O by means of a feather which engages a longitudinal groove in the shaft so that it is rotated thereby, but is free to slide thereon. The worm N is caused to travel in company with the saddle A to and fro along the driving shaft O by means of the bracket P. With this arrangement the worm N always bears the same relationship to the worm-wheel M and, by the rotation of the shaft O, drives the worm-wheel and disc irrespective of the movement of the saddle A along the machine bed.

CONTINUOUS SYSTEM OF PIPE MOULDING.

In many classes of work it would be difficult, if not wholly impracticable, to put into operation a system of continuous moulding and casting. There are, however, cases where there is ample scope for the employment of such a system. In the manufacture of cast-iron pipes, for example, the large number and tonnage of exact duplicates to be cast makes continuous work particularly desirable, and the simple shape of the pattern and core makes it comparatively easy to arrange a continuous system for this purpose. In a recent issue of "Engineering News" the following particulars and illustrations are furnished of the Herbert system of pipe casting installed at the new plant of James B. Clow & Sons, Coshocton, Ohio. Circular floor or turnable systems have been tried with some success, but in general are open to the objection that a delay or accident at any one flask may hold up the entire plant. The Herbert system, it is claimed, does away with this difficulty entirely, and at the same time introduces improved methods of moulding, drying, and coring. The most important single feature of the Herbert system is the moulding machine, in which the pattern itself is made to ram or press the sand into shape. The flask is secured in a vertical position above the machine and the sand is shovelled in. The pattern is then forced up through the sand from below by an hydraulic ram, thus forming the mould.

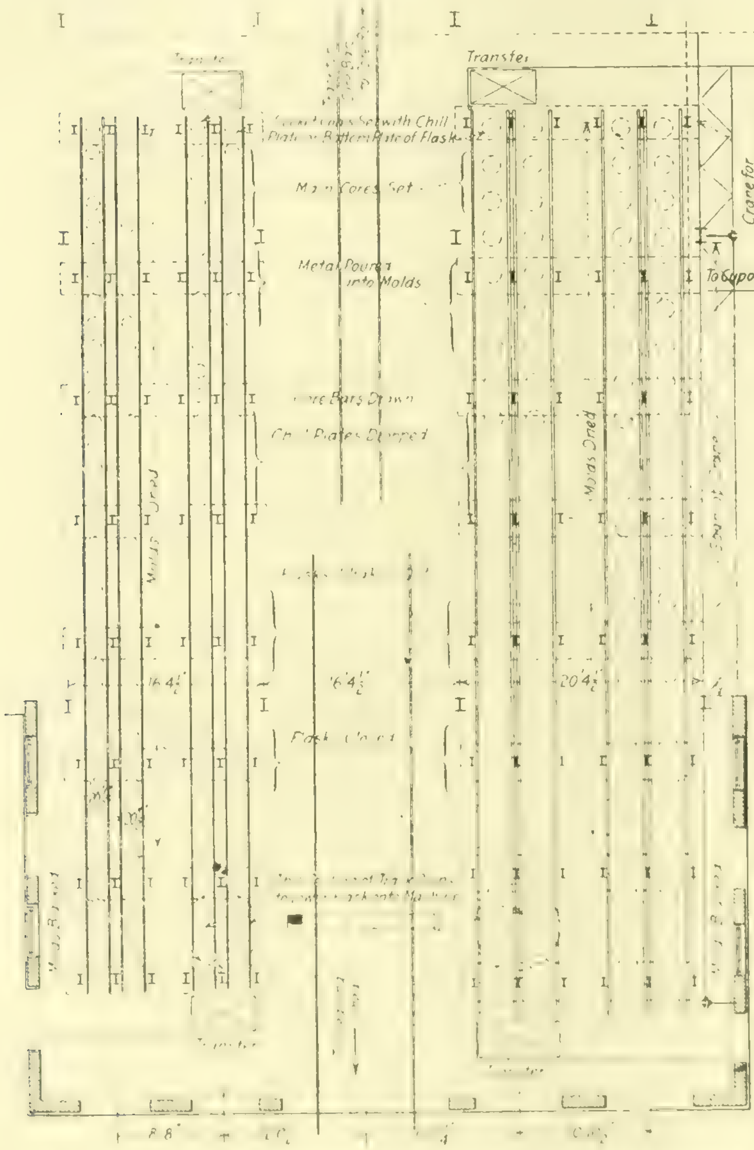


FIG. 1. PLAN VIEW OF COSHOCTON PIPE FOUNDRY, SHOWING SEQUENCE OF OPERATIONS.

The whole process of moulding and casting in the Herbert system is performed with the flasks standing erect in a pit. The pit is made large enough to contain four rows of 25 or 30 flasks each, and is deep enough so that the upper ends of the flasks protrude only 2ft. or 3ft. above the main floor above, from which most of the work is done. The flasks are held upright in parallel rows by rails running lengthwise of the pit, which rails are supported on a suitable framework erected between the rows of flasks. The rails are on the level of the main floor, and the flasks are hung upon them each on a separate truck. The entire train of flasks on any one line of rails can be moved along the track at once by means of hydraulic rams mounted at the end of the line.

The moulding machine is set up vertically in a subpit at one end of the main pit (see Fig. 2) so that its upper end is at a convenient height to receive the lower ends of the flasks as they are pushed towards it along the rails above. The moulding machine is installed in duplicate, that is, with two cylinders side by side, so that two flasks can be rammed at the same time. To correspond, there are two racks above, along which two rows of flasks are moved towards the machine. There are two other tracks, parallel to the first pair, to which the flasks discharged from the moulding machine are transferred. The flasks move in opposite directions on the two pairs of tracks. After passing over the machine, where the mould is formed, each pair of flasks moves on to a transfer car just beyond the end of the track or runway. This car carries the flasks across in line with the adjacent pair of tracks, on which they are started back toward the opposite end of the runway. At the commencement of this return trip the moulds are blacked, after which they pass over burners fed by producer gas whereby the blacking and moulds are thoroughly dried. Upon reaching the further end of the runway, each pair of flasks passes again on to a transfer car, which takes them across to the first pair of tracks. Here the cores are inserted and the flasks pushed further along ready to be poured. After pouring, the core bars are drawn, the flasks opened, and the newly-cast pipe lifted out. In removing the pipe the sand is shaken out of the flask and falls through a grating to the mixing and tempering plant in the pit below, whence it is returned by a bucket elevator to the moulding machine ready to be used over again.

The Clow plant has been in use for some months manufacturing 4in. and 6in. pipe. Both of these sizes are made in the same flasks, using, of course, different patterns and cores. The same pit is to be used also for 3in. pipe, but a different set of flasks—of smaller diameter—will be used for this size. A duplicate installation is now nearing completion, which will turn out 8in., 10in., and 12in. pipe. The two installations occupy what is really a single pit about 90ft. by 50ft. in plan and 12½ft. deep. They are separated, however, by a platform at the main floor level (12½ft. above the bottom of the pit). This platform is about 16ft. wide and extends the whole length of the pits. The tracks for the cars on which the core bars are returned to the core room are laid on this central floor, or platform, which supports also the skids along which the pipes cast are rolled to the cleaning shed. The plan view, Fig. 1, gives an idea of the general arrangement. In each pit, the pair of tracks next the central floor is used for coring, pouring, shaking out, and moulding, while the outer pair of tracks is used for drying the moulds. Between the two pairs of tracks is a 3ft. walk or gangway. The length of each track from end to end of the pit is 72ft. and the drying tracks (two in each pit) are kept full of flasks. In the 3in. to 6in. pit there are 36 flasks on each drying track. The other two tracks have each only 24 flasks, so that the total number of (single) flasks in this pit is 120. The capacity of the pit is 30 pipes per hour, or 600 pipes per day of two 10-hour shifts.

The moulding machine is perhaps the most essential feature of the Herbert system, since it permits the flasks to be readily rammed in the position in which they are to be poured, and moreover permits the mould to be completed in about 2½ minutes. The form of flask used is shown in Fig. 4. It is made of cast iron divided in half longitudinally. The two halves are held together by dowels and cotter keys. The length of the flask is about 13ft. The flasks for 6in. pipe have an inside diameter of 9¼in., and a wall thickness of about ¾in. These same flasks are used also for 4in. pipe. Each flask is suspended vertically from the rails of the runway between the two axles of its trucks, which are attached at a point about 2½ft. from the flask's upper end. On the ends of the axles are flanged wheels, which roll on the rails of the runway. The track gauge is 20½in. Each half of the flask is hung separately on two small rollers arranged to roll transversely along the axles of the main wheels. These rollers are brought into play when the two halves of the flask are separated for shaking out. About 1ft. below the point at which the trucks are attached, the flask has a pair of buffers extending parallel to the rails of the runway

fore and aft. These buffers serve to keep the flasks spaced the proper distance apart (2ft. centre to centre for the flasks for 6in. pipe), and transmit from flask to flask the push of the hydraulic ram which moves them along the runway. A second pair of buffers near the lower end of the flask, which can be plainly seen in Fig. 3, serves to maintain the spacing at the lower ends.

Immediately above the moulding machine a section of the runway track long enough to accommodate one flask is arranged to be lowered a few inches and raised to position again by means of hydraulic plungers. The empty flask is rolled on to this drop-section of the track and lowered into position at the upper end of the moulding machine, where it is secured by keys pushed into slots in the four dowel-pins projecting from the top of the machine. A light metal tube (16 gauge), known as a measuring tube, is then lowered into the flask by a man on the platform above. The two tubes for the two cylinders of the machine are hung side by side on ropes passing over pulleys and are counterbalanced so that they can be easily raised or lowered to the proper position. The lower end of the tube carries a hollow chilled-iron cone about 18in. long, which fits over the conical end of the pattern.

When the measuring tube has been put in place, sand is shovelled into the flask around the outside of the tube. The sand is then levelled off with a special strike at the upper end to fix definitely the quantity of sand in the flask. The pattern itself consists simply of a cast-iron cylinder, having the proper diameter for the pipe to be cast. For 6in. pipe the pattern diameter is $7\frac{1}{8}$in. The outside diameter of the measuring tube is somewhat smaller than that of the pattern ($6\frac{1}{2}$in. diam. for 6in. pipe), so that, when the pattern is forced up through the mould by the hydraulic ram of the moulding machine pushing the chilled-iron cone ahead of it, the sand is compressed to the desired consistency. Two or more measuring tubes of different size are kept on hand for each diameter of pipe. If it is found that the mould is being rammed too hard, due to possible variations in the quality of the sand, a tube of slightly larger diameter can be used. With the larger tube there will be less room for sand between it and the flask, and thus with less sand in the flask the mould will not be rammed quite as hard.

It was found that when the maximum or base diameter of the cone was made the same as that of the pattern, the sand was not sufficiently compressed. For when the main pattern was drawn downward out of the mould, the sand would expand apparently by its own elasticity so that the bore of the mould would be left slightly smaller than the pattern. This difficulty was satisfactorily adjusted by making the base of the cone, in the case of 6in. pipe, $\frac{1}{16}$in. larger in diameter than the pattern. Then as the cone passes up through the mould the sand expands behind it enough to snugly hug the pattern, and when the pattern is drawn the mould remains of the correct diameter.

A sectional view of the moulding machine is shown in Fig. 3. One cylinder is shown with the pattern at the top of its stroke, and in the other cylinder the pattern is just starting upward. Just before the main pattern which carries the cone completes its stroke, the pattern for the socket of the pipe is pushed upwards by the main ram, and thus rams the socket end of the mould. The socket pattern is held up in the mould by four small hydraulic plungers until after the main pattern is lowered through the mould, when finally the small plungers let down the socket pattern, and the operation of moulding is completed. The main pattern slides with a close fit through the annular socket pattern. The height at which the socket pattern stands before it is pushed upward can be adjusted by means of screws interposed between it and the four plungers. If it is found that the socket is being rammed too hard, the screws can be adjusted to slightly raise the socket pattern. There will then be less space for sand at the lower end of the flask, and the socket mould will consequently not be rammed so hard.

After the socket pattern has been raised by the ram, the measuring tube with its cone is removed from the upper end of the main pattern and in its place is put the spigot pattern, which is shown in Fig. 3. The spigot pattern is designed to form also the mould for the riser and the gates through which the molten metal subsequently enters the mould. It likewise forms the guide for the upper end of the core. It is fastened to the top of the main pattern by a key inserted in the slot. The hydraulic pressure is then removed, allowing the ram and patterns to descend by gravity until stopped by the contact of the spigot pattern with the upper end of the flask. This operation rams the upper end of the mould. The ram is now raised again so as to "draw" the spigot pattern, which is then removed, and the main pattern is drawn by simply letting it descend to its initial position. The drawing of the main pattern sleeks the mould.

The socket pattern is held in position while the main pattern is drawn out and acts as a stripping plate to prevent the breaking of the lower corners of the mould. Finally, the socket pattern is lowered and the mould is complete except for the cores. The flask is next detached from the top of the machine and raised with the drop-section of the runway track to the original position. It can then be pushed

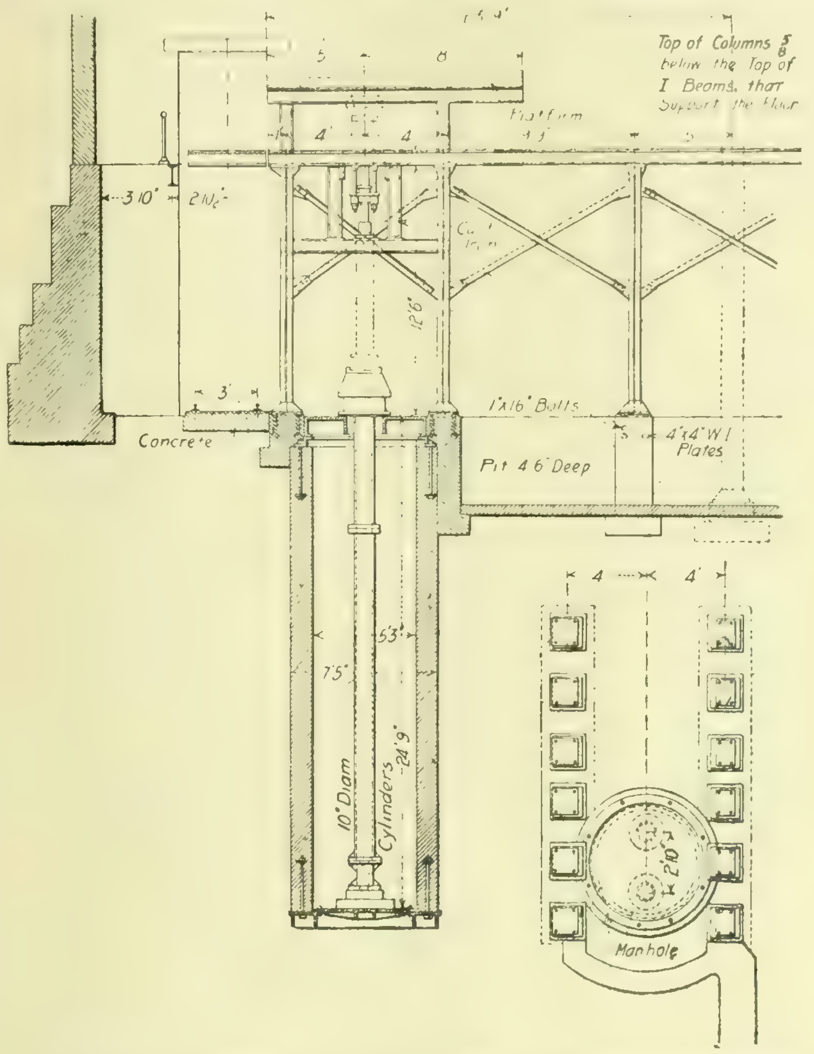


FIG. 2.—SECTIONAL ELEVATION AND PLAN AT END OF PIT, SHOWING LOCATION OF PIPE-MOULDING MACHINE.

along on to the transfer car and started back on the return track.

For moulding the large pipe (8in. to 12in.) a slightly different machine will be used. It is the same in its general principles, in that the mould is formed by a pattern pushed up through the sand from below, but the larger ratio of diameter to length necessitated a change in the arrangement of the pattern and its hydraulic ram. The ram is made hollow and is open at the bottom. Instead of sliding in a cylinder, it is telescoped over a stationary hollow pillar. Water is admitted into the pillar at the bottom to force up the ram. This construction is intended to ensure a more perfect alignment of the pattern during its passage through the mould. It has the further advantage of not requiring so deep a sub-pit. The pattern is made hollow like the ram but is of larger diameter and is telescoped over the ram and secured to it by suitable fastenings at its open lower end, which fits against a flange or collar on the ram. The different sized patterns can be attached to the same ram. A small space is left between the outer wall of the ram and the inner wall of the pattern, and steam is admitted to this space to heat the pattern. It is found that better moulds are obtained with a hot pattern, the sand being left more evenly packed and smoother than when the pattern is used cold.

Vapour rises from the flasks on the transfer car just after

they leave the moulding machine. This is due to the drying of the sand by the heat remaining in the flask. The hot sand and flasks help also to dry the blacking, which is put on by a man on the moulding machine platform just as the flask begins its trip along the return track. The blacking is applied with the help of a plunger which is lowered through the mould. The plunger is inserted in the upper end of the mould and the proper quantity of blacking poured in above it. The plunger is then lowered by means of a length of window cord and the blacking goes with it down the mould, coating the walls as it passes. The plunger, or dasher, is simply a cylindrical wooden block fitting loosely in the barrel of the mould. To the top of the block is secured a rubber disc of slightly larger diameter, which acts as a packing ring to hold the blacking above the dasher.

After the moulds have been blacked, the flasks pass on along the runway to the drying burners. These burners are fed with producer gas. The same producers furnish gas also for the core ovens, the ovens where the pipes are heated before being coated with tar, and for gas engines which can be used to supply power for the entire plant. The burners are spaced 2ft. apart to correspond with the spacing of the flasks The flame is adjusted to a height of about 18in., so that it rises a foot or more into the lower end of the mould. The condition of the moulds is inspected by the light of the flame. The volume of gas is graduated so that the burners furthest from the blacking platform give more heat than the first burners Thus the heat is gradually increased as the moulds become drier. During the drying process the upper end of the flask is kept covered by a perforated metal plate to restrict the flow of air up through the mould. (See Fig. 5.)

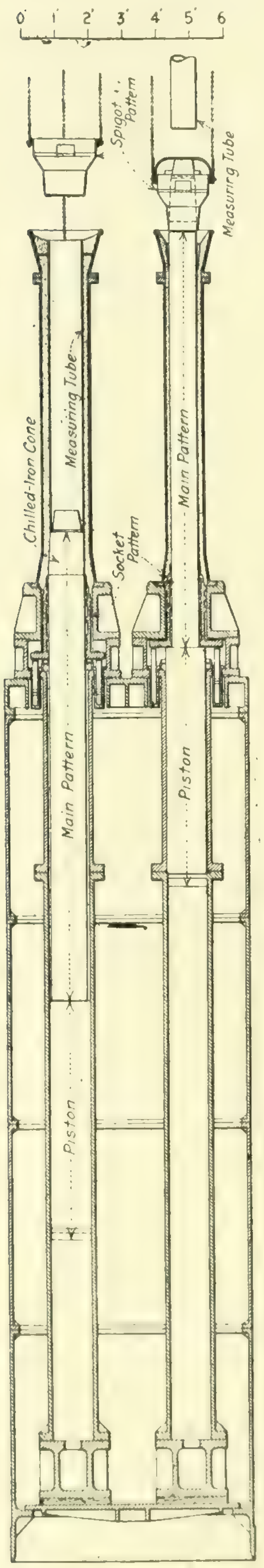


FIG. 3.
HERBERT PIPE MOULDING MACHINE. Sectional view with Flasks in position for moulding Left hand flask ready for ramming. Right hand flask, mould completed)

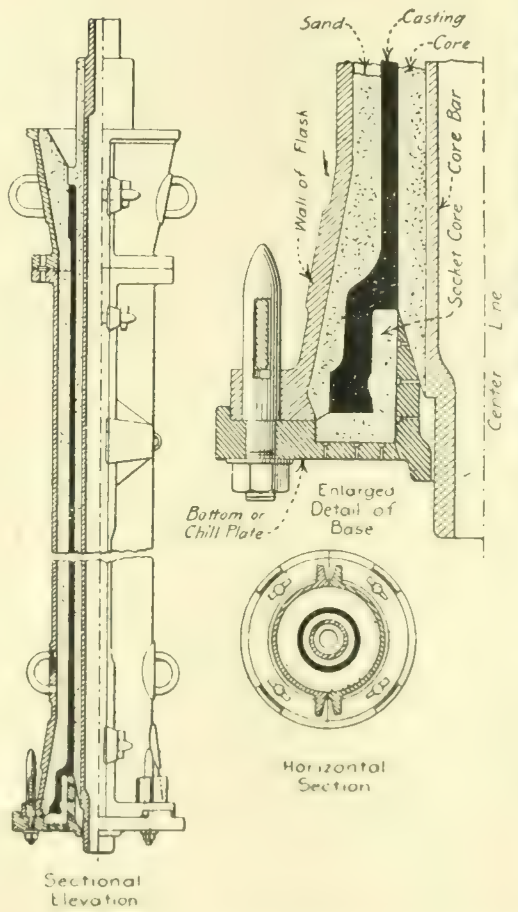


FIG. 4
SECTIONAL VIEW OF FLASK AND MOULD WITH CASTING IN PLACE

The time required for drying a mould is the controlling feature of the rate at which the whole process can be operated. A 6in. mould can be dried in about one hour and 40 minutes. Since there are 25 burners under each of the two parallel return tracks, the flasks can be advanced one step (equal to the distance between burners) at intervals of about four minutes. The whole row of flasks is moved at once, as already mentioned, by means of hydraulic rams at the end of the runway. Thus, on the two drying tracks there are two rows of flasks advancing at the rate of one flask every four minutes. In other words, the flasks are delivered in pairs at four-minute intervals, that is, at the rate of one flask in two minutes, or 30 flasks per hour, and the output of the pit cannot be increased beyond this point without installing longer drying tracks with more burners. After leaving the last burner, the flasks are pushed on to the second transfer table, which returns them to the first track.

Before the main core can be inserted the bottom plate and socket core must be put in place at the lower end of the mould, which up to this time has been left open. The bottom plate is shown in place in the mould in Fig. 4. The socket core is made with sand built up around the projection in the middle of the bottom plate. These cores are made by a man working at a bench set up in the pit at this end of the runway and are dried in an oven close at hand. As shown in Fig. 4, the projection at the centre of the bottom plate has a conical socket which catches the lower end of the main core and holds it in position in the centre of the mould. The lower end of the core is coned to fit this socket

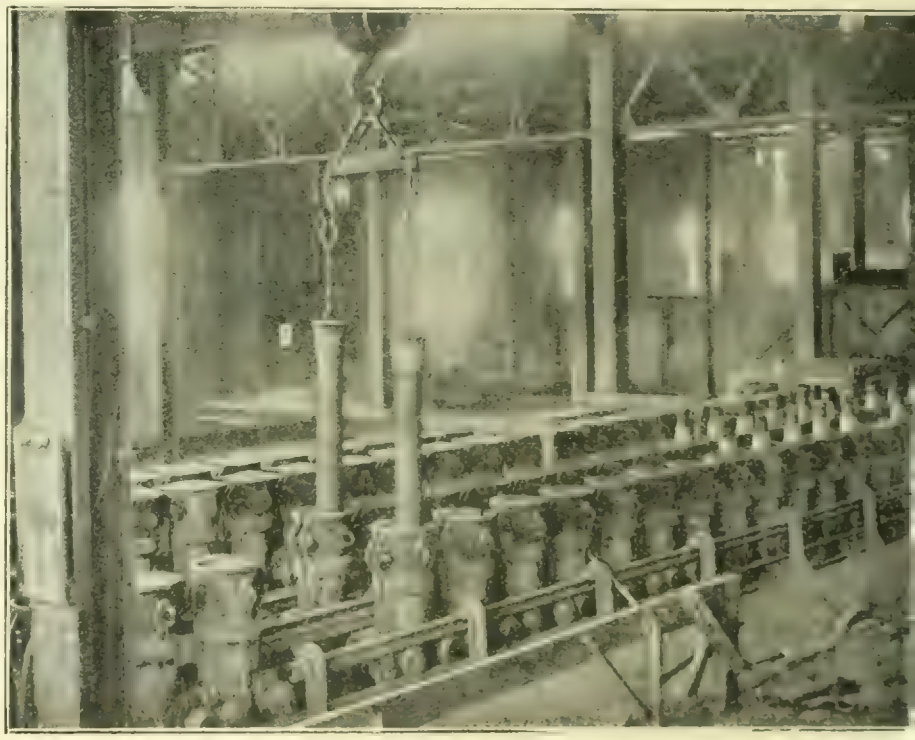


FIG. 5. VIEW SHOWING METHOD OF REMOVING PIPES FROM THE FLASKS AFTER CASTING

The main cores are lifted from the cars on which they come out of the ovens by a 3-ton crane and lowered vertically into the moulds. The fact that the flasks are held vertical by their buffers makes it easy to lower the cores quickly into position without danger of spoiling the mould. The upper end of the core is centred in the mould by a collar formed on the core, which fits into a groove made for this purpose by the spigot pattern.

As soon as the core has been inserted the mould is ready to be poured The number of moulds to be poured at one time depends upon the relation between the capacity of the ladle and the weight of iron required for each pipe. The ladle used at Coshocton holds about 3,000lbs. of iron, which permits the pouring of eight or 10 6in. pipe at one time. The ladle is brought from the cupola by a 5-ton travelling crane and lowered into position beside the runway. The ladle is tipped by hand by one man by means of a geared hand wheel The empty ladle is returned by the crane to the cupola, where it can be exchanged, if more iron is wanted

at once, for a second ladle which has been filled in the meantime.

After the pouring, the 5-ton crane returns to the runway to draw the core bars from the moulds. The bars are drawn in pairs by means of the yoke shown attached to the crane hook in Fig. 5 (which shows the same yoke in use for shaking out the pipe). The core bars are placed by the crane on a push-car running on a track close beside the runway. When the car is loaded it is pushed by hand back along its track to the core strikes, where the core bars are again put into use. After the core bars are drawn, chains are lowered through the centre of a pair of moulds and attached to the pipe at the lower end. The chains loosen some of the sand remaining in the pipe as they pass through. The flasks are then opened and the pipes are lifted out by the crane, as shown in Fig. 5. Holding-down rails are provided to prevent the flasks being lifted from the pit if the core bars or castings should stick.

The operation of removing the casting at the same time loosens the sand in the flask. The sand falls through a grating and shaking screen into the trough of the tempering and mixing machine from which it is conveyed by a bucket elevator to the rotary screen on the moulding machine platform. A clay-wash mixer is mounted in the pit close to the boot of the bucket conveyer so that clay wash can be added to the sand at this point as required. The arrangement of the sand-handling plant is shown in Fig. 6.

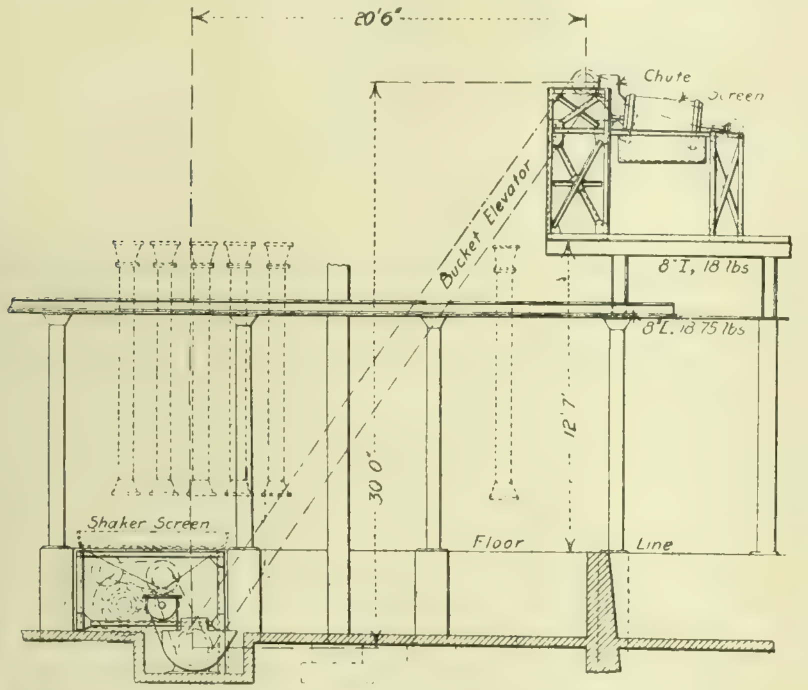


FIG. 6.—SECTIONAL ELEVATION ALONG CENTRE LINE OF ONE PIT, SHOWING SAND-TEMPERING AND MIXING PLANT AND ELEVATOR.

The flasks are closed up again by hand after being shaken out, and are pushed by hand the short remaining distance to the moulding machine. Ball bearings were used on the wheels of the 6in. flasks at Coshocton, but have not proved altogether satisfactory. In the new plant for the larger sizes of pipe Hyatt roller bearings have been used. Some trouble is experienced in opening and closing the flasks at the pit first put in operation, on account of the sticking of the transverse rollers. The rollers are sometimes locked rigid by cast iron spilled from the ladle in pouring. This trouble has been dispensed with in the newer plant by housing the transverse rollers under protecting shields or casings.

The pipes lifted from the moulds are put down by the crane across a pair of skids about 8ft. apart, along which they are rolled out of the pipe foundry to the cleaning shed. While passing along the skids the pipes are cleaned by tapping and scraping, after which they are passed along to the cutting-off lathe. This lathe is so arranged that the pipe drops into position on the lathe bed as it rolls in along the skids. About two minutes is required to cut off each pipe. The lathe at the same time turns the bead on the spigot end of the pipe.

From the lathe-house the pipes pass along the skids to the tar tanks. They are first rolled into an oven and heated by producer gas to a temperature of 300° or 400° Fah. The heated pipes are dropped into a tank filled with molten tar which has been recovered as a by-product from the gas producers. In lifting the pipes from the tar tank, one end is held higher than the other so that the surplus tar runs out of the pipe, leaving it neatly coated inside and out. The tarred pipes are rolled along the skidway to the testing-house, where they are subjected to an hydraulic pressure of 300lbs. per square inch. After passing this test, the pipes are rolled on to a scale and weighed. The weight of each pipe is marked upon it with white paint, and it is then rolled out into the shipping yard.

The number of men needed to operate the pipe-casting plant is 32, 16 in each pit. Four of these work at the moulding machine, two at platform, and two in the pit below. Two men are required for the blacking– one on the platform and one in the pit. One man makes the socket cores. One man operates the 3-ton crane for placing the cores, and another the 5-ton crane used for pouring, drawing the core bars and shaking out. Two men are required at opening and reclosing the flasks, two operate the push-car that takes the core bars back to the core strikes, and one man rolls the completed castings along the rails leading to the cleaning shed, the others assisting generally.

The several hydraulic rams used at the moulding machine and for moving the flasks along the runway and for operating the transfer cars are supplied with water from a single hydraulic accumulator, where it is stored at a pressure of 300lbs. per square inch. The accumulator piston is 24in. diam. and has a stroke of 12ft. Water is supplied to the accumulator by a 3-throw double-acting pump driven by a 100 h.p. electric motor. The other power required in the pipe-casting pit is that for a 5 h.p. motor, which drives the bucket elevator and the sand-mixing plant, and for a 2 h.p. motor on the clay-wash mixer.

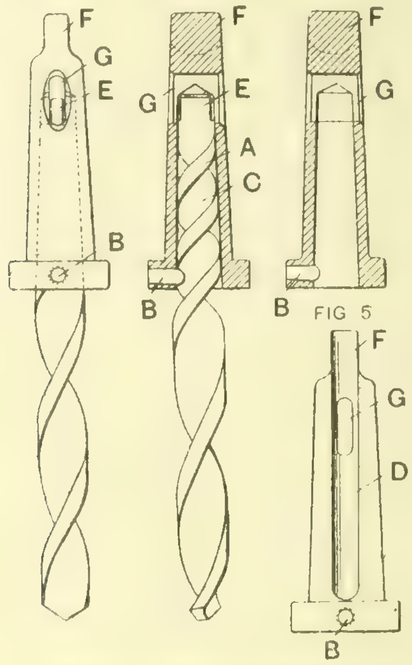
The core ovens and core-forming machines are conveniently located beyond the end of the casting pit. At the end of the building farthest from the pit are placed the mills for grinding the core mud. One mill, of the ordinary Chilian type, driven by a 20 h.p. motor, is provided for each pit. From the mills the mud is taken to the first core strike. The core bar is first wound with hay and then coated with mud while being rapidly revolved in the machine.

A straight edge or strike is used to give the mud coating a true cylindrical shape. An extra ring of hay wound on the bar near one end forms the foundation for the collar on the core which later serves to centre it in the mould. A dozen cores at a time are transferred on a suitable car into the first-coat oven. From this oven they pass to the second core machine, where another coat of mud and a finishing coat of blacking is applied. Then, after being baked in the second-coat oven, the cores are ready for use and the core bars are rolled out on the tracks close to the end of the casting pit, where they can be conveniently picked up by the 3-ton crane.

TAPER SHANKS AND SOCKETS FOR DRILLS.

DEVICES for securing drills, reamers, and other tools in their sockets have been proposed in which the internal studs engage in helical grooves in a cylindrical tool shank so as to drive the tool against an end abutment in the socket; also devices having external driving projections engaging the spiral grooves of a twist drill below a tapered shank which is secured in a tapered socket. In both of these securing devices the studs or projections are intended to be used as the main driving means and to take the greater part of the torque. In the designs illustrated herewith, the invention of the Pratt & Whitney Company, of Hartford, Conn., U.S.A., the socket and shank are so arranged that the studs take no substantial direct part in the drive of the tool, but serve merely to cause the slightly-tapered faces of the shank and socket to bind tightly together for driving, with a grip automatically increasing on increase of resistance being met with in the course of the work, and for this purpose the helical groove is formed in the tapered portion of the tool and the stud is inside the tapered socket so that any torque upon the tool which cannot be met by the surface grip on the tapered shank brings about a screw motion instantly increasing the grip without throwing any appreciable portion of the work on the stud. Or the relative positions of the stud and groove may be reversed. It is essential for the efficiency of this action that the stud and groove be actu-

ally inside the socket so that the stud cannot exert any bending action on the tool. The groove in the tapered shank may in the case of a twisted drill be formed by a continuation of the twist at a reduced pitch. Where tapered socket sleeves are employed between the driving spindle and the tool shank



TAPER SHANKS AND SOCKETS FOR DRILLS.

they may be provided with an external longitudinal groove making a driving engagement with the stud in the outer socket.

Fig. 1 is an elevation of the drill and sleeve. Fig. 2 is an elevation of the drill showing the sleeve in section. Fig. 3 is a longitudinal section of the sleeve, and Figs. 4 and 5 are elevations of a modified form of drill and sleeve. In the arrangement shown in Figs. 1 and 2 the drill is constructed from a piece of twisted metal, the convolutions of which extend along the tapered shank A of the drill and form helical grooves C therein. In this type of drill, owing to the grooves being already formed in the shank, it is only necessary to provide an internal projection in the socket of the sleeve or machine spindle to complete the holding device. The projection comprises a tapered stud B which is inserted into a correspondingly tapered hole in the sleeve or machine spindle from the interior of the socket.

In applying the arrangement to a drill or other tool having a solid tapered shank, one or more helical grooves may be milled therein to provide the desired positive connection with the internal projection or projections in the tapered socket of the machine spindle or tapered sleeve. In the example shown in Fig. 4, the helical groove C extends from a flat surface that is formed on the solid shank of the drill. The tapered sleeve may, if desired, also be formed with one or more grooves such as D (Fig. 5) extending along its outer tapered surface to form a driving connection with the internal projection or projections of a surrounding sleeve, or of the socket in the machine spindle. Each of the tool shanks or sleeves may be provided with the customary tang E or F respectively, to enable it to be used in connection with a machine spindle or sleeve that is formed with a transverse slot for engagement with such tang, the transverse slot G shown in the drawings being more particularly intended to receive a tapered key by means of which the drill can be dislodged from the sleeve.

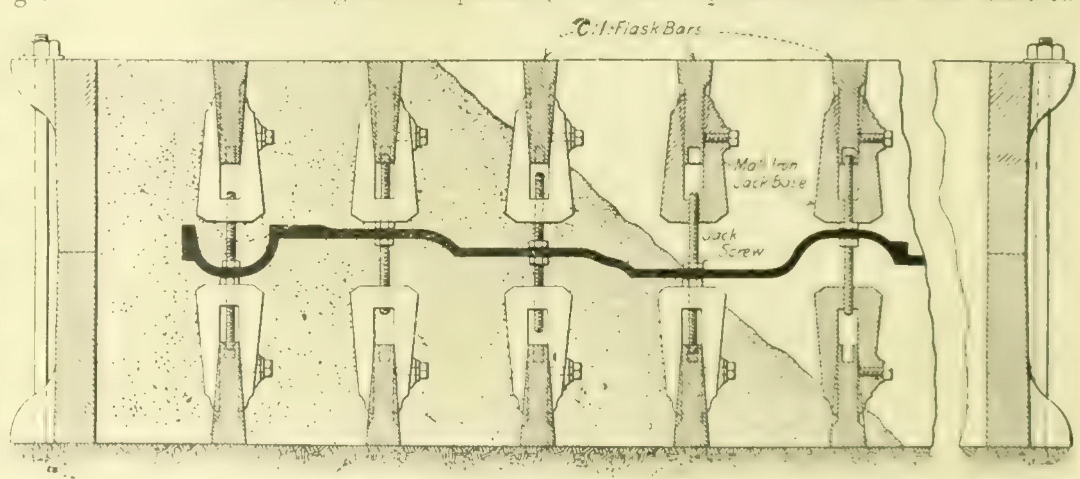
Leeds Boiler Explosion Formal Enquiry.—The formal investigation ordered by the Board of Trade to be held regarding a boiler explosion which occurred at Lane Side Mills, Leeds, is fixed for hearing in the Town Hall, Leeds, on Wednesday, the 17th inst., at 11 a.m.

A NEW MOULDING FLASK.

MUCH trouble is experienced in making thin castings of large area on account of warping. Due to unequal cooling in different parts of the casting, it may twist or warp so badly as to become worthless. Many contrivances have been tried by foundrymen for preventing this warping, but none has met with enough success to be generally adopted. According to "The Engineering News," Mr. Henry E. Thompson, of 253, Clinton Avenue, Newark, N.J., has patented a device which is claimed to completely solve the problem for a large class of castings. This consists of a cast-iron moulding flask equipped with a number of "straddling abutments" resembling small jack screws, which are clamped to the flask bars, both in cope and drag, and screwed down to such a position as to bear against the casting and hold it to shape while cooling. The abutments are adjusted to the proper position by bringing them up against the pattern before the sand is put in. Thus the bearing heads of the screws are flush with the surface of the mould when the sand is rammed around them. The accompanying illustration shows a sectional view of a mould with the abutments in place bearing against the casting.

In preparing the mould, the pattern is placed on a moulding board and the drag set over it as usual. The divided bases of the abutments are then slipped over the cross bars and the jacks are roughly adjusted to the surface of the pattern before clamping them to the bars with the set-screws shown in the illustration. By turning the screws, they are then brought into easy contact with the pattern, and the drag is filled with sand and rammed. After turning over the drag and adjusting the cope, a second set of abutments is attached to the cope bars and brought up against the pattern as before.

To prevent the formation of fins around the edge of the casting at the parting line, thin plates of metal are used to



SECTION THROUGH MOULDING FLASK, SHOWING CASTING HELD IN PLACE BY SCREW ABUTMENTS.

separate the edges of the cope and drag during moulding. These separators are removed before closing the flask after the pattern has been drawn out, and as a result the two parts of the mould are pressed tightly together when it is closed. Bolts are used, as shown in the illustration, to clamp the two parts of the flask together and ensure a firm backing for the abutments.

As shown in the cut, the flask bars are of the usual tapering section, but wide flat-bottomed grooves are provided at intervals along each bar to receive the bases of the abutments. In the lower edge of the bars are holes corresponding with the middle of each groove to receive the points of the main screws. This permits the screw heads to be brought up close to the bars. The bases of the abutments are made of malleable iron, and the screws of wrought iron.

Junior Institution of Engineers.—A meeting of this Institution will be held on Friday evening, January 19th, at 8.30 p.m., at the Institution of Electrical Engineers, Victoria Embankment, when a paper on "The Sighting of Small Arms and Artillery," by Sir George Greenhill, M.A., will be read. On Saturday morning, January 20th, at 9.30 a.m., a visit will be paid to the works of the Western Electric Company, Ltd., Woolwich.

POWER REQUIREMENTS OF A STEEL TUBE MILL.

BY A. S. AHRENS.

In the last few years remarkable progress has been made in the application of electric power to rolling mills, including both the main and auxiliary drives. This progress has been general, and electric drive is now being considered for practically every type of mill. Among these, tube or pipe mills occupy a prominent place. In the tube mills, especially those using the welding process, progress has been very rapid and there are several mills of this kind entirely motor-driven, steam finding a place only in the generating station.

One of the first tube mills to adopt electric drive was that of the Spang-Chalfant & Co., Pittsburg. At this plant small

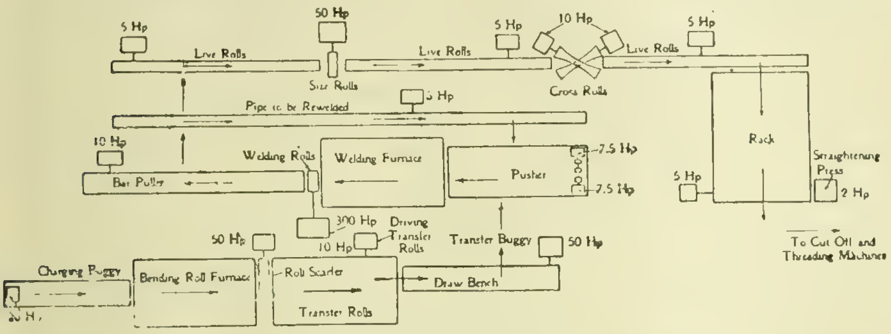


FIG. 1. DIAGRAM OF A TYPICAL LAP WELD TUBE MILL.

tubes are made by the butt-welding and large tubes by the lap-welding process. Unless otherwise stated, the description and illustrations here given cover the making of 18in. pipe by the lap-welding process, and ¾in. pipe by the butt-welding process. The stock from which the pipes are made consists of rolled steel plates of suitable length and width, called skelp. The travel of the material, through the different processes, from the skelp to the finished pipe, cut off to exact length and threaded, is shown diagrammatically in Fig. 1.

The service requirements of motors for this kind of work are exceptionally severe. Many of the motors must operate in close proximity to the furnaces, and hence are subjected to high temperatures. The passage of the metal through the rolls must be continuous, as, if a pipe gets stuck, a considerable delay may result. For this reason no circuit breakers or fuses are provided, and motors are chosen of rugged mechanical structure and large torque, and are expected to continue in operation in spite of adverse circumstances. The heating effect of the load, in most cases, need not be considered, as it is very intermittent in character and as the mills usually are rolling pipe of a smaller size than the maximum for which the motors are selected. On the other hand, the

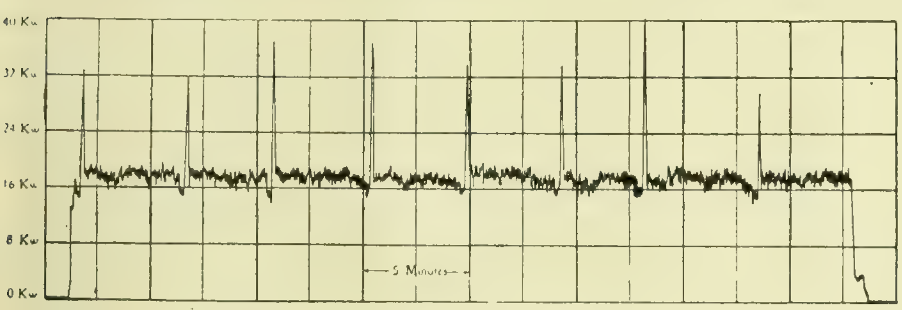


FIG. 2.—GRAPHIC METER RECORD OF MOTOR DRIVING SCARFING ROLLS.

possible high initial temperature of the motors must be considered in determining the allowable temperature rise.

On account of the severe operating conditions, excessive heat, and large amount of dust and dirt, induction motors with squirrel-cage secondaries are used almost exclusively. Practically all of the motors drive through large gear reductions, and in the majority of cases they run continuously in one direction, the operation and reversing of the rolls being accomplished by means of clutches. Although the load is of a very intermittent character in most instances, the peaks are nearly always of too great duration to allow the satisfactory use of flywheels.

The charging buggy of the bending roll furnace is driven by a non-reversing motor of 20 h.p. running at 875 revs. per minute. This motor is applied to a drive which must be reversed from 100 to 150 times an hour. The frequent reversing of large motors is, of course, objectionable both on account of the strains on the motor and on account of the heavy rushes of current in the transmission system. In the Spang-Chalfant plant this motor is of the mill type construction, with a squirrel-cage rotor, and runs continuously in one direction. It has a double shaft extension, each end being connected through an induction clutch and a set of gears to the drum which drives the cables. Thus, for the operation of the buggy in the forward direction, one clutch is energised, while for reversing, the second clutch is used. On account of the use of induction clutches, with the motor in continuous operation, the load is picked up very gradually without excessive peaks.

The 50 h.p. motor on the scarfing rolls runs at 575 revs. per minute and operates continuously in one direction, there

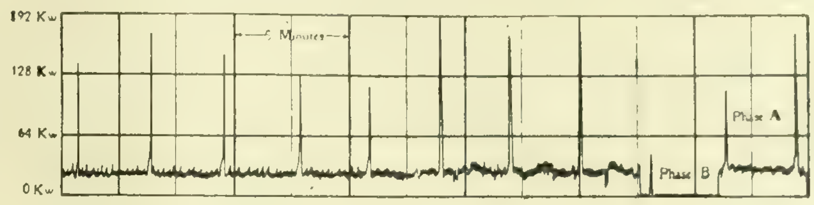


FIG. 3.—GRAPHIC METER RECORD OF MOTOR ON WELDING ROLLS.

being no occasion for reversing the rolls. During the time between passes, which, as shown by the curves, Fig. 2, averages about 4½ minutes, the motor operates under a friction load of about 50 per cent. of full load. The load period, while a plate is passing through the rolls, lasts about 10 seconds. The power required varies with each piece, depending on how near to exact width the skelp is. The power also varies with the size of the skelp, the curve in Fig. 2 being taken while skelp for 18in. pipe was being scarfed, the capacity of the mill being 24in. pipe. Although the load on this motor is very intermittent and the peak load occurs for only 4 per cent. of the total time, a flywheel cannot be used to advantage as the time required for the skelp to pass through the rolls is too long. The motor must, therefore, be depended upon to pull the piece through the rolls under all conditions. This motor operates in very close proximity to the furnace and to the heated skelp.

It is possible, especially for pipes of small or medium size, to scarf the skelp in special motor-operated scarfing shears, although this method is not common. In this case also the load is very intermittent in character, the power load occupying about 45 per cent. of the total time of operation. The actual amount of power at the peaks depends entirely on the amount of metal removed, and is independent of the size of pipe being made.

After leaving the scarfing rolls, the skelp is carried forward on the transfer rolls to the draw bench. Here it is

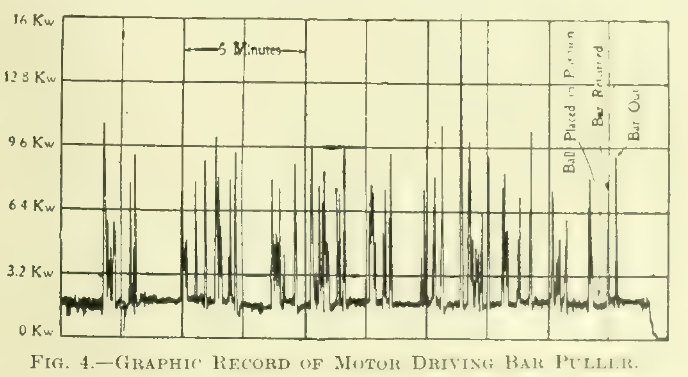


FIG. 4.—GRAPHIC RECORD OF MOTOR DRIVING BAR PULLER.

attached to an endless chain by means of mechanical tongs or jaws and is pulled through the bender on the draw bench, where it is formed in a die around a mandrel into circular shape, with the edges overlapping but not closed. The motor and the chain operate continuously, the friction load being equal to about 15 per cent. of full load. About eight seconds are required for the bending operation. The pipe is then rolled down an incline to the transfer buggy in front of the welding furnace.

The transfer buggy is a motor-operated truck, carrying a trough to receive the pipes from the draw bench, and hold them while the truck is moved back and forth in front of the welding furnace, under the welding furnace pushers. It is driven by a 5 h.p. direct-current mill type motor, which is

equipped with a solenoid operated stop brake in series with the motor. The buggy is in continual operation, it being estimated that the brake is set over 1,000 times per hour.

The pushers feeding the pipe into the welding furnace present an application essentially similar to the charging buggy in that induction clutches are used to allow a non-reversing motor to be used for service which requires frequent reversing. The application has, however, been worked out to greater detail. The pusher consists of three endless cables, revolving on drums. From each cable is suspended a framework, having a holder, in which one end of a steel bar is placed, the other end engaging the pipe while it is still in the transfer buggy. The drums which drive the cables are mounted on a shaft which is in turn geared to two shafts

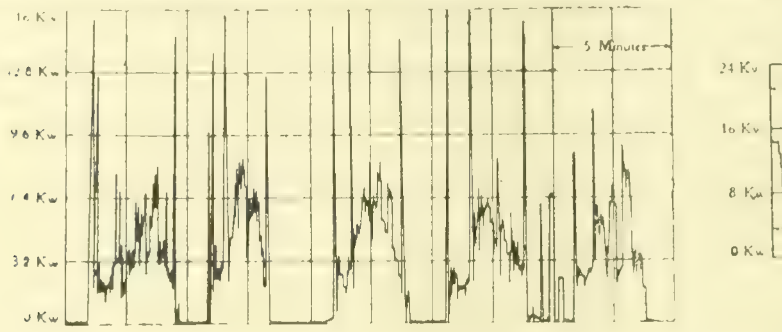


FIG. 5.—GRAPHIC RECORD OF MOTOR DRIVING PIPE CUTTING-OFF MACHINES.

revolving in opposite directions, each driven by a motor of 75 h.p. running at 850 revs. per minute. By means of the clutches any drum can be driven in any direction, only one drum being operated at a time.

The pipe, which is still at a red heat from the bending operation, is brought to a welding temperature in a furnace of the Siemens regenerative type. It is then pushed from the furnace in a suitable position to enter the welding rolls, being directed by troughs in the floor of the furnace. A 300 h.p. motor running at 450 revs. per minute is geared to the rolls, with a large flywheel connected to the main gear, as shown in Fig. 8. By mounting the flywheel in this manner, it operates at a much higher speed than if connected directly to the rolls and a much smaller wheel can be used to produce the same flywheel effect. The distance between the bending and welding furnaces is very small in this plant, making it impossible to mount the flywheel between the gears and the motor.

The pipe is in the rolls about three seconds, during which time the load on the motor is increased, as shown in Fig. 3, to six times the friction load. At the time the curve was taken about 18 pipes were being welded per hour or one in 3½ minutes. The peak load is on the motor about $\frac{1}{70}$th of

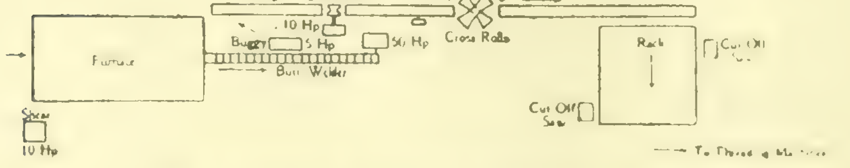


FIG. 6.—DIAGRAM OF A TYPICAL BUTT WELD TUBE MILL.

the cycle. It will be seen, therefore, that this duty is of the most intermittent kind, and that the motor must be selected for its ability to stand the momentary overload rather than for its continuous capacity. From the standpoint of production also, the momentary overload capacity of the motor is given important consideration. If a pipe sticks and becomes cold, valuable time is lost in releasing it from the mill, and this must be avoided if at all possible. There are no protective devices in the circuits, and a motor is installed large enough to pull the pipe through under practically any conditions. This fact accounts for the comparatively low average load shown by some of the curves. It should be noted, also, that the welding roll motor, as well as several others, is situated very near the furnace, which makes it necessary to give the capacity of the motor special consideration; the temperature of the surrounding air is over 100° Fah. even in winter.

The bar puller, which is driven by a 10 h.p. motor running at 850 revs. per minute, consists of small revolving rolls, which grip the bar and pull it one way or the other, the reversing being done by a mechanical clutch. The load produced is very irregular, as shown by the curve in Fig. 4. The peaks occur when the bar is being run to the rolls, and again when the bar is returned.

The pipe is lifted from the racks in front of the welding furnace by a set of hydraulically-operated levers. If inspection shows that the weld is perfect, the pipe is rolled down an incline to the live rolls feeding the size rolls. If the weld is not perfect, the pipe is raised on an hydraulically-operated turn-table, and turned end for end before returning to the welding furnace. This gives a back lap which produces a more perfect weld than would be possible with two rollings in the same direction.

After welding, the pipe, still white hot, is run through the size rolls, which reduce it to correct external size, and then through the cross rolls where, with a whirling motion, it is

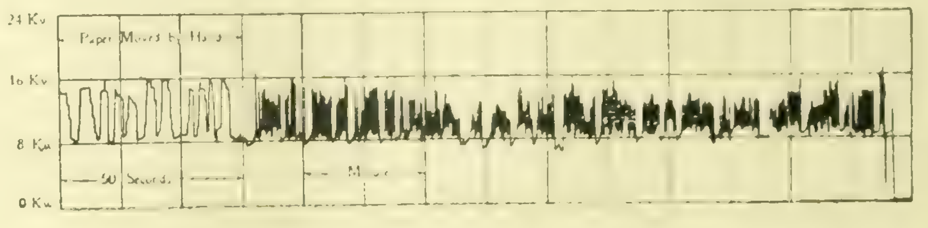


FIG. 7.—GRAPHIC RECORD OF MOTOR ON BUTT WELDER.

straightened. It is conveyed to the size rolls by the live rolls. To ensure accurate sizing, the pipes are usually passed through the rolls three times, the reversing of the rolls being accomplished by means of a clutch. This operation also requires the reversing of the live rolls, which is done by reversing the motors, thus producing a very peaked load on the motors. The motors for driving the live rolls are of 10 h.p. running at 950 revs. per minute, and the motor for driving the sizing rolls 50 h.p. running at 590 revs. per minute. As shown in Fig. 10, the load on the sizing rolls is similar to that at the welding rolls, though the peaks are not so severe. Due to the greater duration of the peaks, a flywheel would be of no assistance in smoothing out the load curve. For this application a motor with a large starting torque and liberal over-load capacity is required. The cross rolls are driven through a double reduction gear by a separate motor of 10 h.p. running at 850 revs. per minute for each roll. To ensure simultaneous operation, both motors are controlled from the same switch, no starting box being necessary.

A number of very interesting features may be brought out by an analysis of the power curve for these motors, shown in Fig. 9. It will be noticed that the power on the motor drops off for an instant as the pipes enter the rolls, and then rises to the full load value. This is probably due to the fact that the velocity of the pipes along the live rolls is greater than their linear velocity through the cross rolls. Thus the pressure on the gears is temporarily relieved, until the motor catches up in speed. The succeeding peaks are caused by the inertia of the pipe as the rotary motion is started, and by reversing the motors while the pipe is in the rolls, which occurs twice with each pipe. During the time that this curve was taken, one of the pipes got stuck in the rolls. This is a condition which is liable to occur at any time, and which the motor must be able to handle. In this particular case, the sticking was not caused by any fault in the pipe, but occurred because the power was thrown off temporarily. When the power came on the lines again, the motors started up with the pipe in the rolls, requiring very heavy starting current. The power was well within the capacity of the motor, however, in this particular case, as the pipe was only 4 in. diam., while the capacity of the rolls is 8 in. pipe.

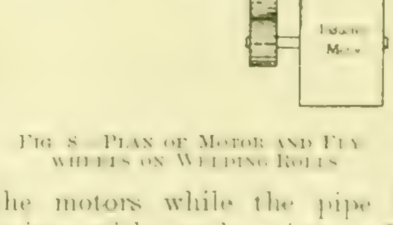


FIG. 8.—PLAN OF MOTOR AND FLY WHEELS ON WELDING ROLLS.

After the pipe has passed through the cross rolls, it has the correct inside and outside diameter, and is approximately

straight. It is then run out on the racks and allowed to cool. Before being cut off to standard length and threaded, the pipe is passed through a straightening machine of the press type, with a flywheel mounted on the cam shaft. Two cylindrical dies, about 12in. in length and of the same diameter as the pipe, are pressed firmly around the pipe every 6in. to 12in. of its length, removing all inequalities.

The pipe cutting-off and threading machine represents a final application which requires the most rugged characteristics on the part of the motor. The record shown by the curve in Fig. 5 was taken while cutting 18in. tubes at an average cutting speed of 38ft. per minute. The average load on the motor while cutting is shown by the curve to be about 6 kw. The starting conditions are exceptionally severe, however, as the motor is started simply by closing a switch. The motor, which is of 10 h.p. running at 590 revs. per minute, was reversed for the reaming operation while running, causing a very heavy peak and was again reversed to set the machine for the next pipe. This manipulation is, of course, very severe on the motor windings and on the gearing. All pipe over 3in. diam. is made by the lap-welding process as described. With smaller pipe it is possible to combine several of the operations into one by butt-welding the joints. The diagram of a butt-weld mill, Fig. 6, shows the greater simplicity of this arrangement. The front corners of the skelp are cut off with the shears before it is placed in the furnace, to assist in starting it through the mandrel. In place of being heated twice, the skelp in the butt-welding process is brought at once to a welding temperature, and the bending and welding are accomplished in one operation. The forward end is grasped by a tong grip which is attached to a travelling chain and is drawn through the bell very much as in the lap-weld bending process. The difference consists in the fact that the mandrel is so shaped that the edges of the skelp are forced together under considerable pressure, causing them to weld. No ball is used, as with small sizes of pipe it is unnecessary.

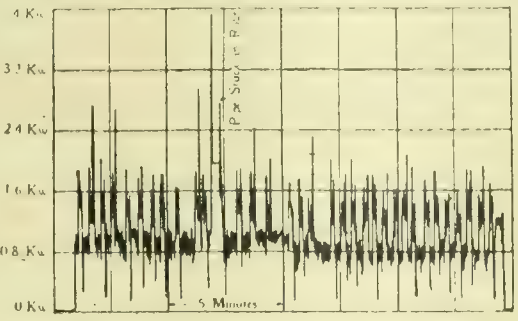


FIG. 9.—GRAPHIC RECORD OF MOTOR DRIVING UPPER ROLL OF THE CROSS ROLLS.

The power requirements for a motor for butt-welding are very similar to those for the draw bench in the lap-weld bending process, in that the motor operates continuously in one direction. No flywheel is used, because, as shown in the power curve, Fig. 7, the interval between peaks is hardly sufficient at times to allow a flywheel to regain its speed. For this reason, and also because of the fact that a delay caused by lack of sufficient power to pull the pipe through the bell is liable to become very costly, the motor must be selected of ample overload capacity, and with very large starting torque. After welding, the pipes are run through sizing and cross rolls, and cut off to size and threaded the same as the lap-welded pipes.

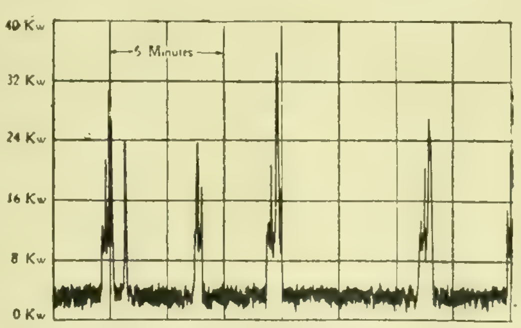


FIG. 10.—GRAPHIC RECORD OF MOTOR DRIVING SIZING ROLLS. SIZING 18IN. PIPE.

Owing to the large capital investments and high labour costs it is absolutely essential in the manufacture of steel products that work proceed with the greatest possible continuity. No interruptions are tolerated that can possibly be avoided. The service is very severe, and in the majority of cases is continuous 24 hours per day. However, electric motors have demonstrated their ability to meet these conditions. In the case of the above plant, the motors have been operating almost continuously since their installation over three years ago. Owing to their rugged and liberal design they have required practically no repairs and no attention, except a regular inspection of bearings, oil, &c. In fact, for two lap-weld mills only three men are required to attend the motors, one being the chief electrician, another his assistant, who is a mechanic, and the third an oiler. These men also attend to the cranes and make any necessary changes in wiring, &c. One advantage in electric drive, which should not be overlooked, is that by means of graphic meters, installed on the motor circuits, a permanent graphic record can be obtained of the different operations accomplished by the motor-driven machines. In this way, data respecting amount of power, cost of work, efficiency of machines and operators can be obtained as by no other method, and changes and improvements made accordingly.—"The Electric Journal."

MODERN USES AND APPLICATIONS OF RADIUM.*

BY HUGO LIEBER, PH.D.

WHEN Prof. Rontgen discovered the Röntgen or X Ray, it was generally believed that the powerful and penetrating rays emitted by the so called Röntgen tube were produced or emitted by the bright fluorescence which constantly appeared when the Röntgen tube was in operation. This belief in the creation of these powerful rays by the fluorescence caused most of the physicists who were investigating this field to experiment with a great many fluorescent materials in order to determine whether similar powerful rays were emitted by any such materials. Among these investigators was Prof. Becquerel, of Paris, who one day, after experimenting with some fluorescent uranium salts, not being able to finish his experiments that day, placed the uranium salts in a drawer of his desk. After several days, upon opening the drawer and seeing the uranium salts, he determined to continue his experiments. When he removed the uranium salts he saw that, by accident, they had been resting during this period upon a photographic plate contained in a securely sealed envelope, such as is generally used for X-Ray and similar purposes. Becquerel then determined to develop this plate for curiosity's sake, and found to his great delight that the plate had been strongly affected by radiations of some kind. This led to further experimentation with uranium materials, leading finally to the discovery of what are now known universally as the Becquerel rays

Madame Curie then took up the investigation of these uranium salts and soon found that pitchblende, the ore from which uranium is extracted, emitted the same radiations as the uranium salts, only in a far larger proportion. Madame Curie then obtained from the Austrian Government, which controls the Bohemian pitchblende mines, some of the refuse of the pitchblende ore after the uranium had been extracted, and she found that this refuse was far more radioactive than either the uranium or pitchblende themselves. This convinced Madame Curie that pitchblende contained something which emitted powerful rays, apparently independent of the uranium. Further investigation led to the discovery of what Madame Curie at that time believed to be a new element, which she named polonium, after the country from which she came. This polonium emitted a very large quantity of radiations, which, however, were of very low penetrating power. It has since been found by Prof. Ernest Rutherford, at that time of McGill University, now of Manchester, that polonium is not a primary radioactive element, but simply a disintegration product of the radium emanation, to which I shall refer later.

Madame Curie continued her investigations and soon found that the pitchblende refuse contained still another element which emitted the same radiations as polonium, besides various other radiations of far greater penetrating power. This element Madame Curie named radium

Experimentation at first led physicists, especially also Madame Curie, to believe that radium emitted three kinds of rays, which, for convenience, were called the alpha, beta, and gamma rays. The alpha rays are of very low penetrating power. They are absorbed even by tissue paper or very thin sheets of aluminium. The beta rays, which greatly resemble the Goldstein or Cathode rays, are of far greater penetrating power. Lastly, the gamma rays, which greatly resemble the Röntgen or X-Rays, are of tremendous penetrating power I

* Abstract of a paper read before the Franklin Institute, Sept. 11th, 1911.

personally have been able to obtain fine photographs with these rays through 12in. of steel.

The study of this new element was then universally taken up by physicists all over the world, and especially have the investigations of Prof. Ernest Rutherford been exceedingly fruitful. Rutherford soon found out that radium itself emits but one radiation, and that is the so-called alpha ray. But, besides this radiation, radium emits a certain gas which is called the emanation. These emanations were found to decay rapidly, and while decaying form a new product, which product also disintegrates or decomposes and in doing so forms another product, which likewise is subject to the same change, and so on. The various disintegration products themselves emit certain radiations, and the process of this disintegration, as determined by Rutherford, is as follows:—

Radium, as stated before, emits the alpha rays, which in reality are small particles of matter that can be detected when the naked radium is exposed to a zinc sulphide screen, as the bombardment of the screen by these particles, which travel at a remarkable velocity, produces scintillations which look like millions of shooting stars or sparks under a magnifying glass. Through the constant giving off of particles the radium atom gradually breaks up, but this is so slow that only one-half of the atom is broken up in about 1,300 years. Besides these alpha particles, radium emits a certain gas, which, as the writer has stated before, is called the emanation. The emanations are very unstable, one-half of them breaking up in about 3·8 days. The emanations themselves emit only alpha rays, and, as said before, rapidly decay, and while decaying form a new disintegration product, which Rutherford has named radium A. Radium A is the most unstable of all the emanation disintegration products, one-half breaking up in about three minutes. Radium A emits only alpha rays, and when breaking up forms another product, which is called radium B. Radium B emits no rays and is transformed in 26 minutes, whereby is produced radium C, which is the most remarkable of all the disintegration products, for radium C emits all three kinds of rays, namely, the alpha, beta, and gamma rays. Radium C is also transformed, and during this transformation the alpha particles which are emitted are expelled with much greater velocity than the alpha particles of the other radium products. These alpha particles are absorbed only after traversing 7 cm. of air, while the alpha particles of the other radium products are never able to penetrate more than 4·8 cm. of air. Besides these alpha particles, the beta and gamma rays are emitted, which are of very much greater penetrating power. Radium C, when decomposing, forms a radioactive residue, which is called radium D. Radium D is far more stable than the other radium products, but it does not emit any rays. Radium D also decomposes and forms radium E, which emits only beta and gamma rays. The life of radium E is short, and its disintegration product is radium F. Radium F is the final radioactive product of radium. It is an element of high atomic weight and is identically the same product as that which Madame Curie discovered at first and named polonium. It is also the same product which Prof. Marckwald, of Berlin, discovered and named radio tellurium. Radium F emits only alpha particles, but a far larger quantity of these than is emitted by any of the other radium products. Radium F is half transformed in 143 days.

If a quantity of radium emanations is left in a glass tube for some time, the glass will be covered by a radioactive deposit which can be dissolved in diluted H_2SO_4. If this solution is kept for a long time, say about a year, the activity of same will be found to have steadily increased. If polished bismuth discs are dipped into such a solution, this radium F may be deposited upon them electro-chemically, and, upon removing the discs, will give off only the alpha rays but no trace of beta rays, and this very fact led Marckwald to believe that he had discovered a new element, which he called radio tellurium.

Besides radium, there have been found other radioactive elements, especially thorium. Thorium is the element from which the so-called Welsbach gas mantles are made. Another radioactive element has been found which is known as emanium; it has been named emanium on account of the great quantity of emanations it emits.

As previously stated, radium is found in pitchblende, the ore from which, in Bohemia, the uranium is extracted. Uranium is used very extensively in the manufacture of Bohemian glassware. After the uranium had been extracted from the ore, the so-called refuse was thrown away, and only since the discovery of radium has this refuse become an extremely valuable product.

However, radium does not appear only in pitchblende, but it appears in any ore that carries uranium, as radium itself is only a product of the decomposition of uranium, and the quantity of radium which is contained in the ore is in direct proportion to the quantity of uranium contained in that ore and can be correctly measured thereby. We have pitchblende in the United States, and it is found especially in Gilpin County, Colorado. Carnotite is also found in Colorado and in some other States. Both of these minerals carry large quantities of uranium, and consequently radium. Furthermore, minor quantities of radium have been found in the so-called monazite sands of North and South Carolina. These are the same sands from which also the radioactive element thorium is extracted.

When radium was first introduced to the scientific world, it appeared as a greyish-yellow powder, in small, irregular crystals, and on account of its tremendously high cost was contained in small, hermetically-sealed glass tubes or vials. It must be remembered that radium itself emits only the alpha rays and emanations. The emanations and their subsequent disintegration products also give off alpha rays, and, later, beta and gamma rays. The alpha rays are of exceedingly low penetrating power and the emanations are of practically no penetrating power; but of all the radiations given off by radium and its subsequent disintegration products fully 95 per cent. consist of the alpha particles, whereas the remaining 5 per cent. consist of combined beta and gamma radiations. As radium formerly was contained only in hermetically-sealed glass tubes, all the alpha radiations, all the emanations, and even a part of the beta radiations were absorbed by the glass tube, and therefore when radium was applied in such tubes only a very small percentage of its total radiations, that is, a part of the beta rays and the gamma rays, could be utilised for physiological and other purposes. This led the writer, after due experimentation, to invent aluminium containers, that is, small containers of exceedingly thin aluminium sheets, which could be hermetically sealed by a suitable device. These containers had the advantage over the glass tubes in that they would permit all of the beta and all of the gamma rays to penetrate them; but even these extremely thin aluminium containers would absorb all the emanations and all of the alpha rays or particles. At that time it was despaired of ever being able to utilise the alpha rays and the emanations as valuable therapeutic agents. After long experimentation, and knowing and appreciating fully the importance and necessity of obtaining radium in such a form that access could be had to the emanations as well as to the alpha radiations, and especially considering the fact that even in naked radium we are able to utilise only those alpha radiations and emanations which are emitted by the direct outside layers of a radium particle, as those emanations and alpha radiations emitted by the under layers are unable to penetrate the upper layers, and knowing that for the utilisation of these alpha particles and emanations the radium to be utilised would have to be with practically no under layers, the writer succeeded in finally constructing what are now known as "radium coatings." Radium coatings are manufactured as follows:—

Radium is dissolved in a suitable solvent. This suitable solvent must of necessity vary in accordance with the substance which is to be coated. Thus, if a metallic substance is to be coated, the solvent should contain a certain proportion of an acid which is able to affect the surface of the material to be coated. If celluloid (which the writer preferably employs) is used, the solvent should contain such ingredients which are capable of softening and affecting the surface of the celluloid, and for this purpose the writer employs largely ether, wood alcohol, acetone, amyl acetate, &c. After the radium has been thoroughly dissolved in these solvents, the proper dissolving of which requires considerable care and experience, as the slightest amount of residue would entail a comparatively large financial loss, the material to be coated, usually either rods or discs, is dipped into the solution. Or, if dipping is not advisable, that part of the material which is to be coated is covered with a small quantity of the radium

solution by means of a pipette. As stated before, this radium solution contains, dissolved therein, the radium usually in the form of either radium bromide or radium chloride of varying activities. Naturally the radium solution should be spread as evenly as possible upon the surface to be coated. Then the solvent is allowed to evaporate, which leaves the radium spread in a thin film all over the article to be coated. Since in the case of celluloid the solvent has the tendency to soften and dissolve part of the surface of the article, the deposited radium is thoroughly embedded in the surface, whereby is fulfilled one of the principles desired, namely, to produce practically nothing but a surface of radium with as little radium as possible in underlying layers. However, if radium were used in this form for physiological purposes, it would be of very little value, for if these radium-coated rods or discs were brought in contact with any liquid or would be inserted into a diseased part and come in contact with the blood or juices of the human or animal body, the radium would completely dissolve and it would cause a complete loss of the material. It was therefore necessary to protect the radium film against loss through solution or mechanical friction, &c. This, however, was a very difficult problem, because of the fact that the main object was to obtain full access to the alpha radiations and the emanations, for if the writer had simply coated these so-produced instruments with a protective coating the alpha radiations and the emanations would certainly have been absorbed by the coating, owing to their extremely low penetrating power. It therefore was necessary to construct a coating which would answer both purposes, namely, be thin enough so that the alpha particles and the emanations could penetrate same, and at the same time be tough and protective enough to protect the radium filament from solution in the liquids with which it might come in contact and from mechanical destruction by friction, &c. The writer finally succeeded in doing this by gradually applying coatings of specially-prepared collodion solutions. These collodion solutions must vary in accordance with the material which has been coated with the radium, the main substance being so-called gun cotton dissolved in alcohol, amyl acetate, ether, &c., to which must be added various other ingredients. The writer finally succeeded in obtaining a coating that provided an absolute protection to the radium film and at the same time was sufficiently thin to permit the alpha radiations and the emanations to penetrate it. This penetration of the thin coating was readily proven as follows: since the alpha radiations are readily visible to the eye when they are brought in contact with zinc sulphide, whereby they produce scintillations, as is beautifully demonstrated in the Crookes spinthariscope: the same scintillation effect took place when the coated rod or disc was placed upon the surface of a zinc sulphide screen and was observed under a fairly good magnifying glass in the usual manner.

That the emanations are able to penetrate these coatings was proven in the following manner: A rod, properly coated and protected, was placed within a glass tube, which was fairly well closed and sealed at both ends by rubber stoppers. After this coated rod was left in the glass tube for several hours (preferably 12 to 24 hours) a certain quantity of emanations collected within the tube. When, therefore, an air current was slowly forced through the glass tube it carried the emanations with it, and the presence of the emanations was proven by means of an electroscope.

The method of measuring radioactive materials by an electroscope depends upon two well-established principles: first, that like electricity repels; secondly, that radium rays as well as radium emanations ionise the air. Ionisation of the air means that the air is made a good conductor of electricity, as dry air otherwise is a non-conductor of electricity.

In the case of the Braun electroscope, an aluminium rod is suspended in a metallic case, which, for convenience, is closed off in the back and front by glass. This aluminium rod is suspended in this case by means of a piece of amber surrounded by hard rubber, both of which are non-conductors of electricity. Suspended and well balanced on this aluminium rod is an aluminium needle which moves very freely. At the lower end of the aluminium rod is an aluminium scale. When the suspended aluminium rod is charged with electricity, be it positive or negative, this electricity will instantly be conducted into the aluminium needle, and the aluminium rod and the aluminium needle will repel each other. However only the aluminium needle can move, and will ascend the scale and will remain there until the electricity contained in the aluminium rod and the needle escapes, which escape would be extremely slow in a perfectly dry room. If we now bring radium or radium rays or emanations in the vicinity of the electroscope, these will ionise the air surrounding the electroscope and cause the electricity in the suspended rod and needle gradually to escape. The more powerful the radium is, or the larger the quantity of radiations and emanations given off, the quicker will the air be ionised, the quicker will be the discharge of electricity, and the quicker also will be the descent of the needle down the scale. By the rapidity of the descent of this needle is measured the quantity of radium or the radioactivity at our disposal.

The emanations should collect within a glass tube in which the coated rod has been contained for some time, if the writer's theory is correct that these emanations penetrate the coating. An air current blown through such a glass tube carries with it the stored-up radium emanations, and by bringing these emanations or the air charged with the emanations in contact with the electroscope the electricity contained therein always readily escapes through the ionised air and the needle of the electroscope falls more or less rapidly.

A still more efficient means of proving that the emanations penetrate the coating is by spreading the radium solution on the inside of a tube. For such purposes the writer uses preferably celluloid tubes, internally coated with a thin radium film having the same protective coating as described before. The tube is closed by means of rubber stoppers with glass stop-cocks, and all the emanations collected within this tube will follow an air current if forced through it.

If the writer's theory is correct and the emanations can penetrate the protective coating, these emanations, as stated before, collect within the tube. Then when the air is blown through the tube it carries with it the emanations. When this so-charged air is permitted to strike the top of the electroscope, the surrounding air becomes ionised and the electroscope needle descends, making it a very simple but conclusive experiment.

Thus, where formerly a glass tube containing a fairly large quantity of radium was required, which was very expensive indeed, we can obtain, by means of these coatings, the same, and even far better, results with only a small proportion of the quantity of radium formerly required. Furthermore, we have access now to all the emanations and the radiations for physiological or any other purposes desired.

The writer wants to direct attention to the following: If the beta and gamma rays, as has been asserted, are those of the greatest influence for physiological purposes or in the treatment of diseases such as cancer, lupus, &c., we must remember that these radiations are produced only by the disintegration of the radium emanation. If we now are able to take a rod or disc or any other instrument properly coated with radium and insert this into the diseased part, the emanations, whose disintegration produces these rays, will, instead of escaping into the tube and there being absorbed, now escape into the diseased part, to be retained there, to disintegrate there, and their subsequent products to produce these beta and gamma rays. Not only will these beta and gamma rays act upon the diseased part while the instrument is being applied, as was the case with the glass tube, but the radium emanation will be retained within the tissues, will continue to disintegrate, form its disintegration products, and continue to act upon these diseased parts.

An extensive series of experiments has been conducted by Prof. C. Stuart Gager, formerly of the Department of Botany, Columbia University, and now of the University of Missouri, to determine the effect of radium rays and emanations on plant life, and especially cell formation. He has shown conclusively that in certain forms and under certain conditions radium rays, and especially the emanations emitted from a coated tube, are able to retard the growth of plants and cell formation. Under other conditions, he very largely increased the growth as well as the cell formation, all depending upon the various methods employed.

One important factor has to be considered in connection with these radium coatings, and that is the following: It is a well-known fact that the waters of the famous mineral

springs, especially those of Europe, have certain healing and beneficial qualities. It also has been established beyond a doubt that if these waters are transported their healing and beneficial qualities are almost entirely lost after a few days. It now has been demonstrated that all of these well-known waters and springs contain more or less radioactivity, that is, not primary radioactivity by having a radioactive material dissolved therein, but what is called secondary radioactivity, such that has been imparted to these waters by having them charged with the gas or the emanations emitted by radium. After having proven this beyond a doubt, it has been the aim of a great many of our foremost investigators to artificially produce waters which would contain emanations absorbed therein. For this purpose the celluloid tube coated on the inside with radium has been used very successfully, and it is a matter of very simple experimentation to prove the efficiency of this device and furthermore to prove the contents of radioactivity in such waters. All that is required is that the air, by means of a rubber bulb, be forced through the tube which has remained closed for several hours, and the escaping air which has been charged with emanations allowed slowly to ooze through a column of water, which should be partaken of as quickly as possible. The writer has personally seen some very remarkable and beneficial changes produced in cases of a most desperate nature.

The celluloid tube coated on the inside also has been used with great success in the treatment of throat and lung affections, the patient being required once or twice a day to inhale the air which slowly passes through the tube and which is charged with the emanations.

The writer also has succeeded in applying the radium coatings to microscopic slides. A small part of the slide is coated with the radium solution and, after evaporation of the solvent, is coated with a collodion especially prepared for this purpose. These slides have proven very efficient and of importance for biological investigations, as they can be conveniently placed under the microscope. Bacteria, cell formation, &c., can be placed upon them, and thus the effects of the radium rays and emanations upon various microbes and cell organisms can be conveniently studied under the microscope.

In a great many cases it has been found impossible to apply the radium either in the form of coatings or in a tube. This occurs because of the seat of the disease and the necessity of repeated treatments. In order to provide for such cases, the writer has devised what is known as radium gelatine. This is a sterilised solution of a gelatine which contains a small quantity of radium and which will coagulate when it becomes cold. However, before becoming cold, it is charged with as large a quantity of emanations as possible. This coagulated solution is heated several times, thereby liquefying it, and each time it is again charged with emanations, so that there is finally obtained a radioactive product which contains primary as well as secondary radioactivity. This gelatine is injected into the diseased parts in liquid form or is inserted by means of tampons, &c. Experience has shown that it is readily absorbed by the surrounding diseased tissues, and the radium rays, the decaying emanations, and the disintegration products are thus brought into play upon these tissues.

Fatal Oil Engine Explosion.—An inquest was held at Netherton touching the death of an engine fitter, who was fatally burnt by an explosion in connection with an oil engine in Netherton Pit. Michael Harrison, engineer at the colliery, said he examined the engine about three hours after the accident, but could find nothing wrong with it either externally or internally. In fact, he found everything in order. Witness described how the engine was worked, and expressed the opinion that some explosive mixture had got into the exhaust pipe, and had exploded in the return air way. When he asked the deceased how it happened, he replied that the engine was missing fire, and he was shutting the oil off, and that was all the explanation he gave. The oil used was what the makers of the engine recommended. The jury found that deceased met his death by an explosion of vaporised paraffin oil and air, which had accumulated outside of the regulator.

CAUSE AND PREVENTION OF BLOWHOLES IN COMPOSITION AND BRONZE CASTINGS.

THE two principal difficulties encountered in making composition or bronze castings are: (1) Dross or dirt in the castings; (2) blowholes or pinholes in the metal. Dross in the castings is usually a case of bad gating or pouring, or defect in moulding. Blowholes or pinholes are always the result of bad melting. Let it be understood that blowholes, however large, and pinholes, however small, are the same. Pinholes are simply blowholes, and the cause is the same as that of larger ones. It is a mistaken idea that blowholes are caused by wet sand or rapid pouring. It will never be found that they are the cause. Blowholes are formed in the casting by gas. During the melting of the composition or bronze, this gas is absorbed, and while the metal is cooling in the mould, it is expelled with the formation of the blowholes. If a small quantity of gas is absorbed, then small blowholes (pinholes) result. If a large quantity is absorbed during the melting, then a large quantity is given out in the cooling of the molten metal in the casting with the result that large blowholes are produced. Such is the theory and facts of the cause of blowholes in sand casting, but there are other agencies which enter the problem and render the gas absorption great or small. Some foundrymen say that scrap metals do not cause them the trouble with blowholes that they experience with new metals, and this may be true if the melting is carried on imperfectly. The reason for this is the fact that pure copper, when melted, absorbs gases far more rapidly than the composition or bronze after made. This will be subsequently explained.

The ideal method of melting metals is in a vacuum, and this is now carried on in the manufacture of electric lamp filaments of tungsten and tantalum. All gases in the metal before melting are then extracted, and there is no opportunity for more to enter; but this method can be applied only to melting very small quantities of metals. The next best method is to melt the metal without fuel, as in the electric resistance or induction furnace. There are, then, no gases present, and air is the only one in contact with the metal. Oxidation takes place, of course, and on this account the process is inferior to vacuum melting. In the other melting process, or the so-called "regular" one, the metal is melted with a carbonaceous fuel of some kind, and this fuel, when burned, forms products of combustion that are the cause of the blowholes. There is rarely complete combustion in a melting furnace, and on this account a variety of gaseous products are formed. These may be carbon monoxide, hydrogen gas, and various gaseous hydrocarbons. Large quantities of carbon dioxide gas, of course, are formed. In addition to these gases there is always more or less sulphurous products.

In melting metals in an open flame furnace, such as a reverberatory furnace, the surface of the metal exposed to the products of combustion is so great that there is a much larger gas absorption than in the case of melting in crucibles, where the surface exposed is much smaller. This fact is why crucible melting always gives the best and soundest castings. Every foundryman knows that if metal is melted in direct contact with the flame or fire, the resulting metal is not as good as though a covering of some kind is used to protect the surface. Either a flux or charcoal is used, and this serves to protect the surface of the molten metal while the melting is going on and prevent the absorption of gases.

It is a singular fact that pure metals absorb gases much more rapidly and vigorously than alloys. Some metals do not absorb gases very readily, while others are apparently eager to take them up. Low melting metals, such as tin, lead, or zinc, do not have the property in any marked degree, while metals which melt at a higher temperature, like copper or silver, absorb them rapidly. Copper, perhaps, is the metal which has the property in the most marked degree, and seems to absorb gas more eagerly than any other, even surpassing silver in this respect. It is for this reason that copper alloys are so apt to contain blowholes and that pure copper castings are so difficult to cast sound and solid.

In melting copper by the ordinary means, that is, with the usual coal, coke, oil, or gas furnace, the amount of gas absorbed depends upon three things: (1) The temperature of the metal; (2) the character of the covering; (3) the length of time in the fire after melting. If copper is heated far above its melting point, the amount of gas absorbed is much greater than if not allowed to rise higher than the actual melting. In other words, the hotter the copper the more gas will be absorbed. The character of the covering on the molten metal also has a direct influence upon the amount of gas absorbed during the melting. The worst possible condition, of course, is to melt the metal without any covering at all, as there is then every chance for gas to become absorbed. Many of the worst cases of blowholes and oxidised metal are caused by this one thing. The covering, in the case of copper, should be charcoal, or its equivalent. A flux of some kind can be used, but on new metals it does not give as good results as charcoal. Charcoal is now universally used, and has these advantages: (1) It is a strong reducing agent, and tends to reduce any oxide of copper that may form; (2) it contains no sulphur; (3) it covers the metal mechanically, and prevents access of the products of combustion. It is a noteworthy fact that in brass rolling mills, where the finest quality of brass is made and new metals used entirely, charcoal, and plenty of it, is employed in melting. If melters would bear this in mind, and keep their copper well covered as soon as melting begins, then there would be far less difficulty experienced with blowholes.

Coal or coke will not answer as a covering for molten metals for the reason that they contain sulphur which produces blowholes and dirty metal. There is nothing so good as charcoal, and it should be rather fine (about the size of coarse gravel) in order to obtain the best results. When too coarse, it does not protect the metal sufficiently, and when too fine, it is apt to blow off.

The length of time the copper is allowed to remain in the fire after melting has a very important bearing upon the amount of gas absorption and its production of blowholes. The longer it is left the more gas will be absorbed. For this reason, the sooner metal is poured after it has melted and arrived at the right heat the better the casting. Leaving metal in the fire too long after melting is a very common error, and is responsible for many cases of blowholes. Not only does the metal then have more opportunity for absorbing gases, but the temperature usually rises so that they are more vigorously absorbed. It should always be the rule to pour metal as soon as it is melted. Moulders are responsible for this condition, as they may not have their "heat" ready for pouring when the metal is melted and, therefore, it is allowed to remain in the fire until ready. This results in the metal remaining melted too long, and, possibly, becoming too hot. As previously mentioned, pure metals absorb gases more readily than alloys, and for this reason, in making new composition or bronze from new copper, greater care is required than in melting metal already mixed. However, alloys absorb gases readily, and what has been said about melting copper applies equally as well to copper alloys, such as bronze, brass, or composition.

To assist the brass founder in melting, the following rules may be adopted for the production of the best quality of metal and sand castings. They will apply equally as well to the melting of the brasses and bronzes as to pure copper.

1. Melt in such a way and with such a heat that *all* the metal becomes liquid at about the same time. This avoids overheating or "burning" one portion of the metal before the rest has begun to melt. A moderate heat is preferable to a high one, even though the melting is a trifle prolonged, as it avoids overheating the exposed portions of the metal.

2. Do not allow portions of the metal, such as ingots or gates, to project above the top of the crucible. When this is done, such portions are overheated and "burned" before the bottom portions begin to melt. It is better to use less metal in the crucible at the beginning so as to avoid this and have all portions covered with charcoal.

(3) Warm the metal up before feeding into the crucible, after that in it has melted, so that it will melt more readily when introduced into the crucible. The metal may be warmed on top of the furnace, and as long as melting does not take place there is no gas absorption.

(4) Put some charcoal into the crucible as soon as the metal begins to melt and add more from time to time, if necessary, so as to keep the surface of the metal free from exposure. If a portion of the molten metal is exposed, then harm will result. A covering of charcoal to a depth of about an inch is usually necessary.

(5) As soon as copper (if new metals are used) is melted and has arrived at the right heat, add the zinc, tin, lead, or other metals to be used. Far more harm results in allowing copper to remain melted for any length of time than mixed metals, as it absorbs gases so readily. This is why it is necessary to add the alloying metals to the copper so soon. It may be said, in this connection, that this feature is one frequently overlooked by melters and is responsible for much bad metal.

(6) Stir thoroughly after adding the alloying metals and allow the heat of the metal to rise to the required pouring temperature. A good, thorough stirring is required for the perfect mixing of the metals.

7. When the right heat has been obtained on the metal, pour it into the moulds and do not allow it to remain in the fire any longer than is necessary. Good castings depend upon this point.

8. Do not allow the heat of the metal to rise far above the pouring temperature and then cool down with gates or scrap. Metal that has once been overheated is injured, and cooling with gates or scrap, while reducing the temperature, will not overcome the injury done in overheating. Metal that has not been allowed to rise above the required temperature is always better than that which has been overheated and cooled down with gates.

9. In conclusion, do not allow moulders to keep their melted metal in the fire while their heat is being put up. The moulds should be ready at the same time as the metal, or before. Better metal will result if the moulders have to wait for it.—"The Brass World."

THE INSTITUTE OF METALS.

THE London meeting of the Institute of Metals will be held next week at the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W., on Tuesday, January 16th, at 3 p.m., and on Wednesday, January 17th, at 10-30 a.m. On the first day of the meeting—January 16th, at 3 p.m.—members will assemble at the Institution of Mechanical Engineers, by the courtesy of that Institution, when the president of the Institute of Metals (Sir Gerard Muntz, Bart.) will present the report of the council on the work of the Institute during the past year, and other routine business will be transacted. The third annual dinner, which will be attended by many distinguished scientists and Government officials, will be held the same evening. The whole of the business of the second day of the meeting—January 17th—will be compressed into a morning, afternoon, and, possibly, an evening session, to be held at the Institution of Mechanical Engineers, commencing at 10-30 a.m., when the following papers will be read and discussed: (1) "A Metallographic Hydroscope," by Prof. Dr. Carl A. F. Benedicks; (2) "A Study of the Properties of Alloys at High Temperatures," by Dr. G. D. Bengough, M.A.; (3) "Further Experiments on the Inversion at 470° C. in Copper-zinc Alloys," by Prof. H. C. H. Carpenter, M.A., Ph.D.; (4) "The Influence of Oxygen on Copper Containing Arsenic or Antimony," by R. H. Greaves; (5) "The Influence of Tin and Lead on the Micro-structure of Brass," by F. Johnson, M.Sc.; (6) "A Contribution to the History of Corrosion: The Corrosion of Condenser Tubes by Contact with Electro-Negative Substances," by Arnold Philip, Assoc.R.S.M., B.Sc.; (7) "The Nomenclature of Alloys," by Dr. W. Rosenhain, B.A.; (8) "The Behaviour of Certain Alloys When Heated in Vacuo," by Prof. T. Turner, M.Sc. Full particulars regarding the Institute, together with forms of application for membership and visitor's tickets for next week's meeting, can be obtained from Mr. G. Shaw Scott, M.Sc., the secretary of the Institute of Metals, Caxton House, Westminster, S.W.

AN IMPROVED DESIGN OF OIL ENGINE.

THE accompanying illustrations show an arrangement of internal-combustion engine of the type in which liquid hydrocarbon is injected at or near the end of the compression stroke into a charge of air compressed into a vaporiser connected to the cylinder of the engine by a more or less contracted neck or passage. The engine, which has been patented by D. Roberts, J. W. Young, and C. James, of Spittlegate Iron Works, Grantham, has been designed with the object of obtaining a higher efficiency and greater power than has been possible with engines of this class, while further the claim is made that it permits of the satisfactory

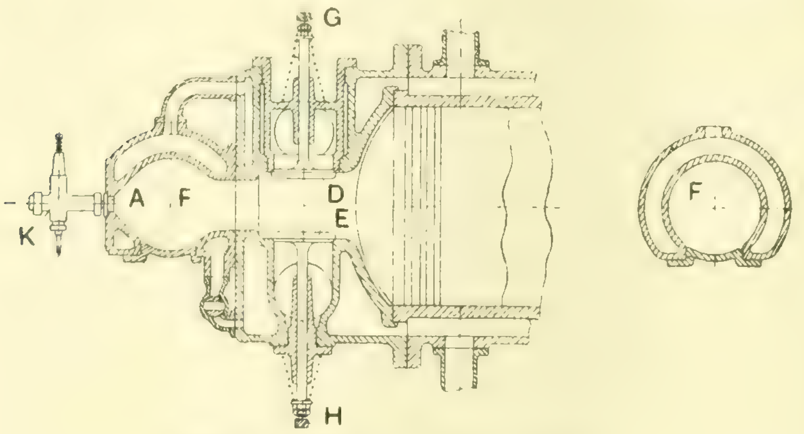


FIG. 1. IMPROVED DESIGN OF OIL ENGINE.

employment without loss of efficiency of a greater range in grades of liquid hydrocarbon than has been hitherto possible.

Referring to the illustrations, Fig. 1 shows a sectional elevation of a portion of a single cylinder horizontal engine adapted to operate on the four-stroke cycle, and a section through the vaporiser. Fig. 2 shows a side elevation and an end view of the engine. Fig. 3 is a vertical section through the vaporiser valve box. Fig. 4 is a similar section of the fuel oil pump. Fig. 5 shows side and end elevations respectively of the governor cam, and Fig. 6 is similar view of the fuel pump operating cam. The air inlet valve D and the exhaust outlet valve E are arranged on the cover of the cylinder as shown. The axes of these two valves are disposed

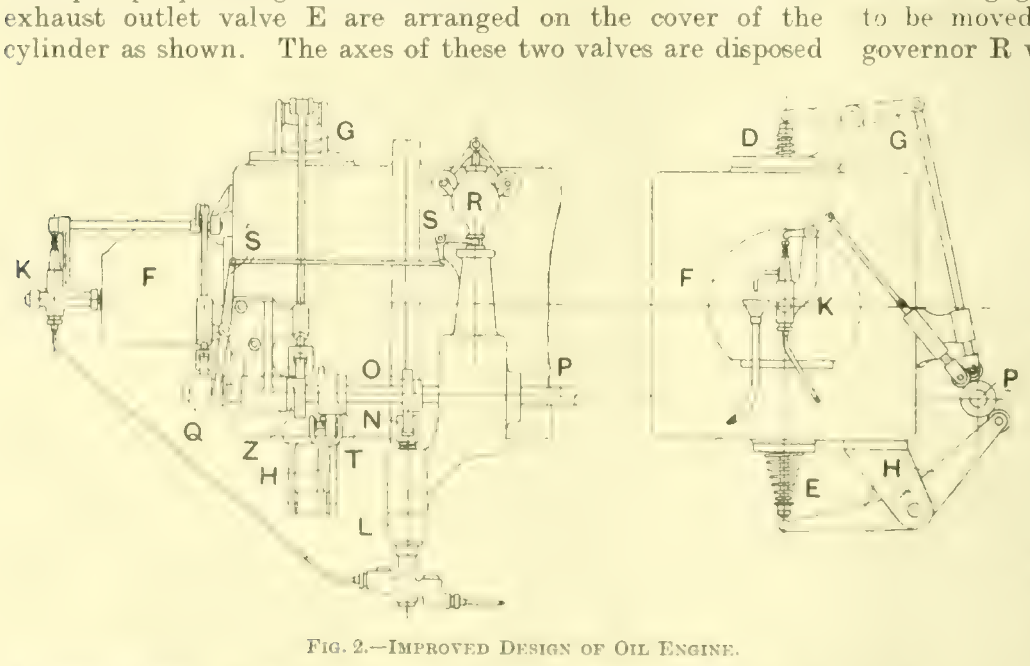


FIG. 2.—IMPROVED DESIGN OF OIL ENGINE.

at right angles to the longitudinal axis of the engine and are located in a vertical plane. The vaporiser F, which is of spherical shape, is provided over the major portion with a water jacket, the unjacketed portion being at the lower part of the vaporiser and constituting the igniter. This igniter is heated up by an external lamp when the engine is first started. At its outer end the vaporiser F is formed with a neck A, the axis of which coincides with the longitudinal centre line of the engine and vaporiser, and which has attached to it the valve box K fitted with a horizontal check valve and a vertical relief valve, the fuel being supplied to the valve box through a pipe which extends from the pump L (see Fig. 2). The pump comprises a cylinder in which there reciprocates a plunger M caused to move on its up or suction stroke by a spring, the upward stroke being limited by a stop. The plunger is depressed by means of the striker N, which is held by a spring against the face of the operating cam O mounted upon the cam shaft P. This cam O shown in Fig. 6 is formed with five faces, namely, the faces U, V, W, X, and Y. The face U is concentric with the axis of the cam shaft P, and is designed to provide an idle period for the pump plunger, in order to give the valve time to seat itself at the end of the suction stroke; the second face V is snail-shaped, and is designed to bring the striker N gently into contact with the pump plunger M. The third face W

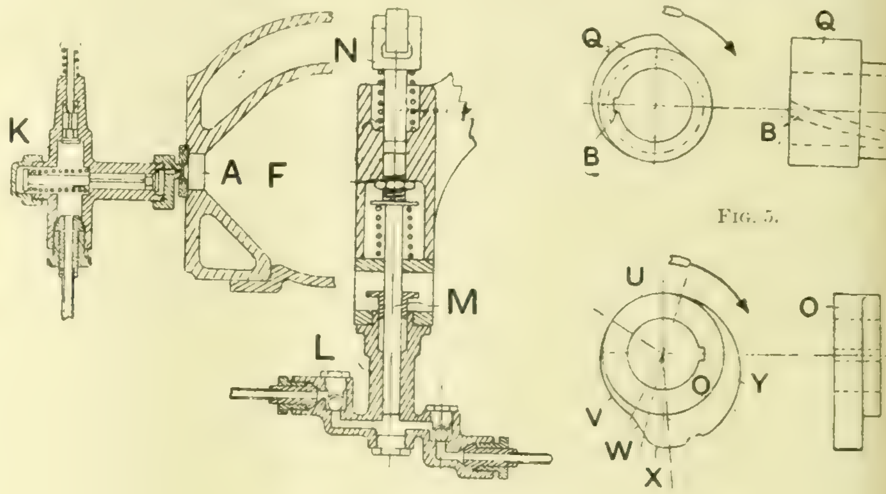


FIG. 3. FIG. 4. FIG. 6.
IMPROVED DESIGN OF OIL ENGINE.

is the actual delivery face and effects the forcing stroke of the pump plunger M. X is an extension of the face W which merges into the fifth face Y, which is again of a snail-shape and permits the gradual or slow return or suction stroke of the plunger.

Upon the cam shaft P there is also mounted the cam Q, shown detached in Fig. 5, this cam serving to actuate the vertical valve in the vaporiser valve box K. This cam is mounted upon the shaft P by means of a key upon the latter which engages in the spiral keyway B in the cam designed to be moved axially along the shaft P by means of the governor R which controls the cam by means of the link and lever mechanism S. The axial movement of the cam causes the same to rotate relatively to the shaft, so that its position is varied as the speed of the engine fluctuates, thus controlling the operation of the relief valve in accordance with the fluctuating speed. The cam shaft P has also mounted upon it the cams Z and T, which respectively control the air inlet valve D and exhaust outlet valve E through the medium of the mechanisms G and H.

In operation, assuming that the engine has been started by the preliminary heating of the hot part of the vaporiser F, the fuel is supplied by means of the pump L to the vaporiser valve box K, and is injected therefrom through the neck A axially into the spherical vaporiser, whereby it is projected into the charge of air which has been compressed into the vaporiser by the compression stroke of the piston. The explosive charge thus produced is ignited by the hot part of the vaporiser and the working stroke of the piston takes place, and is succeeded by the exhaust stroke in the ordinary manner.

A New Submersible Boat.—The Admiralty have, we learn, placed a contract with the Scott's Shipbuilding and Engineering Company, Greenock, for the building of a submersible boat of the "Laurenti" type. The new submersible will be of the twin-screw type, with twin 6-cylinder Fiat engines in one engine-room, with electric motors for propelling the boat when submerged. The torpedo tubes will be forward under the bow and the storage tubes above it.

THE ELECTRIFICATION OF THE SHELTON MILLS.*

BY W. H. LAKE.

As the members of this institute have considered the electrically-driven mills at Shelton of sufficient interest to warrant a visit of inspection, the writer trusts that a short statement of the considerations which led to the adoption of electric driving, with a brief description of the details of the plant and of the results so far attained, may also prove interesting. The first question that arises is why electric driving was considered desirable in this instance? It was recognised that electric driving was not of necessity the most economical, and it was adopted only after careful consideration of the special circumstances of the case.

The word economical in this connection is used to imply economy in pounds, shillings, and pence—that is, in financial units, and not in heat or electrical units. The tendency amongst engineers engaged in the production and perfection of machinery is to put forward the most efficient, and, in many cases, the most expensive plant. The function of the purchaser's engineer is to analyse the alternatives offered, and it may involve the rather ungrateful duty of rejecting the more efficient and more costly in favour of the less efficient and cheaper in order to obtain the best return on the capital expended.

The circumstances of the present case were as follows: At Shelton Works are four mills, a sheet mill, 16in., 12in., and 10in. mill, which are employed in rolling both steel and iron, but more of the former. The engines of the mills and of the auxiliary machinery in connection with them were supplied with steam from nine boilers in connection with the heating furnaces and five hand-fired Lancashire boilers. There was an obvious and immediate saving to be made by dispensing with the consumption of the fuel burned under the hand-fired boilers and the labour in connection with it.

Two methods of doing this suggest themselves. First, to improve the efficiency of the mill engines so that the steam consumption would be reduced to half its present amount. This method would not have materially improved the consumption of the wasteful steam auxiliaries, and would have necessitated new furnace boilers to provide steam at a higher pressure, unless the bold example set by Messrs. Dunlop, of Glasgow, had been followed, and steam turbines adopted for driving the mills through gearing. It would also have suffered from the defect of perpetuating the furnace boilers instead of forming a preliminary step towards their removal, along with the adoption of improved methods of heating. The second method is to link up sufficient of the mills to a source of power derived from waste heat, if such be available.

Three sources of power presented themselves: First, the power rendered available by the use of blast-furnace gas engines. To make use of this would have involved the replacement of some of the blastfurnace blowing plant at Etruria Works, and to obtain the full advantage offered by this method would have involved also the electric driving of Etruria Mills. In conjunction with this possible source of power, the fuel cost of the present method of working was considered, in conjunction with the capital expenditure required for the necessary alteration, and with the time that must elapse before the plant could be in full operation. This point is of especial importance in old and cramped works. Given room for extension and convenient traffic arrangements, a great amount of new work can be put through in a comparatively short time. In a works which is already sufficiently congested by the normal processes of manufacture it is not possible to carry out a radical and extended series of improvements quickly without serious and costly interference with the ordinary conduct of the business. It became clear, on examination, that in this instance the saving to be obtained by this method of working would not warrant the necessary expenditure of capital.

The second possible source of waste heat was a forge which would provide a surplus of steam over its own requirements, but at a low pressure on account of the age and nature of the boilers. Here was a source of waste heat, which could be used at a low pressure in steam turbines to generate electricity for driving the mills and other purposes.

The third source was the exhaust steam from the reversing mill engines at the Etruria Works, which was discharged into the atmosphere, the whole output of which, over and above that required for heating the feed water, was available for generating electricity. As this source was distant 670 yards from the Shelton Works, only electrical means were suitable for the transmission of the power. This third source had the advantage over the second that more steam in all was available, and that the working was more constant than in the second case. It happened also that further supplies of electrical energy were required at Etruria, so that a larger generating station could be installed than would have been justifiable by the immediate requirements of the Shelton Works.

These circumstances provided the following ideal conditions for the application of electric working: (1) An ample supply of heat. otherwise wasted, as a source of power. (2) A demand for current sufficient to warrant the installation of a unit of good size, thereby keeping down the capital cost per kilowatt installed. (3) A good load factor, so that the cost per unit generated would be moderate. (4) The engines driving the mills, which it was desired to replace, were of an uneconomical character. (5) There were a great many engines on small auxiliary machines and in scattered workshops which could be most profitably converted to electric driving. (6) A works so cramped that the relief from the necessity for dealing with the fuel for and the ashes from the hand-fired boilers was an appreciable benefit.

It is generally asserted that with electric driving an increased output is to be anticipated on account of the better speed regulation of the mill, and this is certainly the case as compared with under-powered steam engines which slow up considerably when overloaded. The smaller speed variation brings the average speed of the mill near the maximum, and this superior regularity aids the men in obtaining quick working. To a very large extent this advantage can be obtained with steam driving of adequate power for the work to be performed, and though an engine of very large overload capacity is not usually efficient on light loads, it may be economical if the steam is sufficiently cheap. In the present instance an increase in output of fully 25 per cent. is obtained on certain sections, and the range of these sections will be increased when improvements in the heating furnaces which are in view have been carried out.

The average kilowatt-hours consumed per ton of finished material in these two mills during the three months' work, including the current consumption for running the auxiliary machines, have been about 90. The savings in labour and fuel on the mill and other outlying boilers have fully met anticipations.

The generating station is treated as a separate department, the current to each department being measured and charged for at a uniform rate. The principal features of the generating plant are as follows:—

At the steel works at Etruria are two simple two-cylinder reversing rolling-mill engines, working non-condensing, the finishing engine with cylinders 50in. by 5ft., and the cogging with cylinders 42in. by 5ft. The steam for these engines is provided by seven 8ft. 6in. by 30ft. Lancashire boilers, hand-fired, and two boilers similar, but 8ft. diam., fired by waste heat from the heating furnaces. The working steam pressure is 120lbs. per square inch, but it is naturally subject to some variation. Four auxiliary engines discharge their exhaust steam to the mains, but three of these will probably be changed over to electric driving. The exhaust steam is discharged from the cogging engines to a vessel made of an old boiler shell and formerly used as a direct-contact feed heater. A 20in. relief valve is fitted at the top of this to prevent excessive back pressure. The steam passes through a 2ft. 6in. diam. riveted steel main suspended in the roof of the mill, to grease separators at the back of the finishing mill engines. The steam from both engines passes

* Abstract of paper read before the Staffordshire Iron and Steel Institute, December 16th, 1911.

from that point through a 3ft. diam. riveted steel tube suspended in the roofs over the stock banks and across the canal to the accumulator, which was made to designs supplied by Mr. P. J. Mitchell. The accumulator is capable of bridging intervals in the supply of exhaust steam of one minute when the turbine is working on full load. The exhaust mains have been arranged with a fall in the direction in which the steam travels. The accumulator is the lowest point in the system and the short riveted steel main from the accumulator to the turbine rises. The system is consequently self-draining.

The generator is a 1,000 kw. Westinghouse impulse-bladed mixed-pressure turbo-alternator running at 3,000 r.p.m. and generating current at 5,500 volts. The turbine is arranged to change over from exhaust steam to live steam before the pressure in the accumulator falls below atmospheric pressure, so as to avoid possibility of trouble from leakage of air into the exhaust mains and engines. The machine will deal with an overload of 15 per cent. on exhaust steam when exhausting to a 28in. vacuum, and will deal with overloads up to 50 per cent. with live steam or a mixture of live and exhaust steam by opening up additional nozzles by hand. The voltage is maintained steady by a Tirrill regulator.

The high and low pressure throttle valves are controlled by a powerful governor through a relay actuated by oil pressure, and additional control for the low-pressure valve is provided by a relay controlled by the pressure of steam in the exhaust mains.

The condenser is of the surface type, of 5,500 sq. ft. tube surface. The cooling water is circulated through the condenser and over the cooling tower by a motor-driven centrifugal pump. The air pump is of the Leblanc type, and along with the water extraction pump is driven by a separate motor. These motors are worked by continuous current at 500 volts, so that they can be started up before starting the turbo-alternator, by current from the old generating station which provides the week-end supply.

In installing a generating plant of this description the effect on the existing plant has to be taken into consideration. It is principally affected by changes in two directions: (1) Back pressure. (2) Arrangements for feed heating.

With regard to the back pressure, even with exhaust mains of ample dimensions, such as those adopted in this case, there is generally an appreciable increase in the average back pressure, which increases the steam consumption of the main engines. The method adopted for compensating for the effects of this was the addition of downtake superheaters to the seven hand-fired boilers. These are of the double flow type and are fitted in the downtakes at the back of the boilers without protective dampers and without by-pass valves. The superheat obtained at the boilers is about 120° Fah.

As to the feed water, the old method of heating this was by direct contact in the shell behind the cogging engines. The objections to this method are that it uses the exhaust steam when there is none to be spared, and thereby reduces the pressure in the exhaust mains below the atmosphere, and some of the air dissolved in the feed water passes over to the turbine with the exhaust steam and reduces the vacuum. The new method of dealing with the feed water is as follows: A portion of the feed water is discharged from the surface condenser as distilled water. The remaining portion is taken from the circulating water system through a Wright's heater softener. Steam is supplied from the accumulator to the heater through a control valve specially designed to maintain a very slight pressure in the heater. This valve is controlled by a bell, with its edge dipping in water in the same manner as a gas governor; it is practically free from friction and very sensitive.

In a plant of this description the amount of exhaust steam is very fluctuating, and is periodically so great that the combined requirements of the turbine and the powers of absorption of the largest feasible accumulator leave a good deal to blow to waste. It was clearly desirable to make as much use as possible of these peaks in the supply of exhaust steam, and by using these to heat the feed water, to minimise the drain on the system in the intervals when exhaust steam is not available. To attain this end, two tanks each of 650 galls. capacity were installed, and the make-up water on its way from the circulating water system to the heater softener passes first through one of these and then through the other. Into each of these tanks there dips a perforated steam pipe from the accumulator, and the head of water over the outlets of the steam pipe is such that the pressure of steam in the accumulator overcomes this head just before it lifts the relief valve on the accumulator itself. Consequently every peak in the supply of exhaust steam raises the temperature of the water in the two tanks practically to boiling point, and so the demands for steam to pass to the water softener by means of the automatic valve mentioned are reduced. During the time the water takes to pass through the two tanks there are generally a sufficient number of peaks in the supply of exhaust steam to raise its temperature to about 200° Fah. A reducing valve has been fitted which passes live steam into the accumulator when the pressure falls below ⅜ of a lb. per square inch.

This arrangement provides the following conditions: (*a*) When there is no exhaust steam the feed water is heated by live steam and the water-softening process continues uninterruptedly. (*b*) When there is only a little exhaust steam, but not sufficient to raise the pressure in the accumulator, the feed heater will take it and the turbine will work on live steam. This is the more economical method in view of the very efficient use of live steam obtained with the turbine. (*c*) When the exhaust steam comes over in normal quantity the turbine takes all it requires, the surplus steam heats a storage of feed water, and consequently in the intervals of the exhaust steam supply the steam given off by the water in the accumulator is entirely available for the turbine, as the temperature of the water passing from the thermal storage tanks to the heater softener is practically the same as that at which it leaves.

As the distilled water leaves the water extraction pump of the condenser it passes through a heat storage vessel similar to the others, and thence flows to join the softened water from the heater softener. The whole feed water in the present instance has to flow some distance across the canal, so the temperature is given a final "boost" by the exhaust steam from the feed pump. The actual temperature varies at the feed pump between 190° and 200° Fah.

The present output obtained with this generating plant is at the rate of 3,600,000 units per annum, allowing for 50 weeks' working, or a load factor over the whole year of about 41 per cent. The plant is charged with the fuel it uses in the intervals when there is no supply of exhaust steam. The works cost of generation, that is, fuel, wages, stores, and oil, works out to just about one-tenth of a penny per unit. The selling price of the current at the station will depend on the charges to be met for depreciation, maintenance, and interest on capital.

In the discussion on Mr. C. A. Ablett's paper, read in 1909 before the Institution of Engineers and Shipbuilders in Scotland, 10 per cent. to cover interest and depreciation was accepted without criticism. Adding 2 per cent. to this for maintenance, thereby bringing the total to 12 per cent., as allowed by Mr. Hooghwinkel in his paper, read before the Sheffield Society of Engineers and Metallurgists in 1908, the current can be charged from the station at one-fifth of a penny per unit. It is to be remembered, however, that there is no stand-by plant installed, and the provision of this would put up the standing charges, and the selling price of the current would require to be increased to 0·25 of a penny. The extra cost would be an insurance premium against failure of supply.

The 3-phase 5,500 volt current required for Shelton Works is transmitted by an overhead line consisting of bare aluminium stranded conductor. The terminal poles are of steel structural work, and the intermediate poles of creosoted timber. At each terminal the line is connected to multiple gap lightning arresters, and passes into a trifurcating box, from which the current is taken through a three-core paper insulated double armoured cable.

In the Shelton sub-station the current is controlled by

high-tension switchgear, in a cubicle similar to that in the generating station, and is transformed and converted to 500 volts continuous current by a 500 kw. Westinghouse rotary converter. The rotor of this machine is so made that its place can be taken by the rotor of the converter in the power station in case of breakdown.

The 12in. mill consists of one stand of three-high bolting rolls, and one stand of finishing rolls worked sometimes two and sometimes three high. The 10in. mill consists of two stands of three-high rolls and two stands of two-high. Each of these mills is driven by a 350 b.h.p. continuous-current compound-wound variable-speed motor, capable of this output continuously, 25 per cent. overload for one hour and 100 per cent. overload momentarily. The speed is variable by shunt field rheostat from 450 to 720 r.p.m. The power is transmitted to the mills, and the speed reduced, by a rope-drive, consisting of 12 1⅝in. diam. ropes. The rope flywheel of the 10in. mill is 10ft. 6in. diam., weighs 10 tons, and runs from 150 to 240 r.p.m. The 12in. mill has the old flywheel of the engine 9ft. 8in. diam., weighing 15 tons, and a rope pulley 14ft. 6in. diam., weighing seven tons, and runs at 90 to 150 r.p.m.

The adoption of the rope drive may appear open to criticism, particularly in the case of the higher-speed mill. The points of advantage are: (1) The two motors are exactly duplicate except for the rope pulleys. (2) The cost of the equipment is smaller by keeping up the speed of the motors. (3) The arrangement of the mills was favourable to the rope drive, and allowed of both mills being changed over to electric driving without any loss of time, and in such a way that it is possible to revert to steam driving quickly in case of need. This provision is not intended as a reflection on the reliability of electrical equipment, and is only being retained until arrangements have been made for some stand-by source of electrical energy. The disadvantage of the rope-drive, the loss of power in the ropes, is to an appreciable extent offset by the greater efficiency of the higher-speed motors. The disadvantage of fluffy matter coming off the ropes and settling on the motor windings has been met by providing a guard of steel plate which encloses the rope pulley on the motor, and confines any dust stirred up by the ropes to the rope race.

Between the flywheel of the 10in. mill and the mill itself there is interposed a disengaging coupling of the writer's design, by which the mill can be instantaneously disconnected from the flywheel. This has already been of service on several occasions by preventing the extension of slight mishaps at the rolls into something more serious.

The motors have proved of ample power for the service required of them. As a matter of fact, the engines never did indicate, and were incapable of indicating, even the normal output of the motors. The motors are, nevertheless, in no way too large. When working with the steam engines the drops in speed were very great on some of the passes, and the time of recovery correspondingly great. Consequently the indicated horse-power was no criterion as to the size of motor required.

As regards the method adopted of driving by direct current, the question may be asked why, when there are methods available for working rolling mills direct from an alternating-current supply and providing the necessary variations in speed, was it considered desirable to resort to conversion to direct current. This method was considered to meet most fully the special circumstances of the case. In the Shelton Works there were already motors at work on a 500 volt D.C. system. Some of these were employed in working cranes, and others for similar service were in view. For intermittent working of this description the D.C. motor cannot be excelled for convenience.

The direct-current system with rotary converter also presented the advantage that the Shelton converter could be made a duplicate of the machine installed in the generating station, and in case of urgent necessity this latter machine could be dispensed with and its parts used to keep the Shelton Mills going in case of breakdown of the rotary there. The direct-current system of working also allowed the adoption of several series of duplicate motors in the smaller sizes for use throughout the whole works. This duplication is at times a source of considerable convenience. These conveniences, however, are not obtained without some sacrifice. Some of the methods available for working the mills by alternating current direct give a higher efficiency at full load and more markedly so at half-load, and are not more costly to install. Had it been decided to adopt the 3-phase current without conversion for the electrification of the Shelton Works no difficulty would have been experienced in obtaining plant to meet the requirements in speed variation.

The rotary converter is of 500 kw. capacity with overload capacity of 25 per cent. for two hours. It is started up from the original direct-current supply to Shelton Works and is usually run without stop from Monday morning until Saturday afternoon. The power to run the 10in. mill light is 50 kw. to 90 kw., and the 12in. mill 45 kw. to 80 kw.

Whilst any accurate comparison must take into consideration all the circumstances of a particular case, a rough comparison between good steam engines and electrical plant may be of interest. The cost of steam may be taken at one penny per 100lbs. inclusive of all boiler plant charges, interest, depreciation, upkeep, fuel, water, and handling coal and ashes, taking fuel at 6s. per ton.

The engines installed at the Tinsley Rod Mills were estimated to use 15lbs. of steam per i.h.p.-hour at their most economical load, or 12lbs. of superheated steam. These are large engines. It may not unfairly be assumed that with smaller engines of about the power under consideration, and with the large amount of light load running which may occur in a non-reversing rolling mill, a good compound condensing engine will require 20lbs. of steam per i.h.p.-hour inclusive of losses in steam pipes.

If further it be assumed that the mechanical efficiency of the engine is about the same as the efficiency of the motor, one electrical h.p.-hour will be required for one i.h.p.-hour in the engine. One i.h.p.-hour with the steam consumption assumed will cost one-fifth of a penny. To obtain one electrical h.p. for this the current must be purchased at about 0·27 of a penny per unit.

The main engines are not the only ones requiring consideration. The engines usually employed for auxiliary machinery will certainly use two-and-a-half times the steam per h.p.-hour assumed for the main engines, and probably more. Consequently it will pay as compared with steam to drive them electrically by power costing two-thirds of a penny per unit. Probably it will almost always pay to drive such machinery electrically with current at 0·75 of a penny per unit, as the cost runs up so enormously when a boiler has to be kept going to drive one or two machines for some special purpose at a week-end.

If the current consumption of the auxiliary machinery is 20 per cent. of the total, this 20 per cent. will be worth 0·75 of a penny per unit, so that electricity at about 0·36 of a penny per unit for both mills and auxiliary machinery will make the cost of power work out about the same as for steam. In some cases it will be most economical to work the mills by steam and the small machinery electrically. Current can, however, be purchased more cheaply as the quantity taken is increased, and when it is generated in a works generating station, the cost of production diminishes with the increased output, so that the possible reduction in cost affects the choice between a partial and complete electrification.

The cost of upkeep of electrical machinery is not great, nor is the upkeep of either a good old or a good modern steam engine of reasonable size great. The upkeep of small engines usually found on auxiliary machinery is undoubtedly very much higher than that of electrical motors for the same work. The rough figures given above have reference only to the case in which the steam is raised by coal firing; the conditions are obviously entirely altered by available free steam or other form of waste heat. Further, some of the later developments in electrical driving appear in certain cases to allow of an output much higher than can be obtained with any form of steam driving in which a flywheel is used; and this point will require consideration where conditions are such as to permit of working the mill up to the utmost limit of its capacity.

The writer wishes to express his indebtedness to Mr. W. Simons, general manager of the Shelton Works, for his permission to publish these particulars.

VALVE CASTINGS AND DEFECTS.

BY A. NAPIER.

It is no uncommon occurrence to meet enquiries as to the methods of overcoming the trouble of excessive wastage in the casting of valves. Frequently valves will be cast and appear good until tested, when defects and leakage will develop, resulting from weak, porous places at some point. The founder may, and often does, labour under the disadvantage of having his mixture specified, in which case it is necessary to enquire whether his treatment of the metal, first, is the cause of the trouble.

Some mixtures are more subject than others to the trouble of segregation of particular constituents, and exceptional care is necessary to prevent this feature producing brittleness and weak places in the castings. A slight alteration in the mixture, or the accidental introduction of a small amount of an undesirable constituent, may lead to a different structure in the alloy, under casting conditions which formerly gave good results. Shrink-holes in the thicker portions of the castings are a defect that should be met by the moulder in the placing and size of the risers, while dross and scum in the metal—a fruitful source of trouble—is a matter for the melter. In view of the extent to which foundry writers have pressed the point of oxidation, it would seem unnecessary to again do more than mention it; but experience shows that oxidation of the metal through improper melting and exposure to the atmosphere and the furnace gases is a daily occurrence. Many defects in valves are directly traceable to careless melting—sometimes to a neglect to take into account, when melting scrap, the loss of certain constituents during previous meltings.

A number of factors may contribute to the production of castings in steam valve work which leak under test. The moulder may be responsible for not gating the mould properly—a very important feature in obtaining sound castings of any description; or, even with a good mould and the correct mixture, if the metal is not hot enough when poured the result will be bad. Overheating, on the other hand, may also cause a large percentage of failures, as oxidation is very liable to result. The shifting of badly-set cores is at times responsible, as may be the design of the casting.

It must not, it will be seen, be supposed that a large percentage of failures in valve castings is necessarily due to a wrong mixture. It may be defective design, as seen in designs with too sharp a change in section between flange and body, or defective moulding which gives a mould too hard or too damp. At the same time, the defects may readily be in the metal, from either of the causes previously mentioned, or the trouble may lie directly in the pouring temperature and the manner of pouring. This was clearly shown by the experiments of Carpenter and Edwards with the aluminium-bronzes (Cu, 91 to 90 per cent.; Al, 9 to 10 per cent.), which were proved to give excellent castings for withstanding pressure. It was found that, in order to obtain the best results, this alloy must be poured slowly and at a temperature not more than 80° C. above that at which it commences to freeze or solidify. But the investigators also laid stress upon the moulding side. This mould must be gated for the metal to enter at the lowest point—*i.e.*, it must be bottom-poured, and the gate should have a well at the bottom, the opening being rather narrow. If a green sand mould, it must not be too damp, and in the case of a close sand being used it is preferable to dry the surface of the lower part of the mould. Nor must the shrinkage of the metal be neglected, but must be met by the use of risers, particularly in the case of large castings.

When using a mixture that has been proved to be suitable, any defect in the resulting castings may be put down to the treatment of the metal, to the design, or the method of moulding; but often mixtures are specified or tried by founders inexperienced in the particular line of castings, which are not suitable. For high grade mixtures it is often desirable to use no lead, though the absence of lead entails more labour in the machining process, the metal turning much tougher. The distribution of the lead between the crystals of the alloy gives it a shorter and free-working grain, but at the expense, somewhat, of the strength. A suitable mixture without lead is: Copper, 90 per cent.; tin, 8 per cent.; and zinc, 2 per cent.

The colour of the castings will be detrimentally affected by the presence of iron in the mixture. Iron is liable to become introduced with the copper, as some brands contain appreciable amounts, or it may enter with re-melted scrap or wasters in the form of core-wires, chips, &c. Aluminium, while a valuable addition to a number of alloys, does not seem to give satisfaction with valve mixtures: for it has been found that when added to the latter the castings generally develop weakness, and leak under test. The aluminium bronze quoted earlier would seem to be in a different class; but as a general rule aluminium is considered undesirable.

Often the use of a small amount of some deoxidising constituent will overcome the persistent trouble with what should be a satisfactory mixture, but which at times is found to give an excessive number of leaky castings. Take, for example, the mixture: Copper, 86; tin, 7; zinc, 4; and lead, 2; this, while giving a fairly good result, will sometimes give castings with brownish spots that display weakness under test, and leak. The spots are generally on the top part of the castings, and result from dirt in the metal. In this case, the introduction of a small amount of some deoxidiser would generally clear the trouble (say about 0·5 to 1 per cent. of 15 per cent. phosphor-copper).

There are, of course, a number of mixtures which are in common use for the purpose which are not strictly suitable for valve castings. Yellow brass is sometimes employed, but cannot be used for valve work nearly so successfully as can red metal, the number of leaky castings being much greater. With red metal the bad castings may normally run from 5 to 15 per cent., but with yellow brass it will be very difficult to keep the waste down to the higher figure mentioned.

Some founders give special attention to the wearing parts of valves, an example being the introduction of nickel into valve-seat mixtures, a typical one having the following composition: Copper, 85 per cent.; tin, 10 per cent.; nickel, 3 per cent.; and zinc, 2 per cent. Monel metal has proved very successful for seats and plungers that are liable to wire-draw.

In passing, it may be as well to draw attention to the importance of good cores for the class of work under consideration; for a bad core, while only costing, perhaps, a very trifle less than a really good one, may readily result in a spoiled casting. The core sand should be burnt sand, beach sand, or similar material, with no constituent that will give off excessive gas when the casting is poured.—"Foundry Trade Journal."

Explosion of a Gasometer at Ilkeston.—About half-past one on the afternoon of Monday last a gasometer containing a million feet of gas exploded with a terrific report at Ilkeston, Derbyshire, shaking the town like an earthquake. The gasometer was lifted and flung 30 yards away, the wall of the water seal in which the gasometer floated was blown away, when the contents swept into the streets with such force that a railway truck was carried 40 yards away. In the track of the torrent was a shop. The owner, with his wife, two children, and a servant girl, thinking an earthquake had occurred, rushed into the cellar for refuge. The water swept through the house, and as it poured down on them the family scrambled desperately up the steps. All escaped except the servant, who was swept back down the steps and drowned. The damage caused by the explosion was extensive, and the railway adjoining was blocked with débris. An employe at the gasworks was taken home suffering from shock, but the others escaped injury, and as the explosion occurred during the dinner hour few were on the premises. The cause of the accident is not clear. Air must in some way have found its entrance into the gasometer to render the contents explosive, and even then contact with a flame would be necessary for ignition. In all probability the matter will be made the subject of enquiry by the Home Office. The gasometer was erected four years ago. Next it was a smaller gasometer holding a quarter of a million feet. This was knocked on one side, but did not explode. The cost of the damage will, it is said, amount to at least £10,000.

INDUSTRIAL AND TRADE NOTES.

The Non-unionist Question in Mines.—On the 3rd inst. about 2,000 miners, chiefly in the Lilleshall Company's coalfield, refused to go down the pits so long as non-union men were employed.

The Crypto Electrical Company, of 159, Bermondsey Street, London, S.E., inform us that they have opened a branch office at 77, Victoria Street, Bristol, where they hold a large stock of their standard pattern dynamos, alternating current motors, transformers, engine sets, &c.

British Trade in 1911.—According to the Board of Trade returns, last year was a record in value for British trade. The total value of imported goods was £680,559,175, an increase of over two millions as compared with 1910. Exports amounted to £454,282,460, showing an increase of nearly 24 millions over the previous year. Adding imports and exports together, the total value of our overseas trade in 1911 is seen to reach the large sum of 1,134 millions sterling.

Strike of Pattern-makers.—On Saturday last the pattern-makers engaged in Coventry engineering shops, which include the Ordnance and motor factories, gave in their notices, on account of the employers having failed to accede to the demand for ½d. per hour advance. About 170 men are affected. The Coventry rate of wages is 42s. 9d. per week, and the rise asked for would bring the pay up to that of London.

Tube Industry to be Restarted at Dumbarton.—The tube mills of the Weldless Tubes Company, Ltd., at Dumbarton, are about to be restarted. A controlling interest in the concern has been secured by Messrs. Babcock & Wilcox, who own extensive boiler works at Renfrew, and this firm will, we understand, really direct operations. Their patent boiler is on the water tube principle, and in its making in the course of a year they consume a vast quantity of tubes.

The Amalgamated Society of Engineers.—The monthly Journal of the Amalgamated Society of Engineers refers with satisfaction to the growing membership, which is now 121,233. During the year it has steadily increased, and in four of the months the increases have been over 1,000 per month. Trade also continues highly satisfactory, and there has been a further decrease in the number of members drawing unemployed benefit.

A Big Torpedo Firing Gear Order for Birmingham.—The largest order ever received in Birmingham for torpedo firing gear has just been placed by the Admiralty. It is for 150 sets, and will find employment for a large number of men for a considerable time to come. Great urgency is insisted upon. It is also stated that a Rugby firm has received an order from the New South Wales Government Railways for three 7,000 kw. turbines and one 5,000 kw. turbine, together with surface condensing plant.

A New Irish Railway.—Cork City Junction Railway was opened on New Year's Day. It is the undertaking of the Great Western Railway of England, which company, by building a bridge over the north and south branches of the River Lee, connected the Great Southern and Western systems with the Cork, Bandon, and South Coast Railway. This system controls the railway service of the south-west of Ireland as far as Bantry. Thus the Great Western Railway now has direct connection between Paddington and Bantry.

Electrical Extensions at Niagara Falls.—At a recent meeting of the Toronto Power Company, it was provisionally decided to devote the sum of £600,000 to extensions of the company's system at Niagara, whereby, in addition to the three 8,500 kw. units now being erected in the power station at Niagara Falls, four others will be installed, bringing the total to 11 units, capable of generating 125,000 h.p. It is also proposed to erect another transmission line between Niagara and Toronto for a voltage of 85,000.

Mineral Production in India.—A report recently issued by the Geological Survey of India shows that during 1910 minerals to the value of £7,700,154 were raised in that country, as compared with £7,687,847 for the previous year. The first position is occupied by coal, of which last year 12,047,413 tons, valued at £2,455,544, were produced. Gold is second with 573,120ozs. and £2,202,486, followed by manganese, 800,907 tons and £849,455, and petroleum with 214,829,647 gallons, £835,927. The remaining products of importance include mica £177,152, and lead £163,022.

The Ironfounders' Trade and the Insurance Act.—A conference of trade unionists connected with the ironfounding industry was held in Manchester last Saturday to consider the Insurance Act. There was a discussion as to the steps to be taken for the setting up of an approved society for the whole of the ironfounding trade. It was generally agreed that it was desirable that the whole of the unions should, if possible, become one approved society. A sub committee was appointed to draft a scheme for submission to the respective Executives.

Fire and Explosions at Leeds Oilworks.—At Leeds on Saturday night the oilworks of Messrs. Hess & Bros. in Kirkstall Road were almost totally destroyed by fire, the damage being estimated by the firm at between £30,000 and £40,000. There were six huge tanks of oil on the premises, one containing 160,000 gallons, another 80,000 gallons, and four smaller ones nearly 300,000 gallons. These exploded one after another. Three firemen were injured by a part of the burning building falling behind them on some casks of oil, which then exploded.

Wages of Marine Engineers.—The Journal of the Marine Engineers' Association for January states that negotiations are being carried on with the Shipping Federation regarding an increase of wages, and that a deputation will shortly meet to discuss the question with the shipowners. The report of the Glasgow Branch states that considerable advances were granted during the past year, but it is added that the increases allowed in some cases were so paltry that the branch could not consider the terms as equitable. The report states that unless the Federation of Shipowners grant more generous remuneration trouble will ensue.

Record Export of Coal.—The Board of Trade returns, just issued, show that the exports of coal from the United Kingdom for the past year were a record in volume. The coal exported was 64,599,000 tons, and, adding the coke and the manufactured fuel, the total directly exported was 67,276,000 tons, an increase of 2,609,000 tons over that for 1910, and 1,500,000 tons above the previous record export. There were also 19,264,000 tons of coal sent out of the Kingdom as bunker coal for steamers in the foreign trade, so that the quantity of fuel sent out of the kingdom as exports and bunkers was above 86,500,000 tons. France, Italy, and Germany are our largest customers for coal.

Thames Ironworks.—A mass meeting of employés of the Thames Ironworks was held on Friday to decide on the Admiralty's question as to whether the men were willing to accept a 53-hour week, and so secure the order for the building of two cruisers, or adhere to the present 48-hour week system. Mr. D. H. Ryder, a member of the Thames Ironworks, presided, the men's reply being left solely to their own decision, the trade union leaders taking no part. The following resolution was carried by an overwhelming majority: "That this mass meeting of the employés of the Thames Ironworks repudiates the authority of the person calling this meeting, and strongly condemns the method of balloting the men, and decides that in future all negotiations be conducted through the responsible officials of our trade unions.

Scottish Iron Production.—The Scottish Ironmasters' Association has issued the official returns of the trade for the past year. The production of pig iron was 1,401,799 tons, showing a decrease of 12,662 tons compared with the preceding year. The consumption amounted to 1,099,956 tons, being 45,070 tons of an increase. The quantity used in foundries fell off by 17,576 tons, but in malleable iron and steel work there was an increased consumption amounting to 62,646 tons. Foreign exports were 146,513 tons, a decrease of 1,244 tons. The quantity shipped coastwise was 159,005 tons, an increase of 9,390 tons. There was sent by rail to England 6,623 tons, an increase of 894 tons. The stocks in Connal's stores are 1,000 tons and in makers' private stores 320,987 tons, showing a decrease in stocks of 10,298 tons.

The Appointment of Factory Inspectors.—In a recent speech, Mr. Arthur Henderson, M.P., in referring to the appointment of inspectors under the Factory Acts, said that, for the most part, they were appointed from the wrong classes. The examination tests were so high that it was very seldom that a practical man had the benefit of the necessary education to enable him to pass the very severe theoretical tests to which he might be admitted. What was the result? They got men properly qualified from a theoretical standpoint sometimes under the Factory Acts. They got men from the universities, but, however qualified they might be who had passed through the universities, if they had failed to receive part of their training in the actual school of experience, they would have limitations that would lead to manifest inability to administer the law in the immediate interest of the workers.

Foreign Contracts for a Darlington Firm.—In connection with the projected extension of the Rio Grande do Norde Central Railway of Brazil, we are informed that the tender submitted by the Cleveland Bridge and Engineering Company, Ltd., of Darlington, for the construction of a new steel viaduct to carry the railway over a river at a point five miles distant from the port of Natal, has now been accepted in preference to other tenders submitted from North America and Germany. The bridge will consist of 10 spans, each 50 metres in length, and the piers will be carried on single cylinders, taken down by means of compressed air to an average depth of 20 metres below low water level. There will be footways for pedestrian traffic carried upon cantilevers outside the main girders. The value of this contract exceeds £100,000, and the work is to be completed within two

years from date. A further contract has also been awarded to the same firm for the construction by means of screw piling of a new wharf at the harbour of Natal, the seaport capital of the province of the Rio Grande do Norde, Brazil.

Messrs. Musgrave & Sons, Bolton.—The second meeting of creditors of Messrs. John Musgrave & Sons, Ltd., engineers, of Bolton, was held in that town last week, and was attended by about 150 creditors, and the following official statement was made at the close of the meeting: "Mr. Harold Mather, of the firm of Mather & Kay, chartered accountants, the voluntary liquidator, presided. He explained that the company was formed in 1897, and up to the last three years had made profits, but a season of bad trade had then set in, and during the last two years and five months the company had made very heavy losses. The total assets as a going concern, shown on the balance sheet (exclusive of uncalled capital), as at December 8th, 1911, showed a substantial surplus over all liabilities. The creditors present agreed unanimously to continue Mr. Mather as liquidator. The receiver and manager (Mr. Arthur Kirkham) appointed by the Court on behalf of the debenture holders, is still in possession of the business and assets of the company, and it was stated by the liquidator that he proposed to confer with the receiver, and to endeavour at an early date to formulate a scheme of reconstruction for the consideration of all concerned."

Leeds Engineering Works.—A rather black picture of the prospects of Leeds as an engineering centre was drawn in some evidence given at Leeds in a rating appeal case by Mr. John McLaren, a leading engineer of that city. Mr. McLaren said Leeds was not holding its position in the engineering world as a manufacturing centre. Serious burdens were placed on manufacturing premises by the rating, and another reason was that Leeds was very badly situated with regard to shipment. The bulk of engineering work was done for shipment to foreign countries, and they had to ship at Hull or Liverpool at a cost of 11s. to 12s. a ton, as against firms on the seaboard. Mr. McLaren added that locomotive firms in Leeds had to compete with a number of the biggest firms in Glasgow, which were close to the shipping, and had got no machinery rating. During his business experience he had known 34 large engineering works closed in Leeds. Leeds used to share with Manchester the tool-making trade, but now there were few firms in Leeds carrying on this trade. Firms had settled in Keighley, Halifax, Coventry, Birmingham, and Newcastle, and Leeds was given a wide berth.

Wages of Post-office Engineers. — The Postmaster-General has announced that the Treasury has sanctioned a revision of the engineering department of the Post Office. The future classification and rates of pay are to be as follow: Superintending engineers and staff engineers—£520, by £20 to £700; London allowance, £50. Assistant superintending engineers and assistant staff engineers—£420, by £20 to £500; London allowance, £40. Executive engineers—£315, by £15 to £405; London allowance, £30. Assistant engineers—£150, by £15 to £300; London allowance, £20. Chief inspectors—£150, by £10 to £200; London allowance, £20. Senior inspectors—London, 57s., by 2s. to 65s.; provinces, 52s., by 2s. to 60s. Inspectors—London, 30s., by 1s. 6d. to 55s.; provinces, 30s., by 1s. 6d. to 48s. Skilled workmen—First class (established), London, 39s., by 1s. 6d. to 47s.; provinces, 37s., by 1s. 6d. to 45s.; second class (established), London, 26s., by 1s. 6d. to 38s.; provinces, 24s., by 1s. 6d. to 36s. Skilled workmen (unestablished) are to be paid at the rate of 6½d. to 7¾d. per hour in London and 5d. to 7d. per hour in the provinces.

The Shipbuilding Industry. — From the returns compiled by Lloyd's Register of Shipping, it appears that, excluding warships, there were 483 vessels, of 1,519,052 tons gross, under construction in the United Kingdom at the close of the quarter ended December 31st, 1911. The tonnage now under construction is about 73,000 tons more than that which was in hand at the end of last quarter, and exceeds by 388,000 tons the tonnage building in December, 1910. The present figures are the highest ever recorded in the society's quarterly returns. There are nine warships, of 61,000 tons displacement, under construction in the Royal Dockyards—one battleship at Devonport and one at Portsmouth, one protected cruiser at Chatham, two third class cruisers at Pembroke, and four submarines at Chatham. In the various private yards the number now building is 50, with a displacement of 231,165 tons, 30 of these being torpedo boat destroyers, eight submarines, four battleships, four armoured cruisers, and four protected cruisers. In addition, eight "foreign or not stated" warships are also being built in private yards in this country, the tonnage of which amounts to 113,200. These are accounted for as follows: Three battleships, one armoured cruiser, two scouts, and two torpedo boat destroyers.

The Strike at Crossley's Works, Openshaw. — The engineers' strike at the Openshaw works of Messrs. Crossley Bros., Ltd., of Manchester, still continues, and no definite step has been taken on either side to bring the parties to the dispute together. The usual monthly meeting of the Manchester Engineering Employers' Association was held recently, but no communication affecting the matter was published. On the outbreak of the strike the men were informed that a discussion of the grievances could not take place until they had returned to work, and it was pointed out that their action was a violation of their own agreements. The strike is not supported by the men's union, which advised them to return to work, and last week-end a ballot was taken by the Strike Committee to decide whether this advice should be taken. In the ballot a majority of 219 were in favour of continuing the strike. At a meeting held on the 2nd inst., after the declaration of this result, the men unanimously decided to remain out. Between 600 and 700 skilled men are directly involved in the dispute, and, in addition, a certain number of labourers have been thrown out of work by the action of the journeymen. The moulding and pattern-making departments and the smithy at the works are not affected.

Machine Tool and Engineering Association, Ltd. — In submitting their first annual report, the Association state that since the statutory meeting on March 29th, 43 additional firms have joined the Association, bringing the total membership up to 80. The number of founder's shares that have been subscribed is 1,499, which at 5s. each gives a total paid-up capital of £374. 15s., as compared with 671 shares and a total paid capital of £167. 15s. referred to in the last report. The directors have appointed a paid secretary to look after the interests of the Association, and also their interests in the Machine Tool and Engineering Exhibition, which is being held next October, and have transferred the registered offices of the company to 104, High Holborn. The result has been as anticipated. During the year several members have applied to the Association for permission to exhibit at various exhibitions, and permission has been given or refused according to the circumstances of each case. The Home Office has also been in direct communication with the Association with respect to the question of adequately guarding gear wheels of machines. The Home Office point out that foreign machine tool manufacturers supply their machines adequately guarded, and that the cost of doing so at the time of manufacture is a relatively small item as compared with the subsequent cost of conversion. The Home Office has stated that in many cases British firms have lost several orders owing to the want of having adequately guarded gear wheels. A representative of the Home Office is calling upon all the firms in the trade, and the directors strongly recommend all members of the Association to act upon the suggestions of the Home Office, as they believe it would be of considerable advantage to the trade. With reference to the Machine Tool Exhibition, which is being held next October at Olympia, full particulars of which are now in the hands of the members, the directors state that the prospects are satisfactory, and the committee has taken steps to arrange for a supply of electric power, steam, and compressed air for the purpose of operating the exhibits.

Bonuses for Apprentices. — At the Neptune Offices of Messrs. Swan, Hunter, & Wigham Richardson, Ltd., the apprentices of the engine and boiler works, who have shown perseverance and ability in their work and studies during the past year, have been presented with the bonuses awarded by the firm, as encouragement to take an increasing interest in their work, with a view to their acquitting themselves well in their future career. The presentation was made by Mr. Geo. Vardy, the engine works manager, who, in the course of his remarks, made special reference to the time-keeping of the apprentices, and said it was very gratifying to find that, since the introduction of the scheme, the time-keeping had steadily improved year by year, and that now it had practically reached high-water mark. Out of the total apprentices in the engine works, 90 per cent. had, on time-keeping, qualified for a bonus, having lost less than 2 per cent. of time during the whole of the 12 months, and, during the same period, 13 apprentices had not lost any time whatever.

Chain Drives: Revocation of Patent.—Some interesting questions in patent law and practice were involved in a case which recently came before Mr. Justice Parker. The patent in question was one (No. 27147 of 1910) granted to Mr. J. C. Merryweather for improvements in automobiles carrying pumps, and the alleged invention appears to have consisted in driving the pump by means of a chain. Messrs. Hans Renold, Ltd., who are manufacturers of driving chains, applied to have this patent revoked. In their view the mere substitution of chain driving for some other method of driving, such as by belt or spur gearing, in connection with any particular class of machines was not proper subject matter for a patent. It was a substitution already made in connection with many different machines, and one which might hereafter be made in connection with many others. To grant patents in such cases would hamper the development of the chain-making industry. They accordingly petitioned for the

revocation of the patent on the ground of want of novelty, prior publication and use, and that the alleged invention was not a proper subject matter for a patent. When the case came on the patentee consented to the patent being revoked, but in connection with the question of costs, raised an objection that the petitioners had given no notice to him of their intention before commencing proceedings. If they had done so, then he contended he might have surrendered the patent and saved some expense. The judge, however, allowed the costs of the petition, remarking that it was doing a kind of public wrong to maintain a patent on the rolls when the patent was void. This case illustrates the fact that it is too easy in this country to obtain patents which cannot be sustained, but which, while they are in existence, must operate as a check upon legitimate industry.

Shipyard Discharge Note Disputes.—An incident which may lead to a big strike of shipyard employés began on the 3rd inst. at the Wear shipyard of Messrs. Austin & Sons, Sunderland. The Shipbuiding Employers' Federation has been endeavouring to establish a system of discharge notes for their employés, and when a number of men presented themselves at the Wear yard they were asked to produce the discharge notes given to them at the end of last year. The men's union having decided that with the beginning of this year the notes which the employers require whenever a man applies for a new job should be ignored, the request was not complied with. The refusal resulted in several of the men being told to leave the yard, and in consequence the other 200 or 300 men employed came out in sympathy. This opposition to the discharge note has since developed at several other yards. On Friday a great many men handed in their notices at the Elswick Works, Newcastle-on-Tyne, and Messrs. Dobson & Co., Walker-on-Tyne. The trouble threatens to extend also to the Clyde shipyards. It is stated that a circular has been issued to the Scottish members of the Boilermakers' Society, drawing attention to the following resolution agreed to by the Shipbuilding and Engineering Trades Federation: "That the shipbuilding and enginering employers be notified that we will advise our affiliated members to refuse to accept or tender discharge notes on and after January 1st." The point in dispute, viz., the question of discharge notes, is one upon which the entire Federation of Engineering and Shipbuilding Trade Unions have laid down a definite principle and promise united support. On the other hand, the Federation of Shipbuilding and Engineering Employers maintained that all men on discharge must take discharge notes, and on applying for employment must tender them. The situation was aggravated by the gradual breakdown of the machinery of negotiation between the employers and the unions. On Monday last, at a conference which was held at Carlisle between the Employers' Federation and the Trade Standing Committee, it transpired that there had been a misunderstanding on the matter in dispute, and, after a friendly discussion, the following arrangement was come to, and embodied in a signed memorandum, namely: "It is mutually agreed that a conference to discuss the question of discharge notes be held on Thursday, January 18th, between the Federation and Shipbuilding Trades' Agreement Standing Committee on condition that the work in the yards of Messrs. P. Austin & Son, Ltd. (Sunderland), Messrs. Sir James Lang & Sons, Ltd. (Sunderland), the Sunderland Shipbuilding Company, Ltd. (Sunderland), Messrs. W. Dobson & Co., Ltd. (Walker-on Tyne), Messrs. W. G. Armstrong, Whitworth and Co., Ltd. (Walker shipyard, Newcastle), and Messrs. Scott's Shipbuilding and Engineering Company, Ltd. (East Yard, Greenock), is at once resumed; that in these yards the use of discharge notes is suspended pending the conference; and that in all other yards the system continue in force as at present, and that a special arrangement be made to meet the case of any workman not in possession of a discharge note."

Engineering Lectures.—The engineering department of the Manchester University have arranged a special course of four lectures. Two will be delivered on January 18th and 25th by Sir William H. White, K.C.B., F.R.S., &c., on "Experimental Research and Engineering Practice"; three by T. de Courcy Meade, M.Inst.C.E., on "Modern Systems of Town Drainage," on February 1st, 8th, and March 7th; one on "The Rating and Power of Internal-combustion Engines," by Dugald Clerk, F.R.S., M.Inst.C.E., on February 15th; and two on "Centrifugal Pumps," by E. Hopkinson, M.A., D.Sc., M.Inst.C.E., on February 22nd and 29th. The lectures will be held in the Engineering Department, and a fee of one guinea will be charged for the eight lectures. Engineering firms may obtain tickets for their staff or pupils at half-a-guinea, provided application is made to the registrar for not less than six tickets.

CORRESPONDENCE.

Balancing of Locomotives.

To the Editor of the "Mechanical Engineer."

Sir,—Your contributor, Mr. James Clayton, writes stating the fact that "the centrifugal effect is the same whatever its (the balance weight's) shape," and at the same time makes it quite evident he either does not believe or does not understand his own statement by writing "the 'blow' or 'shock' is applied more gradually to the rail by spreading the weight round the wheel, in crescent form, than would be the case if the same weight were concentrated at its centre of gravity," which is sheer nonsense. No weight ever can be concentrated at its centre of gravity. The centre of gravity is a geometrical point having position without magnitude, but a weight may be distributed about or around its centre of gravity in any form circumstances or the designer dictates. The balancing moment is the weight in pounds multiplied by the distance of its centre of gravity from the centre at which equilibrium is desired to be established. The only argument Mr. Clayton has to offer in support of his absurd ideas is that locomotive designers use crescent-shaped balance weights, but at once shows he does not know why they use them by writing, "It is not contended that by making the balance weight extend well round the wheel the amount of such weight can thereby be reduced," when as a matter of fact it is because a reduction of weight can be effected and a sounder steel casting obtained that crescent-shaped weights are used. In other words, a given weight spread in crescent form at the rim of a wheel will give a greater balancing moment than the same weight placed in sector form between three or four spokes of a wheel, which was the usual practice when wrought-iron welded wheels were in common use. I hope it is unnecessary to point out to Mr. Clayton that "hammer blow" and "shock to the rail" are merely descriptive terms for centrifugal effect, and not in any way the technical title of some mysterious force in diabolic alliance with prolate cycloids.—Yours truly,

Jas. Dunlop.

69, Armadale Street, Dennistoun, Glasgow,
January 6th, 1912.

Wireman Electrocuted.—At Crook, on the 8th inst., John Brett, wireman at Pease's Bowden Colliery, was electrocuted by picking up in a mistake a live wire.

Design of Oil-fired Open-hearth Furnaces.—As a result of a printer's error, the source of the paper on this subject, which appeared on page 5 of last week's issue, was omitted. The paper, it should have been stated, was presented at a meeting of the American Foundrymen's Association.

Trackless Trolley System for Aberdeen.—The Tramways Committee of the Aberdeen Town Council at a recent meeting decided to recommend the council to introduce a trackless trolley system of tramways in the Footdee district of the city. This system has been in operation for some time in Bradford, Leeds, and in several continental cities.

Speed Trials of the Cruiser "Lion."—The new battle-ship cruiser "Lion," which is the largest warship in commission, and also the longest cruiser in the world, maintained a speed of 29·7 knots in her eight hours' trial. The "Lion" left Plymouth on Monday morning last for her eight hours' full power trial, and concluded it at seven the same evening with perfectly satisfactory results. The contract horse power of 70,000 was maintained throughout by her turbine engines. Her designed speed was 28 knots. The log gave her a mean speed of 29·7 knots for the run. The maximum speed reached was 31·7 knots. So far the "Lion's" trials have given complete satisfaction. In her 24 hours' trial at three-quarter power her mean speed was 24½ knots.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1910.

Mill rolls. Davies. 21504.
Melting furnace. Stock. 21829.
Systems for supplying steam to feed water heaters and low pressure turbines. Morison. 26195.
Valves of internal combustion engines. Bowen & Richards. 26781.
Wrenches. Albrecht & Albrecht. 29041.
Air pumps. Quiggin. 29123.
Nut locks. Norlund. 29179.
Vacuum steam engines. Comstock. 29193.
Gear for converting rotary motion into reciprocating motion. Sheppard. 29195.
Coal ramming machines. Marks. 29277.
Friction clutches. Carter. 29330.
Supply of air and liquid fuel to rotary internal combustion engines. Beeby & Platts. 29351.
Driving gear for internal combustion engines. Rieseler & Derry. 29390.
Production of gaseous fuel. Southey. 29501.
Treatment of iron or steel for the prevention of oxidation or rust. Heathcote, and Rudge-Whitworth, Ltd. 29504.
Rotary radial cylinder pumps. Hele-Shaw & Martineau. 29554.
Nut locks. Morley. 29693.
Roller bearings. Cooper. 29702.
Method of and apparatus for igniting explosive mixtures. Hughes. 29719.
Cylinders of petrol engines. Bartlett. 29730.
Means for forming and governing the working charge of liquid fuel engines. Griffin. 29761.
Carburetters for internal combustion engines. Cheeseman and Florence. 29834.
Valve gear for internal combustion engines. Matthew, Perrot, and Rubury. 29947.
Friction clutches. Schneider. 30006.
Power operated percussive tools. Haddan. 30032.
Variable gear for road vehicles. Prestwich. 30168.

1911.

Furnace roofs. Hutchinson & Crowe. 19.
Valves and valve gear for the motors of feed pumps. MacLeod and Macfarlane. 190.
Method of and apparatus for reducing ores of volatile metals. Hughes. 570.
Water heater or steam generator. Lindskog. 942.
Ore concentrators. Marks. 1829.
Distributing valve gear for steam engines. Morley. 2350.
Steam boilers. Henning. 2886.
Device for stuffing boxes. Jellcock & Yardley. 3669.
Engine pistons. Neckarsulmer Fahrradwerke Akt. Ges. 4452.
Utilising exhaust steam. Wadagaki. 5151.
Vacuum augmenters. G. & J. Weir, Ltd., and Petermoller. 5210.
Vertical water tube boilers. Newton. 5698.
Gas burners for melting furnaces. Brayshaw. 5931.
Internal combustion turbine engine. Hebden. 6265.
Die heads or holders for screw cutting machines. Herbert and Vernon. 6316.
Boiler furnaces. Niblock. 6799.
Apparatus for indicating the speed of ships. Kempson & Morse. 7598.
Couplings with bayonet joints for pipes and tubes. Rudolph. 9145.
Lubricators. Griffin, and Warne, Wright, & Rowland, Ltd. 9225.
Furnaces for smelting metals. Wimmer. 10939.
Internal combustion engines having rotating sleeve valves. Harris, Gardiner & Grant. 11110.
Steam superheaters. Stirling Boiler Company, and Constantine. 13104.
Steam engines. James. 13898.
Machines for cutting coal. Hurd. 14371.
Treatment of the exhaust gases of internal combustion engines. Von [illegible]. 15195.
Mechanism for rotating the tool in boring hammers. [illegible] Metall Act. Ges. für Maschinen und Bergbau. [illegible]
Process for [illegible] steel castings. Gebhard. [illegible]
[illegible]. Reeves. [illegible]
Steam engines. [illegible]. [illegible]
Drilling [illegible]. Fischer. [illegible]
Safety valve for diving cylinders. [illegible]. [illegible]

Tube rolling mills. Koch. 17997.
Steam engines. Newkomm. 18091.
Fixing rails on permanent way. Henry. 18139.
Steam turbine. Lee. 18275.
Ore classifiers. Compagnie d'Entreprises de Lavage de Minerais. 18453.
Coal and rock drills. Davies. 19620.
Flywheels. Düll. 20059.
Electrical welding machines. British Insulated and Helsby Cables, Ltd., and Bucher. 21942.
Ore concentrators. Deister. 22892.
Automatic signals for railway vehicles. Siemens Bros. & Co. 23911.
Pumping apparatus. Aaron. 26658.

ELECTRICAL, 1910.

Electric heating apparatus. Berry. 21665.
Electric current regulating and controlling apparatus. Hirst and Brook. 29339.
Eddy current absorption brakes. Thomas. 29731.

1911.

Electric regulators. Leitner. 81.
Armatures for magneto-electric generators. Albion Motor Car Company, and Murray. 188.
Electric motor control systems. British Thomson Houston Company. 5993 and 6095.
Portable telephones. Fairweather. 6345.
Telephone transmitters. Turner. 8982.
Trolley wheels for electrically driven vehicles. Pintner. 10038.
Electric furnaces. Rochling'sche Eisen und Stahlwerke Ges., and Rodenhauser. 10231.
Spark gap devices for wireless telegraphic and telephonic apparatus. Bellini & Tosi. 10266.
Insulators for high tension electricity conductors. Franz Clouth, Rheinische Gummiwarenfabrik. 13676.
Method of and apparatus for regenerating burnt out carbon and metal filament electric lamps. Bloch. 16230.
Drum type controllers for the shunt control of electric motors. Allen, West, & Co., and Moggridge. 16870.
Furnaces for the production of metallic sodium by electrolysis. Scheitlin. 18804.
Boosting transformers and voltage regulators. Siemens Schuckert werke Ges. 18868.
Means for automatically controlling heat in electric heating apparatus. Nightingall. 19942.

METAL QUOTATIONS.

TUESDAY, JANUARY 9TH.

Aluminium ingot	63	per cwt.
,, wire, according to sizes, &c. ......from	102/-	,,
,, sheets ,, ,, ...,,	120/-	,,
Antimony .... £27 10 - to	£28/-	per ton
Brass, rolled	7¼d. per lb.	
,, tubes (brazed)	9⅞d.	,,
,, ,, (solid drawn)	8d.	,,
,, ,, wire	7¾d.	,,
Copper, Standard	£64 -/-	per ton
Iron, Cleveland	49/6	,,
,, Scotch	55/6	,,
Lead, English	£16/-/-	,,
,, Foreign soft	£15 13 9	,,
Mica in original cases, small	6d. to 2/-	per lb.
,, ,, ,, medium	2/6 to 4/-	,,
,, ,, ,, large	4/6 to 8/6	,,
Quicksilver	£8 -/-	per bottle.
Silver	25¾d. per oz.	
Spelter	£26/15/-	per ton.
Tin, block	£193 -/-	,,
Tin plates	13/6	,,
Zinc sheets (Silesian)	£30 10	,,
,, (Stettin; Vieille Montagne)	£30 15	,,

Fatality while Experimenting with Sodium Peroxide.—While F. G. Goddart, works manager at the Chiswick Soap Works, and his assistant, named Brown, were experimenting on New Year's morning with sodium peroxide in the manufacture of soap, the substance, which had been mixed with oil, took fire and exploded, and the men were so terribly burned that they subsequently died in the hospital. At the inquest held on Monday last, a chemist at the works said that, in his opinion, there was a gradual rise of temperature, owing to the presence of moisture in the drum in which the oil was being mixed with the sodium peroxide, until it reached ignition point, when it suddenly ignited. A verdict of "Accidental death" was returned.

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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

Contracts for Engineering Work.

In his presidential address to the Manchester Association of Engineers on Saturday last, Mr. Michael Longridge departed from the hackneyed lines which usually characterise deliveries of this kind and which partake either of the nature of historical reviews or of disquisitions on some particular field of which the exponent has special experience. The subject of his discourse was the nature of the relationship between purchasers, contractors, and consulting engineers, and the problems that arise out of engineering work as defined and controlled by specifications. As the chief engineer of one of the leading boiler insurance companies, he is frequently required to act as adviser or arbitrator in power schemes and is thus brought into intimate and not always pleasant contact with the questions and differences that arise when personal interests arising out of written specifications and verbal arrangements come into conflict. During latter years there has been a tendency for these differences to become more serious, owing to advances in engineering science, changes in business methods arising out of the Limited Liability Act whereby boards of directors or other authorities have been largely substituted for private individuals. It is time there was a little plain speaking, for some of the methods at present pursued are very unsatisfactory. If Mr. Longridge's suggestions do not meet with entire approval they will at anyrate prove advantageous by drawing attention to some generally-admitted evils, and by their discussion and ventilation it is to be trusted tend to their abatement. It is too much of course to expect the entire removal of differences where commercial bargains are concerned and interests and duties sometimes come into antagonism. Not long ago, when mills and works were largely owned by individuals and the engineer was called in, to use Mr. Longridge's simile, like the "family doctor or the family solicitor," his advice was accepted, his bill paid, and clients were usually content. Much good work was doubtless done, but first cost

was not considered as it is now and the skill required to turn out a good job less, but, on the other other hand, engineers free from independent criticism were liable to become opinionated and their designs and methods antiquated. With the supercession of private purchasers by municipal committees and joint stock companies a different relationship has sprung up. We have keener competition and keener criticism, with their attendant advantages and disadvantages. Work is put out to tender and has to be specified in more or less detail for the protection of purchaser and contractor, and it is out of this method of fixing engineering work that friction and disputes so often arise, owing to its varied character. The drafting of a clear, complete, and practical specification is not an easy matter. It requires both theoretical and practical knowledge, besides ability, to express given requirements in clear language. Careless drafting may lead to misunderstanding, even with the best intentions, and is easily aggravated when interpretation is dictated by unregulated opposing interests. Under present conditions it is hardly surprising that plans and specifications are often of an indefinite character and replete with vague expressions, especially if the contractor feels, as he often has a justification for doing, that the order will probably go to the lowest tender, irrespective of the real value of the work, and that efforts will be made in any case to squeeze the last drop out of him. Cheap work is no doubt often secured in this way, but it is just as often "nasty," while the contractor to recoup himself for what not infrequently proves a loss on the job, strains the specification so as to secure as many extras as possible in his final bill. A practice sometimes followed by purchasers is to send competing plans and tenders to a consulting engineer, with a request for an opinion as to which is most advantageous. It is easy to give such an opinion, but this does not necessarily mean that the one so selected is the best from an engineering point of view, or best calculated to meet the requirements of the purchasers, and the consulting engineer if he is wise will, as Mr Longridge states, "explain the difficulty, suggest that he should go into the matter himself, decide what ought to be done, and draw up his own specification for the work, with provision for inspection during construction." This course is much fairer to contractors, though it is not free from difficulties, and may inflict unfairness upon them if the consulting engineer happens to have a lot of "fads" and insists upon them, for they may entail special expense in tools or manufacture. Sometimes the question of inspection is only raised by the purchaser after the order is placed, and this often leads to soreness, for such inspection to be real entails a certain amount of expense through arrest of work in the shops, and if not provided for in the tender is unfair, however beneficial inspection itself may be when rightly conducted. Under such conditions it is undoubtedly the duty of the consulting engineer to secure to the contractor the recompense which is his due, as well as in the other cases where his authority has to be exercised in making alterations after contracts are fixed. It is unreasonable, when purchasers have accepted tenders in open competition, to strain vague phrases to their extreme limits under cover of an inspecting authority, and the latter should not permit themselves to be made party to such conduct. The interpretation of a specification should bear an equitable relationship to the tender price when it has not been drafted by an inspecting authority. These illustrations do not exhaust all the ways in which difficulties may arise. Others are enumerated in Mr. Longridge's address, which we reproduce on another page, and which we would strongly commend to the perusal of all concerned in the placing or executing of orders for engineering work. Mr. Longridge suggests that some of the difficulties which arise from defaults of contractors might be obviated by a more generous publication of the details of construction, since cost of manufacture and efficiency of work often depend upon them, and opinions as to their relative merits and influence on cost could be duly considered by purchaser and consultant before a bargain was struck. But it is not difficult to see that this would not meet every case. The moral of the difficulties outlined and troubles experienced in daily practice is that purchasers of engineering plant, if they have not actual knowledge or full confidence in firms to whom they entrust work, should secure the services of an engineer of repute to advise as to their needs, specify their requirements, and supervise the construction of the work, while, on the other hand, contractors before binding themselves should have a clear understanding as to what the specification covers and entails.

Erosion of High-speed Screw Propellers.

IN a recent issue (December 22nd, page 761, ante) we referred to the vagaries of corrosion as manifested in steam boilers, but its peculiar action is not confined to them alone. The wasting of the propeller blades of steamships has furnished many analogous problems to engineers, chemists, and metallurgists. Experience has in some cases evolved solutions, but their tentative character has not infrequently been proved by the recrudescence of troubles with some slight alteration of working conditions. A striking illustration of this is afforded by some extraordinary corrosion to the manganese propellers of the "Lusitania" and "Mauretania." Engineers had come to regard this material as practically immune from the corosion which used to be so common with steel propellers in seagoing ships. There was nothing to account for the trouble on the Cunarders beyond the fact that in these ships the propellers were driven by turbines, and operated at much higher speeds than is the case with reciprocating engines. The matter was serious, for manganese-bronze is a costly alloy, and the renewing of propellers means serious loss of time and expense, while experience showed that unless some remedy could be found it would be necessary every few months. Under these circumstances the Manganese Bronze and Brass Company, Ltd., of Caxton House, Westminster, were commissioned to make an investigation of the cause of the trouble, and if possible provide a cure. The last issue of "Engineering" gives an interesting and instructive article describing the investigation, and also the solution, which it is pleasant to record has been found, by Dr. O. Silberrad, to whom the research was entrusted. The account given by our contemporary shows how apparently inexplicable phenomena may be unravelled by painstaking research. The intense and deep-seated character of the erosion suggested that galvanic action was probably the active agent, but careful investigation of the electrical condition of the ship showed the differences of potential to be too minute to account for the rapid action observed; while further, that the corrosion, unlike that usually noticed in still water, where the zinc dissolves more rapidly and leaves a spongy mass richer in copper, was non-selective as between the copper and the zinc, though it was selective as between the eutectic and the "mixed crystals" which formed the main body of the alloy. In other words, it was the eutectic and not the zinc constituent which dissolved. This furnished a clue to the mystery, and suggested that the relative motion of the surfaces of the water and the alloy exerted a strong influence on

the way in which the alloy was eroded. From this point the investigation resolved itself into ascertaining, firstly, what influence water velocity had upon erosion, and secondly, the discovery of some alloy free from eutectic which would possess the necessary tenacity and elasticity. Metallurgically the problem was to combine the required physical properties with a tenacity of 38 to 40 tons per square inch. Had a tenacity of 15 tons been adequate the question would have presented no difficulty. An extensive series of experiments were then made with possible alloys, which were subjected to the eroding action of water escaping under a head of three tons per square inch, the time required to produce a standard loss by erosion furnishing a measure of the resistance of the alloy to erosion. Without going into the details of these experiments, it may be stated that they led eventually to the evolution of an alloy which has fully satisfied the requirements. This alloy, termed "Turbadium," is equal in strength to manganese bronze, having a tenacity of 38 to 40 tons, an elastic limit of 18 to 19 tons, and an elongation of 15 per cent. on 2in. — while its resistance to erosion has been demonstrated not only by the experimental tests, in which it showed a resistance five times as great as ordinary high-tension bronze, but by six months' actual service on the "Mauretania." The remarkable ability of the alloy to resist propeller erosion suggests that it may find other applications in places where, owing to local conformation, negative pressure exists, and causes broken condition of the stream of fluid passing over them. "Dr. Silberrad holds that erosion proper is a purely mechanical effect, though it is sometimes aggravated by chemical influences, but in all cases differs from ordinary corrosion in that the products of the reaction, instead of forming as they do sometimes a protective coating to the metal attacked are carried away by the rush of the fluid, leaving a fresh surface exposed to attack," and the behaviour of the wing propellers of the "Lusitania" rather supports this view. They were not so closely situated to the hull as those of the "Mauretania," nor were they corroded so severely. It had been suggested that this was due in part to the chemical action of the air which in the latter case was carried down with the propellers in greater volume; but Dr. Silberrad suggests "it is more likely due to the increased rub of the broken water, since air at anything like ordinary temperatures is practically without effect on manganese bronze in the presence or absence of water, salt or fresh," and this is supported by the fact that it is at the parts where cavitation is most likely to have occurred such wasting as was found took place. The investigation, it will be seen, has not only provided a solution to a particular trouble of a serious kind, but shed considerable light on a phenomena hitherto little understood.

Standard Colours for Heating Pipe Systems.—Standard colours for pipe systems have been adopted by the Verein Deutsch Ingenieure, the Association of Miners in the Dortmun District, and the central Unions of German Heating Engineers, and of German Revision Engineers. Green is to indicate water; yellow, gas; blue, air; white, steam; black, tar; pink, lyes; pink with a red ring, acid; brown, oils; and grey, vacuum. A black ring or band indicates impurity; a red ring, danger; thus a green pipe with a black ring carries refuse water, a white pipe with a red ring carries superheated steam, a yellow pipe with a brown ring oil-gas, a yellow pipe with a blue ring producer gas, with a green ring water gas, &c. It is not proposed to paint the whole pipe, as this would in many cases be impracticable. What is proposed is to fix a label of sheet metal at suitable spots and intervals, indicating in addition the direction of flow and further particulars.

THE EFFECT OF SPEED ON ALTERNATING STRESSES.

THE effect of speed on alternating stresses has recently been much discussed in connection with the paper read at the Institution of Mechanical Engineers in October last (see "Mechanical Engineer," November 3rd, 1911, page 553). A further contribution to the subject was made at a recent meeting of the Royal Society, when a paper was read by Prof. B. Hopkinson, F.R.S. In the apparatus described the test piece ($\frac{1}{2}$in. diam. by 4in. long) is fixed vertically, the lower end being attached to heavy masses. The upper end of the piece carries a weight. This weight is attracted by an electro-magnet placed above it, and excited by alternating current. The pull thus applied varies periodically between zero and a maximum value, the frequency of the variation being twice that of the current. The test piece behaves as a spring, the lower end of which is held fixed while the upper end carries the weight, and is free to move in a vertical direction. The adjustments are such that the natural period of the vertical oscillations of this system is approximately equal to the period of the varying magnetic pull. This accordingly sets up large forced oscillations of its own period. By thus using the principle of resonance with a current-frequency of 60 per second the range of pull applied by the magnet may be magnified from 20 to 70 times, and the stress produced in the piece can readily be made to alternate between 20 tons per square inch tension and 20 tons per square inch compression. The number of complete cycles per minute is 7,200, and 1,000,000 reversals can be performed in $2\frac{1}{2}$ hours. The test piece is fitted with a simple form of optical extensometer whereby continuous observation can be kept of the change of length occurring in a cycle of stress. From the change of length the stress can be calculated if the piece is approximately perfectly elastic under the stress which is being applied. An independent estimate of the limits of stress can also be obtained by observing with a microscope the range of movement of the weight and calculating its acceleration from that range on the assumption that the motion is simple harmonic. These two methods of obtaining the stress were found to agree closely for the mild steel used in the experiments up to a range of stress of about 30 tons per square inch. Endurance tests made in the new machine on mild steel showed that the steel would stand at least 20,000,000 cycles of stress, covering a range of 29 tons per square inch. Comparative tests of the same steel made by Dr. Stanton at the National Physical Laboratory in a direct stress-testing machine giving about 1,110 reversals per minute showed that at this speed the probable life of the material under the same range of 29 tons per square inch would be less than 100,000 reversals. Similar comparisons with both higher and lower ranges of stress confirmed the conclusion that at the high speed of over 7,000 reversals per minute, the endurance is much greater than at 1,100 reversals per minute, both in the number of cycles and in the actual time required to produce fracture.

The Use of Cadmium for Tungsten Lamp Filaments.—One of the new uses for metallic cadmium is in the manufacture of tungsten electric lamp filaments. Tungsten itself cannot, says "The Brass World," be successfully made into the filament by the customary method employed with other metals, of melting, casting, and afterwards drawing into wire. The melting point is too high to allow this to be done. In order to produce the wire in a condition suitable for the filaments, however, an intermediate process is used. Tungsten, as obtained from its oxide, is always in the form of a heavy metallic powder. This powder is mixed with an alloy of cadmium, mercury, and bismuth in the following proportions: Cadmium 42 per cent., mercury 53 per cent., bismuth 5 per cent. This alloy is smooth and uniform, and when heated becomes plastic so that it may readily be impregnated with tungsten powder. The two are ground together in a mortar, so that an intimate mixture is produced. The amount of tungsten used is from 30 to 50 per cent. of the mixture. To obtain the wire an extrusion method is employed. The tungsten and alloy mixture is forced through a die and issues in the form of a wire. The wire is then heated to drive off the alloy, after which the temperature is increased to render the tungsten solid. This latter heating is carried out in a vacuum furnace in order to remove all of the foreign substances in the tungsten.

1,000 B.H.P. CRUDE OIL LOCOMOTIVE.

DUNLOP "ADIABATIC" "CLOSED-CIRCUIT" AIR TRANSMISSION SYSTEM.

To reduce the present coal bills of a railway by 40 per cent. seems rather a tall order, but that is what is proposed by the design of the crude oil locomotive illustrated in the accompanying drawings.

So far as it resembles the ordinary type of locomotive, it may be described as a similar-ended four-cylinder engine, with the cylinders placed two at either end. It is intended to do the work at present performed by the largest sizes of steam locomotives used on British railways. The engine, as shown, is complete, no tender being required, and being similar ended, it does not require to be turned at the end of a journey, the control apparatus being arranged in duplicate.

The cylinders, 15in. diam. by 26in. stroke, operate the six coupled wheels in such a manner that the reciprocating weights completely balance each other. This balance is brought about by the double cranks on the intermediate driving wheels. Balance weights will, of course, be required for such of the revolving weights as do not mutually balance. The driving wheels are 6ft. 7½in. diam., placed at 7ft. centres, the bogie wheels being 3ft. 4in. diam., also placed at 7ft. centres. From centres of driving wheels to centres of bogies is 10ft. 6in., and the total length over buffers is 49ft. 6in.

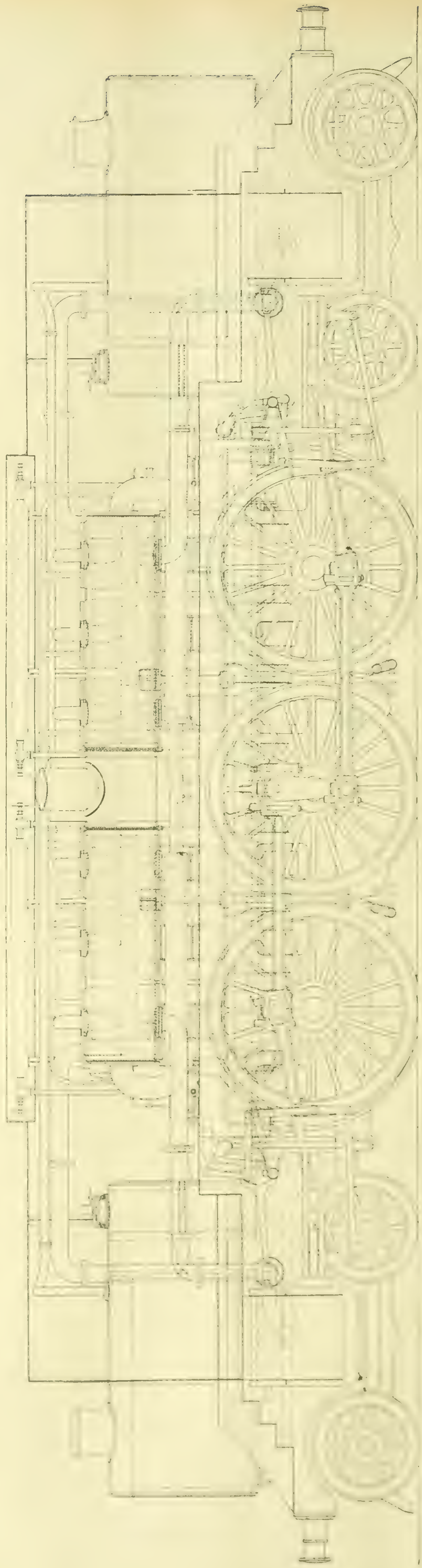
The cylinders are fitted with 9in. diam. piston valves, actuated by a radial reversing gear, the distinguishing feature of which is that the floating lever moves in a fixed path at all times, so that with equal laps and leads the port openings and cut-offs will be equal at either end of the cylinders for all grades of expansion, and for both directions of running. It will be noted only a very small proportion of the valve gear weight hangs on the valve spindles, so that no further guide is required for these than is provided by the front and back spindle bushings.

The brake gear is operated by two cylinders arranged front and back, with eight blocks on the six wheels, giving an equalised pressure on each wheel. The sand boxes are arranged front and back as usual, and fitted with air-operated sand traps.

Above the driving wheels, instead of the usual steam boiler, is placed a 6-cylinder single-acting 2-stroke cycle combined internal-combustion engine and air compressor. This engine operates with crude oil on the constant pressure combustion system, and has a small 2-stage air compressor at either end of its crank shaft for supplying air for the injection of the oil, for starting the main compressor, and for making up leakage from the "closed-circuit." The air is stored in bottles in the roof of the locomotive housing.

To form an "adiabatic" "closed circuit," the exhaust pipes of the locomotive cylinders are connected to the inlet branches of the air-compressor cylinders. The delivery branches of the air compressor cylinders are connected to two tubular air heaters forming part of the silencer, through which the exhaust gases from the internal-combustion cylinders pass to the atmosphere by way of the central chimney shown. The air heaters are connected by a double bend equalising pipe, and have pipes leading from them connected to the valve chests of the locomotive cylinders. There is no storage capacity in the circuit; all that is done is to make the capacity of the locomotive exhaust piping equal to the capacity of the air heaters and the pipes connected to the valve chests of the locomotive cylinders.

Above each of the bogies a double-cylindrical tank is carried, the longer portions being water tanks with open filling pipes shaped like the usual locomotive chimney. Cooling tubes are provided, and fans driven by chains from the ends of the internal combustion engine crank shaft draw air through these tubes, discharging it downward between the water tanks and the short length tanks, which are oil tanks. There is another oil tank placed between the halves of the internal combustion engine just behind the central chimney, the capacity of the three tanks being equal to seven hours supply at maximum power. The capacity of the water tanks

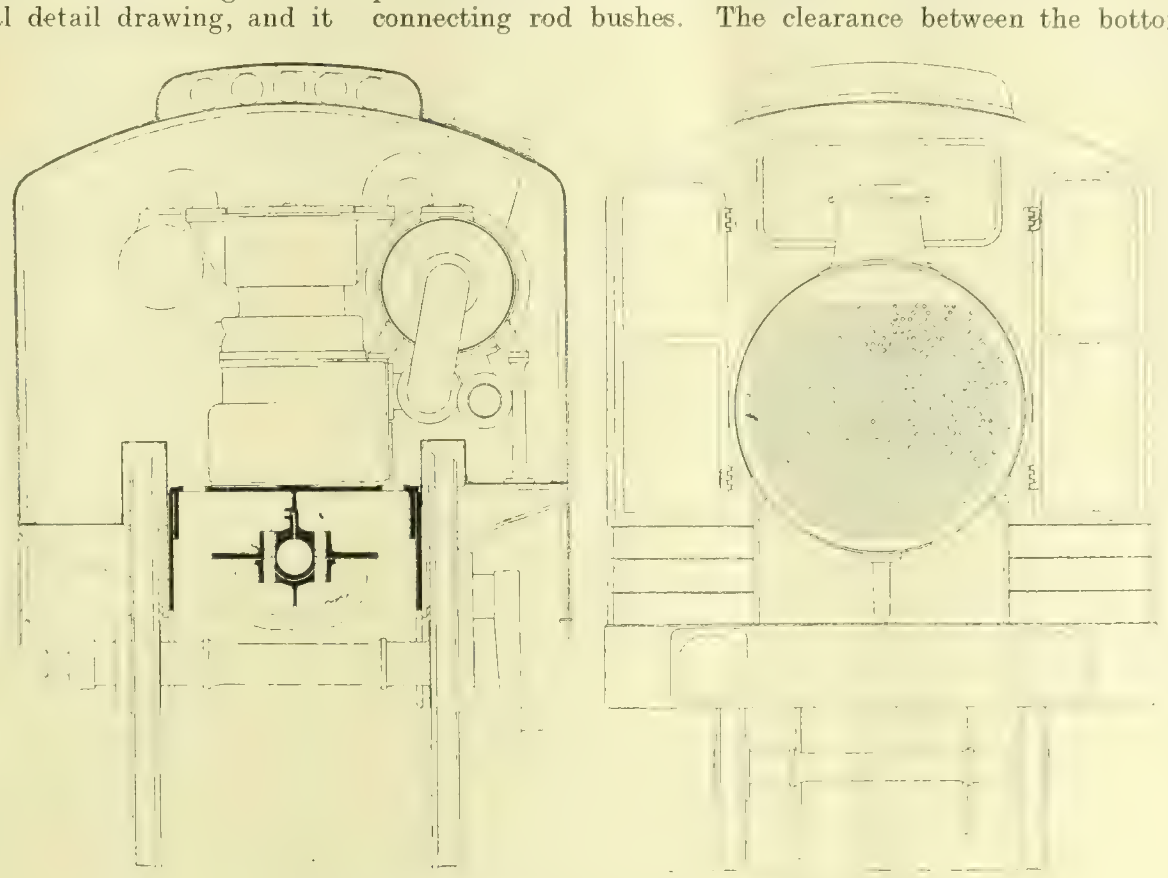


GENERAL ELEVATION, 1,000 B.H.P. "CLOSED-CIRCUIT" CRUDE OIL LOCOMOTIVE.

is such that without being cooled in any way there would be sufficient water for seven hours' working at maximum power, but as the cooling tube surface equals 3 sq. ft. per horse-power, the amount of water consumed will be trifling compared with the water consumption of a steam locomotive.

An interesting point in connection with the cooling system is that each tank cools the half of the internal-combustion engine nearest it, and discharges into the opposite tank, the contents of the tanks being in this way exchanged every 11 minutes. The object in arranging the cooling system in this way is to equalise temperatures independently of the direction in which the locomotive may be running. This equalisation of temperature will be effective also in the case of a fan breaking down. The water-circulating pumps are of the valveless rotary type, and driven by gear wheels from the ends of the crank shaft of the internal-combustion engine. The use of this type of pump ensures that water level variations due to working on inclines will be limited to each tank and not distributed over both tanks. Pumps of a similar type and similarly driven are used to operate the vacuum brake apparatus on the locomotive and on the train.

The construction of the internal-combustion engine air compressor is shown in the sectional detail drawing, and it may be noted is of the 3-port valveless type, with crank case compression. The lower port on the right is the air inlet port, the upper port being the exhaust port. The port on the left is the transfer port. The upper portion of the engine forms an air compressor with flat ring inlet valve and flat disc delivery valve. The air compressor diameter is 13½in., the combustion-cylinder diameter being 19in. The stroke is 12in., and the speed is 500 revs. per minute. The effective combustion-cylinder area is of course the annular area formed by the difference in the two diameters. The result of this is that this construction of engine has just twice the charging pump capacity an ordinary engine of this type has. It is well known that the ordinary crank case compression type of engine is comparatively inefficient owing to its limited charging pump capacity, and to the more or less direct path it provides between the transfer and exhaust ports, making the thorough scavenging of the cylinder practically impossible. In addition to having twice the charging pump capacity, this new construction of engine ensures thorough scavenging from the fact that the compressor piston (which acts as the deflector) extends the whole length of the combustion cylinder. The inlet and transfer ports are one-fourth the cylinder area, the exhaust port being one-fourth more than these ports in area.



Cross-section. End Elevation.

1.000 B.H.P. "Closed-circuit" Crude Oil Locomotive.

The air delivery valve is of special interest owing to the high speed of revolution. The valve seats on a loose cover plate with drilled holes, through which the air is discharged. From the plan view given, it will be seen the valve also has drilled holes, which register between the holes in the cover plate. By this means the valve is caused to discharge through the holes in addition to all round its edge, thus minimising the lift required for a given discharge area, and consequently minimising the inertia and momentum effects. The valve is ⅛in. thick, and its discharge area is one-fourth the cylinder area. The most important feature about the valve, however, is the fact that although merely a flat plate it constitutes the whole apparatus for controlling the output of the compressor. The valve stop, it may be noted, is a flat face with grooves formed on the top cover of the compressor. The grooves communicate with a hole drilled through the cover, this hole being connected to the inlet of the compressor by a pipe, with a cock or valve which can open or close the passage. If this cock is opened, then when the valve rises against its stop, it will be held there owing to the difference between the inlet and delivery pressures, and the delivery pressure following the compressor piston on its downstroke will prevent the inlet valve opening. In this way the output of the compressor is arrested until delivery pressure is again admitted to the grooves in the stop face.

The small 2-stage compressor valves are of the usual compressor type, the use of this type being possible in this case owing to the stroke being 6in. only.

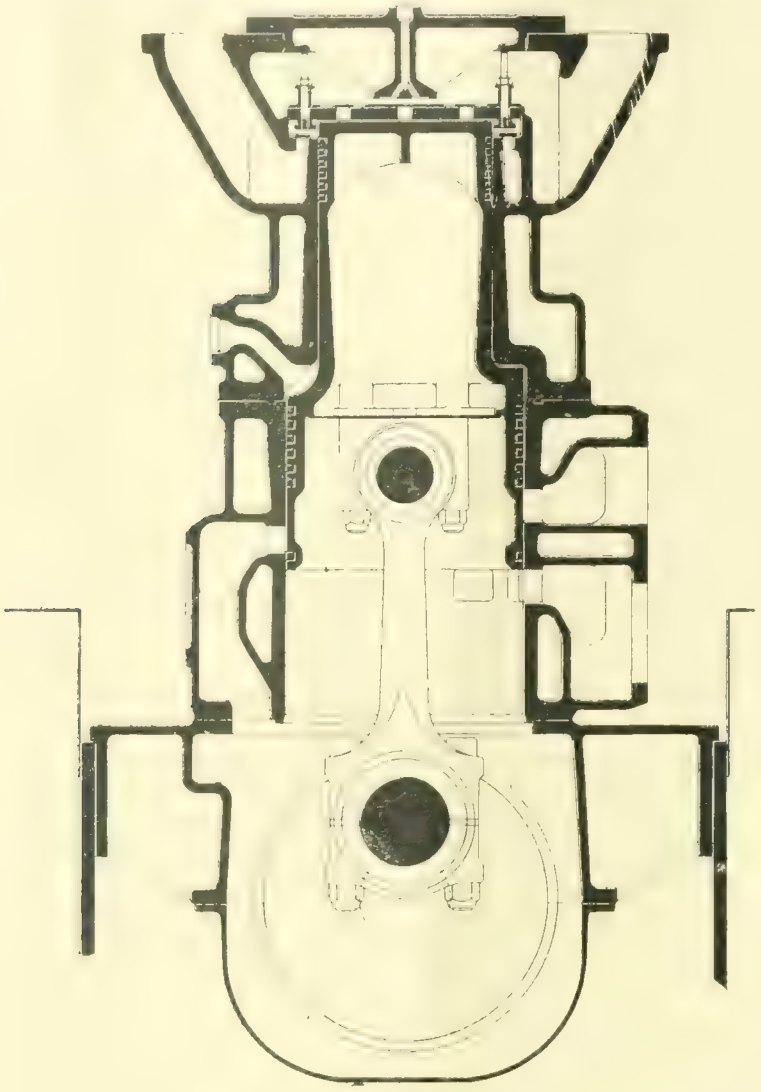
The combustion cylinders are fitted with oil-injection valves, air-starting valves, and oil pumps operated by a valve shaft on the left-hand side of the engine in the usual manner, and a governor is fitted to maintain a constant speed of revolution.

The crank case of the engine is a light steel casting, and the main bearing caps are formed with semi-circular flanges projecting beyond the radius of the crank webs, so that the bottom covers of the crank case may be moved into the dotted position shown when it is desired to examine or remove the connecting rod bushes. The clearance between the bottom of the crank case and the axle circle shown is the usual 2in. It will be seen that the whole of the working parts are easily accessible, and that unusually generous allowances of bearing surface have been provided throughout. Pumps worked by the valve shaft provide for the forced lubrication of the bearings.

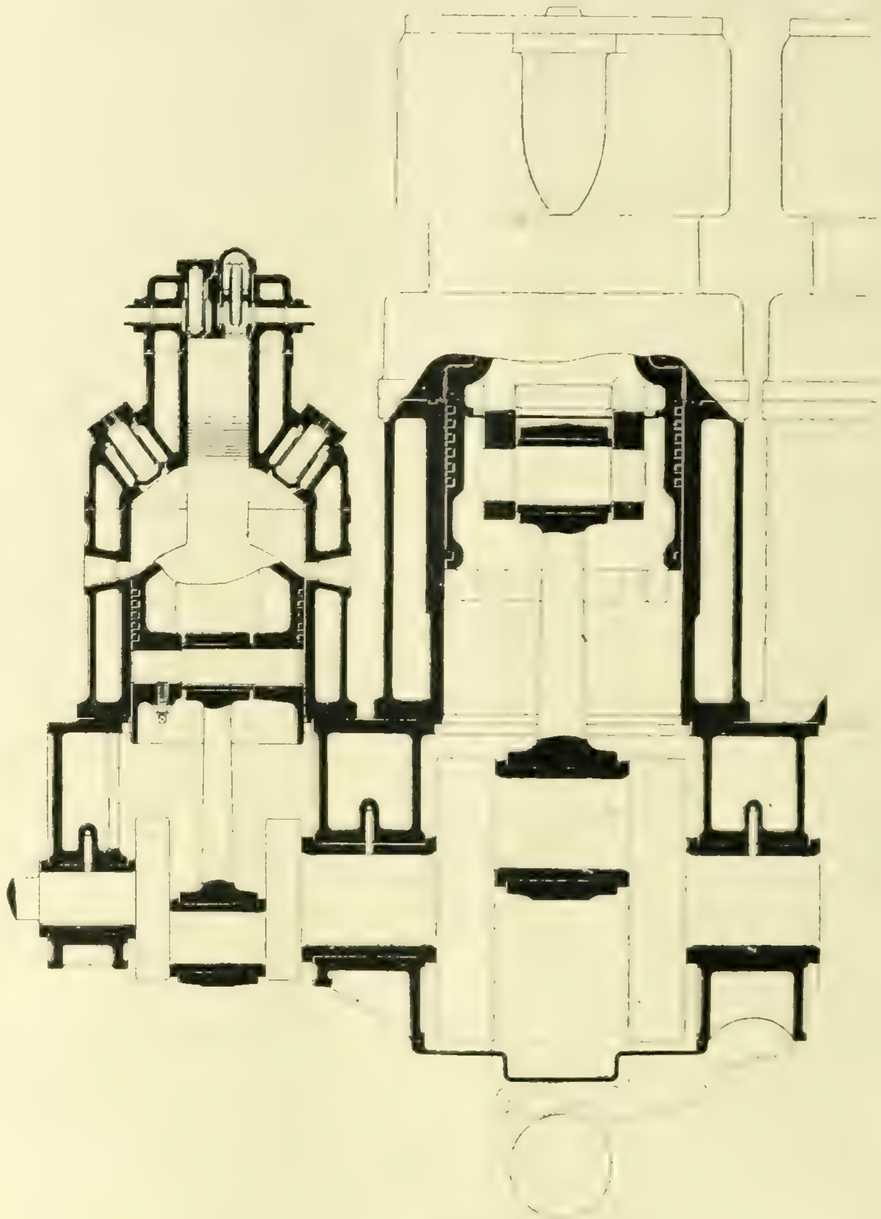
Before this locomotive can be started for the first time, the air-storage bottles in the roof of the engine housing are charged with air from an outside source, at a pressure of about 200lbs. per square inch above the maximum pressure of combustion. The main compressor is started by admitting this high-pressure air to the combustion ends of the cylinders in the usual manner.

The apparatus by which the locomotive is controlled is shown in diagrammatic form. The first is the apparatus by which the quantity and pressure of the air in the "closed-circuit" is maintained against leakage. This apparatus is quite automatic in its movements. When the main compressor is first started it draws air from the atmosphere through the usual anti-vacuum valves fitted on the locomotive cylinders, and discharges it to the delivery pipe until the pressure is such that acting on the underside of the piston below the non return valve of the apparatus, it lifts the valve and allows high-pressure air from the storage bottles to enter the main compresser inlet pipe by way of the branch

on the right. When this happens, the anti-vacuum valves close, and the charging of the "closed circuit" is completed by air from the storage bottles. The spring-loaded plunger on the left has two diameters exposing equal areas to the



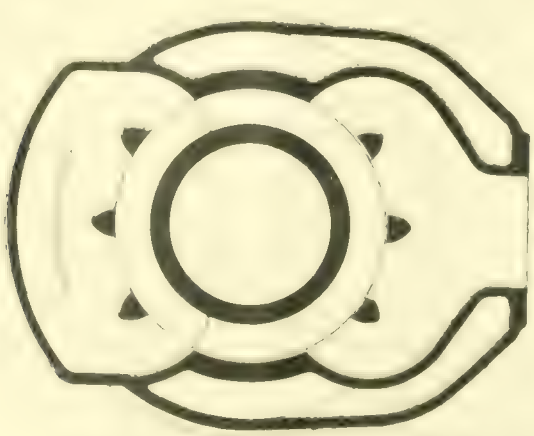
Cross-section.



Longitudinal Section.

1,000 B.H.P. 2-Stroke Cycle Crude Oil Air Compressor.

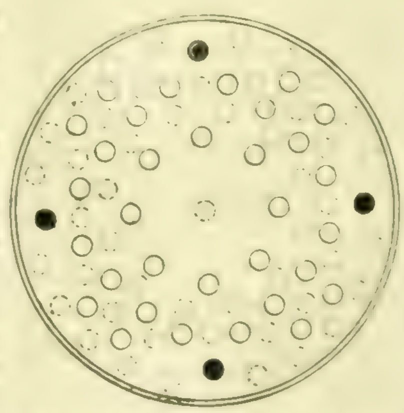
inlet and delivery pipe pressures. When the pressure in these pipes is 150lbs. per square inch, the plunger rises and cuts off communication between the delivery pipe and the underside of the piston, and at the same time, by means of the groove on the plunger, puts the piston into equilibrium. The non-return valve will at once close, and the "closed-circuit" is thus left charged with an artificial atmosphere of 150lbs. per square inch. As the inlet and delivery sides of



Section through Transfer and Exhaust Ports.
1,000 B.H.P. 2-Stroke Cycle Crude Oil Air Compressor.

the "closed-circuit" are of equal capacity, any increase of pressure in the delivery pipe above 150lbs. is followed or accompanied by a similar decrease of pressure in the inlet pipe, but the combined pressures on the areas of the small plunger will be constant, consequently so long as no leakage takes place the plunger will remain in its raised position no matter what differences of pressure may exist between the inlet and delivery pipes. As soon as half the sum of the pressures becomes less than 150lbs., the spring will force the plunger down, and the non-return valve will open and close as before described to make up the leakage.

The second control apparatus is the valve by which the main compressor delivery valves are caused to be held off their seats, and by that means regulate the quantity of air delivered to and consequently the power developed by the locomotive cylinders. The valve is a simple slide valve, having delivery pressure on the back of it and exhausting at its centre. It has a blanking sector and an exhaust slot, each capable of covering the six ports which are connected one to each of the holes through the main compressor covers. These connections are not made direct, but as branches from pipes connecting two similar valves. The valve on the right is blanked, *i.e.*, it is in its neutral position. The valve on the left is in the position at which all six compressor cylinders are in operation. By moving this valve so that the exhaust slot comes over one or more of the six ports, the number of compressor cylinders in action may be varied to suit the power and speed required from the locomotive. If the valve on the left is put in the neutral position, that on the right can be used in the same way to control the output.



Plan View of Delivery Valve and Valve Seat.
1,000 B.H.P. 2-Stroke Cycle Crude Oil Air Compressor.

The third control apparatus is that by which the radial reversing gears are operated. To move the gears the usual power and cataract cylinders are used, the cataract cylinder being fitted with a special form of locking valve. This valve is shown in section at the centre of the diagram, and is under air pressure at all such times as no pressure exists in the power cylinder. Oppositely, when pressure is admitted to the power cylinder to move the gears in either direction the pressure is exhausted from the cataract locking valve, and so permits the desired movement to take place. The duplicate valves are in the neutral position on the right and the normal position on the left respectively.

The fourth control apparatus is that for the automatic vacuum brake. The valve seat has two ports connected to the exhausting pumps and the train pipe respectively. The valve has two corresponding ports connected by a bridging cavity, and an open port for admitting air to the train pipe. The valve on the right is in the neutral position, the valve on the left being in the running position. The valves are used in the same manner as the usual combination ejector valves.

The fifth control apparatus is that for the sanding traps. The valve seats have two ports, the valves having cavities extending over the ports. The outer ports are connected to the front and back sand traps, the inner ports being simply connected together. The valves have air pressure on the backs of them, and are in the normal running position. It will be evident that by moving either valve in one direction or the other the front or back sand traps may be operated.

The peculiar effect the "closed-circuit" has in making air transmission a highly economical method of transmitting power will be understood by the following calculations. The formulæ are based on the simple arithmetical method contributed to our pages by Mr. Dunlop some 10 years ago:—

Let p = pressure of air entering cylinder in pounds per square inch absolute.

P = pressure of air leaving cylinder in pounds per square inch absolute.

WP = working pressure of air in pounds per square inch on gauge $= P - p$.

t = temperature of air entering cylinder in deg. Fah. absolute, *i.e.* $= 61 + 461 = 522$ say.

T = temperature of air leaving cylinder in deg. Fah.

c = compression period as a fraction of stroke.

d = delivery period as a fraction of stroke $= 1 - c$.

MP^n = mean pressure throughout stroke in pounds per square inch for characteristic conditions $n = 1{\cdot}33$.

MP^i = mean pressure throughout stroke in pounds per square inch for isothermal conditions.

WL = per cent of work lost due to isothermal conditions, *i.e.*,

$$= \frac{MP^n - MP^i}{MP^n}$$

then

$$T = \left(t \sqrt[4]{\frac{P}{p}}\right) - 461$$

$$c = \frac{\sqrt[4]{\left(\frac{P}{p}\right)^3} - 1}{\sqrt[4]{\left(\frac{P}{p}\right)^3}}$$

$$MP^n = 4p\left(\sqrt[4]{\frac{P}{p}} - 1\right)$$

$$MP^i = p\left(1 + \text{hyp. log of } \frac{P}{p}\right) - p.$$

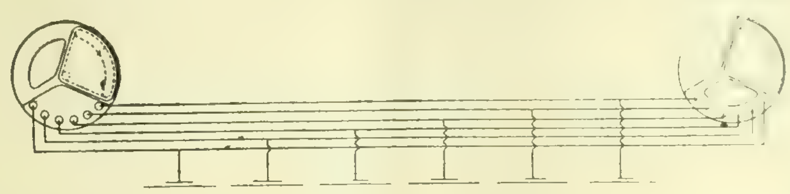
It will be understood that the quantity and the pressure of the air supplied to the locomotive cylinders can be varied in two ways, *i.e.*, by altering the cut-off in these cylinders and by varying the number of compressor cylinders in action. Table I. gives the results for four working pressures, viz., 50lbs., 100lbs., 150lbs., and 200lbs. For purposes of comparison Table II. gives similar results for open-circuit isothermal working.

TABLE I.—"*Closed Circuit.*"

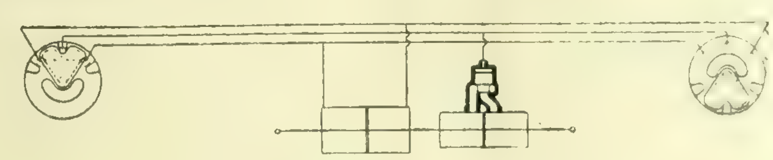
p	140	115	90	65
P	190	215	240	265
WP	50	100	150	200
t	522°	522°	522°	522°
T	102°	149°	205°	280°
c	26%	37·5%	51%	65%
d	74%	62·5%	49%	35%
MP^n	44·52	78·2	99·72	109·2
MP^i	42·0	71·97	88·04	91·26
WL	5·66%	7·96%	11·71%	16·42%

TABLE II.—*Open Circuit.*

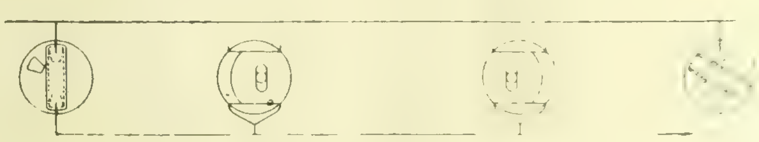
p	15	15	15	15
P	65	115	165	215
WP	50	100	150	200
t	522°	522°	522°	522°
T	291°	406°	489°	554°
c	66·6%	78%	83%	86·4%
d	33·4%	22%	17%	13·6%
MP^n	26·52	39·72	49·26	57·76
MP^i	21·98	30·54	35·96	39·93
WL	17·11%	23·11%	26·99%	30·86%



DELIVERY VALVE CONTROL APPARATUS.



REVERSING GEAR CONTROL APPARATUS.



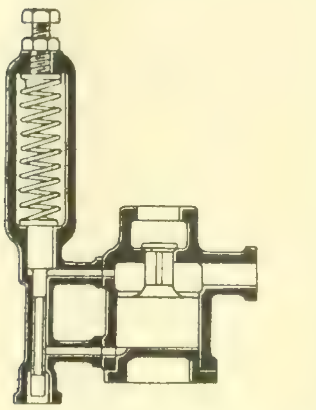
VACUUM BRAKE CONTROL APPARATUS.

SAND TRAP CONTROL APPARATUS.

In comparing these tables it will be noticed the rise in temperature for 200lbs. working pressure on "closed-circuit" is less than the rise in temperature for 50lbs. working pressure on open-circuit. With regard to temperature, it is of course understood that on open-circuit isothermal working any rise of temperature whatever is a loss, whereas on "adiabatic" "closed-circuit" working a rise of temperature is not a loss, but the greater the rise of temperature the less the quantity of heat that can be taken up in the air heater. For that reason the working pressure will be kept as low as possible for any given power.

It will be recognised that heating of the air takes place at constant pressure, the increase in volume being directly proportional to the absolute temperatures before and after heating. At 200lbs. working pressure an increase of 120°—*i.e.*, from 280° to 400°—increases the volume by a $\frac{1}{6}$th.

The corresponding compression and delivery periods show that on "closed-circuit" much smaller compressor cylinders are needed for any given quantity of compressed air. As a consequence the cut-offs in the locomotive cylinders for complete expansion will be much longer relatively, and it must not be forgotten that in "closed-circuit" working there is no such thing as incomplete expansion, any expansion not completed in the locomotive cylinders being completed in the air compressor cylinders. In open-circuit working there is in almost every case a considerable loss from incomplete expansion, in addition to the heat loss. The latter is the quantity *WL*, and like the rise in temperature is more for 50lbs. working pressure on isothermal open-circuit than it would be for 200lbs. working pressure on isothermal closed-circuit. As the locomotive, however, works on "adiabatic" "closed-circuit" the quantity *WL* is not concerned.



AUTOMATIC LEAKAGE MAKE-UP APPARATUS.

To suit the double method of varying the pressure provided for in this engine, and also to suit the high exhaust pressures, the anti-vacuum valves are placed at each end of the cylinders along with compression relieving valves, so as to minimise the effect of an unsuitable choice of quantity or pressure of air for any given load or speed. For mountain grades stop valves between the compressor and locomotive cylinders will enable the latter cylinders to exercise a braking control and also to make up leakage from the "closed circuit." From the fact that little or no storage of compressed air is present there is no tendency to "persistent slipping" with this engine such as exists in steam locomotives. When slipping takes place a rapid equalisation of the pressures in the inlet and delivery pipes sets in and at the same time the governor of the compressor checks the tendency to race, with the result that the locomotive at once commences to slow, but immediately afterwards picks up automatically, no attention being required from the driver. This, of course, refers to incline work. Slipping at starting also more or less automatically corrects itself, but the driver is then in any case handling the control valve.

The approximate heat distribution of a constant pressure combustion crude oil engine is as follows:—

40 per cent. converted into useful work at the crank shaft.

28 per cent. lost in the water circulated in the cylinder jackets.

32 per cent. lost in the exhaust gases.

If the efficiency of the air heater is only 16 per cent. it follows that for each horse-power indicated in the air compressor cylinders there will be $1 + \frac{32 \times \cdot 16}{40} = 1{\cdot}128$ i.h.p. in the air supplied to the locomotive cylinders, and if the mechanical efficiency of the locomotive is 90 per cent. there will be $1{\cdot}128 \times {\cdot}9 = 1{\cdot}015$ b.h.p. developed at the rails.

Crude oil engines of the type under discussion have developed a brake horse-power for an hour on a consumption of 0·4lbs. of oil. If it is assumed this locomotive consumed as much as 0·5lb. per horse-power hour, and the oil costs 40s. per ton, then to develop 1,000 h.p. at the rails for one hour would cost

$$\frac{1000 \times 40}{2 \times 2240 \times 1{\cdot}015} = 8\ 9\tfrac{1}{2}$$

The most economical steam locomotive will consume at least $3\frac{1}{2}$lbs. of coal per horse-power hour, and if the coal costs only 10s. per ton, then to develop 1,000 h.p. for one hour would cost

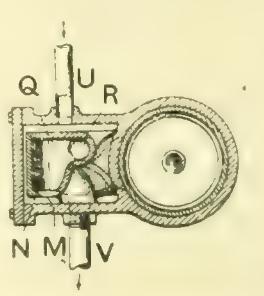
$$\frac{3{\cdot}5 \times 1000 \times 10}{2240} = 15/7\tfrac{1}{2}$$

That is to say, although oil costs four times the price of coal, the cost of operating the oil locomotive is less than 60 per cent. of the cost of operating the steam locomotive.

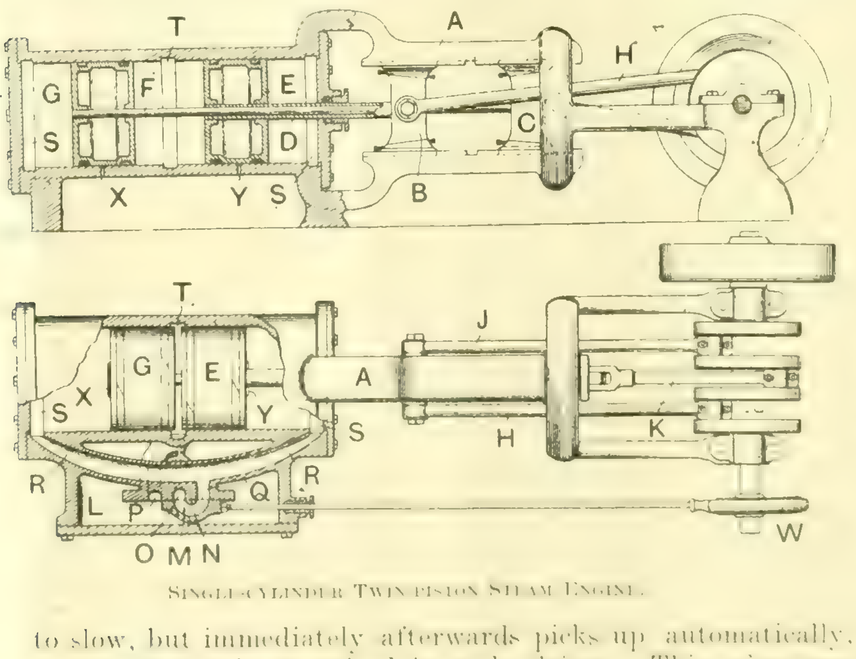
This system of locomotive construction is being developed under the Dunlop patents by Messrs. "Closed-circuit" Air Transmission, Ltd., 10, Jamaica Street, Glasgow.

SINGLE-CYLINDER TWIN-PISTON STEAM ENGINE.

THE accompanying illustrations show a design of steam engine, the invention of Edgar James, Lincolnton, North Carolina, U.S.A. Integral with the cylinder is a frame A serving as a guide for crossheads B and C. Crosshead B is secured to a hollow piston rod D passing through a gland and attached to piston E. Crosshead C is secured to a piston rod F, passing through crosshead B and rod D, and is secured to a piston G. To the two outer sets of crank discs are connected the rods H and J attached to crosshead B. A rod K extends to crosshead C. The valve chest L contains a valve M connected with eccentric W by a rod, and has a passage N to communicate with the exhaust passage O in the centre and with the passages P and Q on each side. Passage Q communicates, through passages R, with channels S in the ends of the cylinder. Passage P communicates with the channel T at the centre of the cylinder.



Steam enters the valve chest through pipe U, thence passes through passage P and channel T, driving the pistons apart. At the end of this stroke the steam will exhaust through channels S and passages R, Q, N, and O. To facilitate the exhaust without interfering with its efficiency auxiliary exhaust openings X and Y are provided between the centre and ends of the cylinder. The location of these auxiliary exhaust ports and the length of the pistons are such that each piston just uncovers its auxiliary port at the end of each reciprocation, permitting a considerable portion of steam to exhaust immediately therethrough and relieving the engine from back pressure, the remaining steam exhausting in the usual manner through the slide valve and pipe V.



SINGLE-CYLINDER TWIN-PISTON STEAM ENGINE.

A Large Locomotive.—One of the largest locomotives in the world has just been built for the Pennsylvania Railroad. The weight of the engine in working order and the tender loaded is 668,900lbs. This is 238,900lbs. heavier than the class "K. 2," the heaviest passenger engine, 272,600lbs. heavier than the class "H 8B," the heaviest freight engine which the Pennsylvania is now using. There are four cylinders, each having a diameter of 27in. and a stroke of 28in. Each of the 16 driving wheels is 56in. diam. The steam pressure is 160lbs., and the total heating surface 7,723·6 sq. ft. The tender will hold 9,000 galls. of water and 30,000lbs. of coal.

EXPRESS LOCOMOTIVE WITH SCHMIDT SUPERHEATER AND STUMPF VALVE GEAR.

FOR some time the construction of locomotives has been in progress designed to use continuous-direction steam flow, thereby reducing some of the waste which occurs with the ordinary process of using steam. The Prussian railways have installed on an ordinary-type locomotive the Stumpf continuous-flow system. This locomotive has been subjected to a series of tests, the results of which are recorded in an article by E. Krauss in the November Bulletin of the International

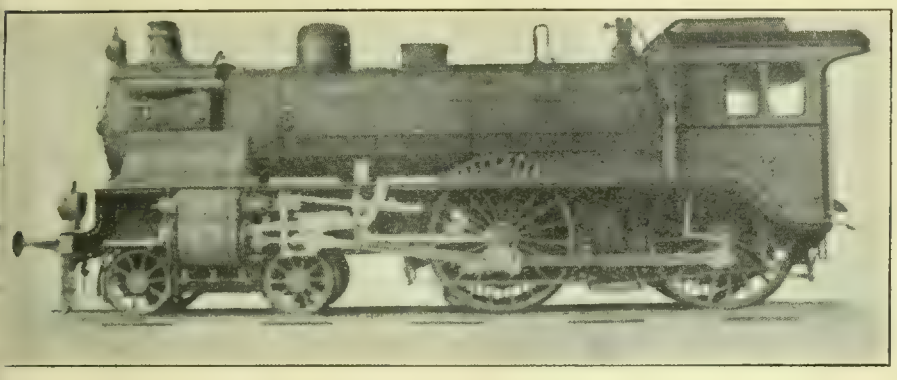


FIG. 1 EXPRESS LOCOMOTIVE WITH SCHMIDT SUPERHEATER.

Railway Congress, for the following abstract of which we are indebted to "The Railway and Engineering Review."

Tests were first made with the locomotive equipped with the ordinary system, and after the locomotive had been converted and equipped with the Stumpf system of continuous-direction steam flow. In changing the locomotive over it was not necessary to alter the general dimensions of the locomotive, the boiler and the frame remaining practically the same. The change consisted in the replacement of the cylinders and their covers, the increase of the wheelbase of the truck, the replacement of the piston and rods, a modification of the valve gear machinery, shortening of the connecting rod, and alteration in the cut-off and exhaust. Fig. 1 shows the locomotive before the change was made, and Fig. 2 shows the locomotive after it has been equipped with the Stumpf valve gear. The principal dimensions of the locomotive are as follows:—

Cylinder diameter	19 $\frac{11}{16}$in.
Stroke of piston	24 $\frac{25}{32}$in.
Diameter of driving wheels	6ft. 10 $\frac{11}{16}$in.
Working boiler pressure, in pounds per square inch	170·7
Heating surface of firebox and boiler, in square feet	1,473·69
Heating surface of superheater, in square feet	434·02
Grate surface, in square feet	24·81
Weight, light, in pounds	124,340
Weight in running order, in pounds	136,690

The arrangement of the inlet valves at the ends of the cylinders was an easy matter. The advantage of this system

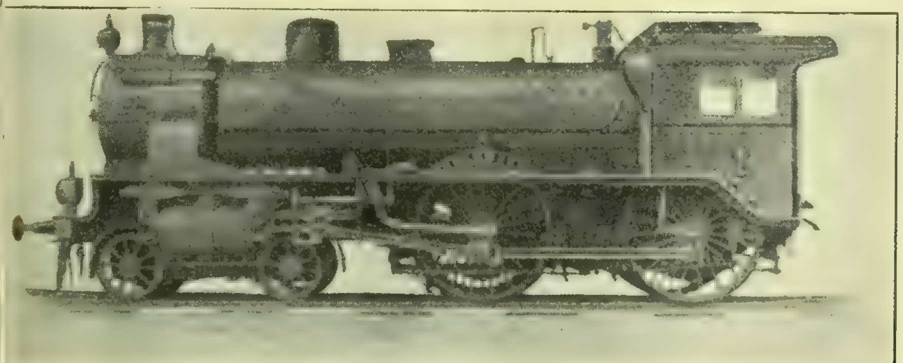


FIG. 2.—EXPRESS LOCOMOTIVE WITH SCHMIDT SUPERHEATER AND STUMPF VALVE GEAR.

lies in the fact that these valves give very small surface for the cooling effect, and thereby cut down the condensation and at the same time provide very large clearance spaces. Fig. 3 shows the method of construction of the admission valves, which are of the double-seated type with springs. The steam is admitted almost directly against one of the faces of the piston, and, during the latter portion of the piston travel, is exhausted through ports in the centre of the length of the cylinder, thence to the exhaust pipe. The opening of the valve is ensured by rollers carried on rods and rolling on valve cams. The exhaust ports are situated in the middle of the cylinder and are 2·164 times the area of the ports which can be obtained with piston valves. While the initial velocity of the steam at the exhaust and its pressure are reduced as much as possible through the exhaust ports to the exhaust nozzles, the necessary vacuum is obtained in the smokebox to ensure sufficient draught. Since the exhaust depends, in this system, upon the position of the piston itself, the admission lead and the beginning of compression are the same for all cut-offs. This is shown in Fig. 4, which is a comparison of the area for the opening of the exhaust on the ordinary type of locomotive both for the cut-off of 30 per cent. and 70 per cent. The drop of pressure begins with the admission lap and continues to the exhaust opening, where it falls to very nearly atmospheric pressure without any back pressure. During the period of compression, which occurs on the return stroke of the piston, heat is generated which is utilised on the out stroke. As the compression begins immediately after the closing of the exhaust port, which takes place at 12·7 per cent. of the piston stroke, it is necessary to provide large compression spaces. These spaces, instead of being made of long channels bounded by large areas, are, however, enclosed by surfaces of relatively small area, making the heat losses less than upon ordinary engines, in which the compression spaces are 16 per cent. at the front end and 17 per cent. at the back end, instead of 11·8 per cent. at the front end and 13·65

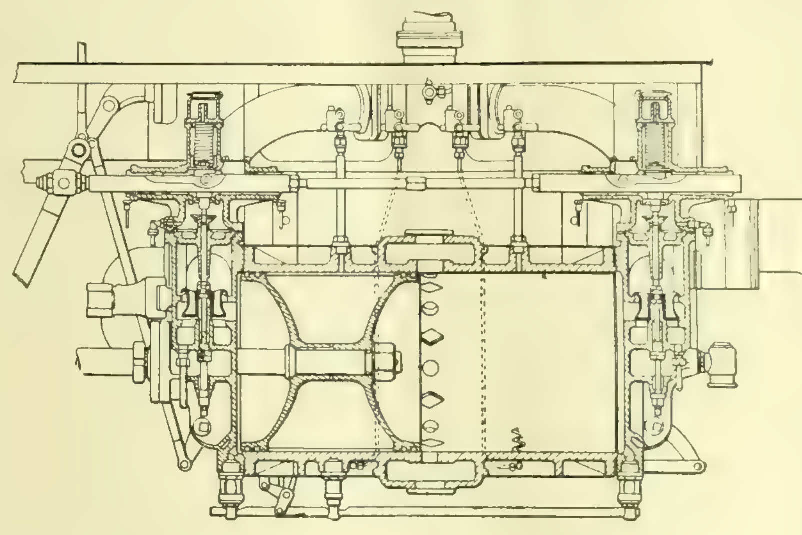


FIG. 3.—CROSS-SECTION OF CYLINDER SHOWING APPLICATION OF STUMPF VALVE GEAR.

per cent. at the back end, as is normal with the ordinary locomotive.

The cooling surfaces of the clearance spaces are 525 sq. in. on the locomotive with the Stumpf valve gear, as against 1,347 sq. in. at the front end and 973 sq. in. at the back end, on the ordinary locomotive; there is therefore a difference of at least 60·9 per cent. at the front end and 46 per cent. at the back end. The steam flowing in the continuous direction through the cylinders does not cool the walls except at the centre of the length. It is at this part, at the coolest portion of the length of the cylinder, that the steam escapes when the piston uncovers the exhaust port. During the time that the crank describes an arc of 89° 2′ in respect to the shut-off; on the ordinary locomotive and in the flow of steam alternating in direction, this arc is equal to 188° 2′ when the cut-off is at 30 per cent., and it is 183° 25′ when the cut-off is at 70 per cent. of the stroke. The exhaust steam is therefore insulated from the inner walls of the cylinder before the crank has made a quarter revolution, and it can then cause no further heat loss.

The water of condensation, evident at the starting until the cylinders have become sufficiently heated, discharges automatically after each stroke of the piston by ports at the lower surface and by a hole $\frac{3}{32}$in. diam. drilled in the metal which surrounds the port; consequently it cannot remove heat from the steam entering the cylinders.

By using two valves only on each cylinder for ensuring the admission of steam, and by eliminating the gear for exhausting, the tightness of which required special care, the losses of steam due to leakage past these parts are avoided.

Small leakages at the inlet valves do not produce any deleterious effect, for if the steam entering the cylinder causes any alteration in the compression curve, it also effects useful work.

The use of admission valves avoids the necessity for fitting a special equaliser, since a single lever gear enables the driver to lift the two valves simultaneously and to place the front and back of the cylinder in communication with each other. Another advantage of this method of equalising is that the cam which causes the opening of the valves leaves the roller of the valve gear; the rod is no longer subject to the pressure of the spring, and the resistance to movement of the mechanism consists only in that of the parts of the link work and

The suppression of the tail rod ensures a reduction in the reciprocating masses which, on the other hand, is increased by the lengthening of the piston, but actually the increase is so small that in the balancing, which is effected to within 3 per cent., there has been no necessity for an appreciable modification in the arrangement of the wheels. On the rails this locomotive runs as smoothly as does the normal type.

The lubrication of the cylinders is effected by a Michalk pump having eight oil supply pipes and actuated by the coupled axle. Oil is distributed to two points on the steam supply, and to two points on the top of each cylinder, and to two points on the sides at the front and back, that is to say, to six points of each cylinder.

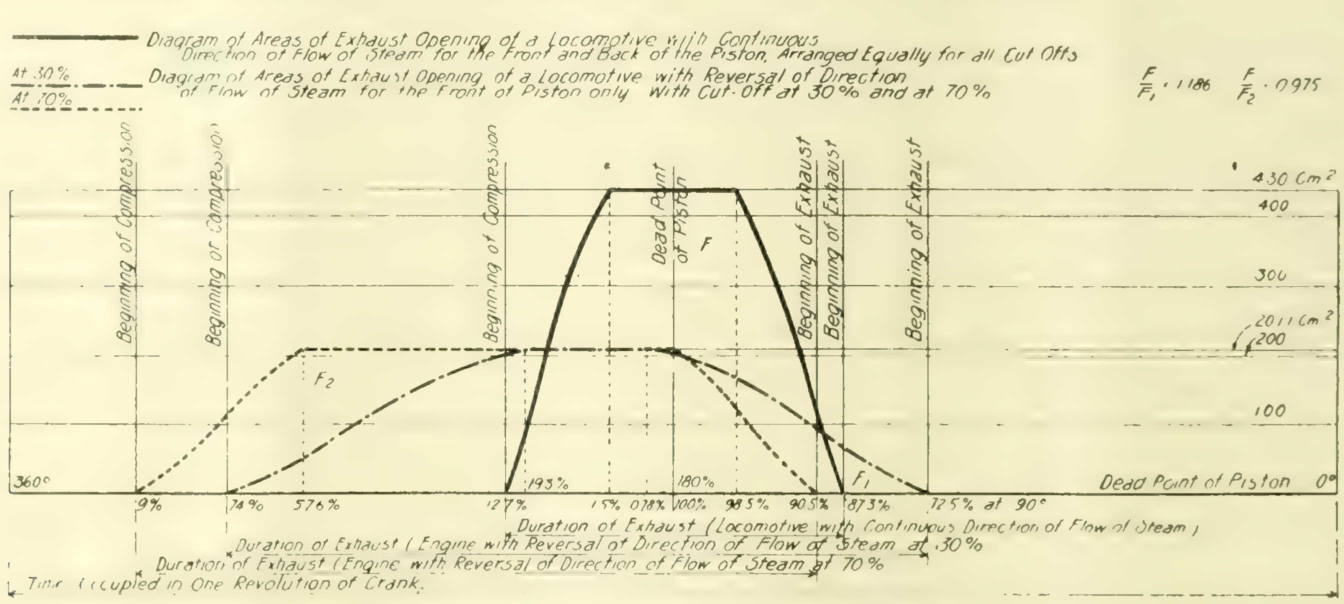


FIG. 4.—COMPARATIVE AREAS OF EXHAUST OPENINGS.

their guides; and, even when the valves are under the full pressure, the resistance to movement is so slight that the parts of the gear for operating them can be made of smaller dimensions than on the ordinary locomotive, with reversal of direction of the flow of the steam.

The setting of the valves is very easily performed; moreover, the cut-off, &c., can be adjusted without difficulty by looking through the ports and adjusting the rod. The double-seated valves have their top diameter $6\frac{3}{16}$in. outside and $5\frac{15}{16}$in. inside, and the bottom diameter $5\frac{29}{32}$in. outside and $5\frac{11}{16}$in. inside. The difference of pressure exerted on the valve is therefore reduced to 625·8lbs. per square inch when the pressure in the steam pipe is of the maximum boiler pressure of 170·7lbs. per square inch. As a precautionary measure each cylinder cover was fitted with an air-admission valve and a relief valve; but it is certain that henceforth the latter will be dispensed with without any disadvantage.

The cooling of the cylinder walls towards the middle has advantages in guiding the piston. In order that the piston may slide over the exhaust ports, it is necessary that it should have a long bearing surface and consequently that the cylinder should be of greater length than in the ordinary type locomotive. For this reason the length of the truck wheelbase was increased from 7ft. $2\frac{3}{8}$in. to 7ft. $6\frac{9}{16}$in. in order to permit of removing the cylinder covers and of withdrawing the piston without lifting the locomotive.

The piston (Fig. 3) consists of two symmetrical steel castings, each of the form of a hollow spherical dish and each fitted with two spring rings. Between these two castings a weldless mild steel ring is held which bears on the lower wall of the cylinder and helps to support the heavy piston; on the other hand, the piston is allowed a small amount of play towards the top of the cylinder. In this manner the intensity of the bearing pressure where contact is made, is very small, and the walls of the cylinder are saved to such an extent that it is unnecessary to fit a tail rod with its stuffing box. The drop of temperature in the cylinder towards the centre of its length is also of advantage in respect to the reduction of wear on the bearing surfaces.

The great distance between the front and back faces of the piston effectively prevents transmission of heat from the side on which admission is taking place to that from which steam is being exhausted. In order that the space round the piston may not become filled with water, the mild steel ring is drilled with eight holes each $\frac{3}{16}$in. diam.

The modification of the valve gear has led to an arrangement which is quite symmetrical for forward and backward running, since it has been possible to arrange the valve rod horizontally. It was found necessary to move the support of the slide blocks a little further back and to lift the reversing shaft above the edge of the longitudinal frame. Apart from these, no radical modification was made in the proportions of the different parts of the valve gear.

In the trials which were made on this type of locomotive it had been found that the commencement of the opening of the valve at the lead took place a little more slowly than with the slide valve, and that the closing of the valve took place less suddenly than had been expected. The curve of the cam was drawn in such manner that the maximum opening was

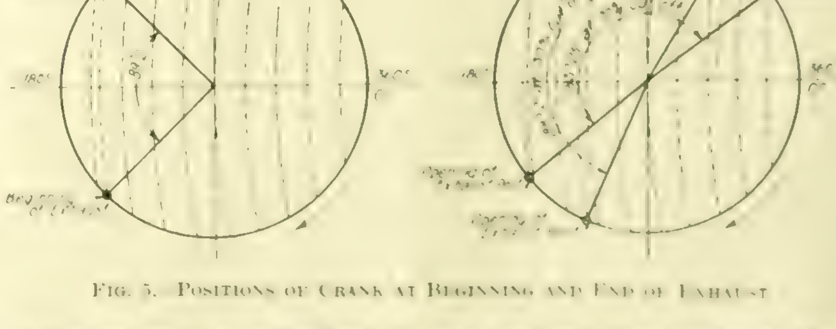


FIG. 5. POSITIONS OF CRANK AT BEGINNING AND END OF EXHAUST.

obtained with a cut-off of 65 per cent. of the stroke of the piston instead of 40 per cent., as was the case on the locomotive with reversal of direction of flow of the steam. It would be possible to obtain better results by adopting a more rapid inclination for this curve, but this cannot be done if it is required that the roller should make contact with the cam gently and without shock; consequently it is not possible to expect that the valve diagram with the double seated valves will show superiority over the diagram with slide valves in respect to the period of admission proper. The advantage of the engine with double-seated valves consists rather in a better thermal utilisation of the steam. It has been found also that a reduction in the diameter of the cylinders from $21\frac{11}{16}$in. to $19\frac{11}{16}$in. is excessive, and that the power of the locomotive has suffered.

The lengthening of the cylinder has involved the shorten-

ing of the connecting rod from 8ft. $4\frac{13}{16}$in. to 7ft. $8\frac{1}{8}$in. For this reason the ratio of the connecting rod length to that of the crank is reduced from 1/8·1 to 1/7·43.

The steam pipe, $4\frac{11}{16}$in. inside diameter, has been replaced where it leaves the smokebox by a double pipe connecting the front and back valve chests. This pipe has been made with an inside diameter of $5\frac{29}{32}$in. in order to obtain as large a capacity in the steam chest as possible near the valves and also to reduce the velocity of the steam at this point. The enlargement of the exhaust to $11\frac{13}{16}$in. with gradual stricture up to its entrance into the smokebox has proved sufficient for reducing the noise of the separate exhausts to a point at which they can scarcely be distinguished, and on leaving the exhaust pipe they are but little louder than the ordinary exhaust

BRITISH STANDARD DEFINITIONS OF YIELD POINT AND ELASTIC LIMIT.

THE Engineering Standards Main Committee having been approached with the request that standard definitions for the terms "Yield Point" and "Elastic Limit" should be drawn up remitted the matter to those sectional committees which had prepared standard specifications for steel and wrought iron, with the result that the following definitions have been unanimously agreed upon. At the request of the Ships Committee a note is added with regard to the use of these terms in the commercial testing of materials used in the construction of ships and their machinery.

DEFINITIONS.

Elastic Limit.—The elastic limit is the point at which the extensions cease to be proportional to the loads. In a stress-strain diagram plotted to a large scale it is the point where the diagram ceases to be a straight line and becomes curved.

> *Note.*—The elastic limit can only be determined by the skilful use of very delicate instruments and by the measurement of the extensions for small successive increments of load. It is impossible to determine it in ordinary commercial testing.

Yield Point.—The yield point is the point where the extension of the bar increases without increase of load.

Practical Definition of Yield Point.—The yield point is the load per square inch at which a distinctly visible increase occurs in the distance between gauge points on the test piece, observed by using dividers; or at which, when the load is increased at a moderately fast rate there is a distinct drop of the testing machine lever, or, in hydraulic machines, of the gauge finger.

> *Note.*—A steel test piece at the yield point takes rapidly a large increase of extension amounting to more than 1/200th of the gauge length. The point is strongly marked in a stress-strain diagram.

Note added by request of the Ships Committee.—The Sectional Committee on Sections and Tests for Materials used in the construction of ships and their machinery, while concurring in the foregoing definitions, desires, however, to make the following remarks with regard to the use of the terms "Yield Point" and "Elastic Limit" in connection with steel and wrought iron for shipbuilding.

The Ships Committee does not recommend the use of either "Yield Point" or "Elastic Limit" in the standard specifications for ship material for the following reasons:—

Yield Point.—In regard to the ascertainment of the yield point there is considerable divergence of opinion as to the best method of determining it, and all methods involve greater time and care than can be expected in the works. While it is possible in works by careful testing at a greatly reduced speed to obtain the yield point in ordinary mild steel and wrought iron, some of the harder steels and other constructional materials have no definite yield point at all, and some have no elastic limit.

Elastic Limit.—It is quite impossible to determine the elastic limit in the time available for ordinary commercial testing. In its determination a specially delicate and accurate extensometer must be used, in the hands of a careful and competent observer, and the determination for each test bar would require a considerable time. It is properly a matter to be left to laboratories organised for scientific purposes.

The Ships Committee is of opinion that the present method of fixing, by experience, the working stress for any material as a proportion of the ultimate breaking stress rather than as a proportion of the elastic limit or yield point, is the best practical method, and therefore it considers that the inclusion in the British standard specifications for ship material of tests to ascertain either the elastic limit or the yield point would not justify the dislocation of the ordinary commercial testing as carried out in the works' test rooms which would be entailed thereby.

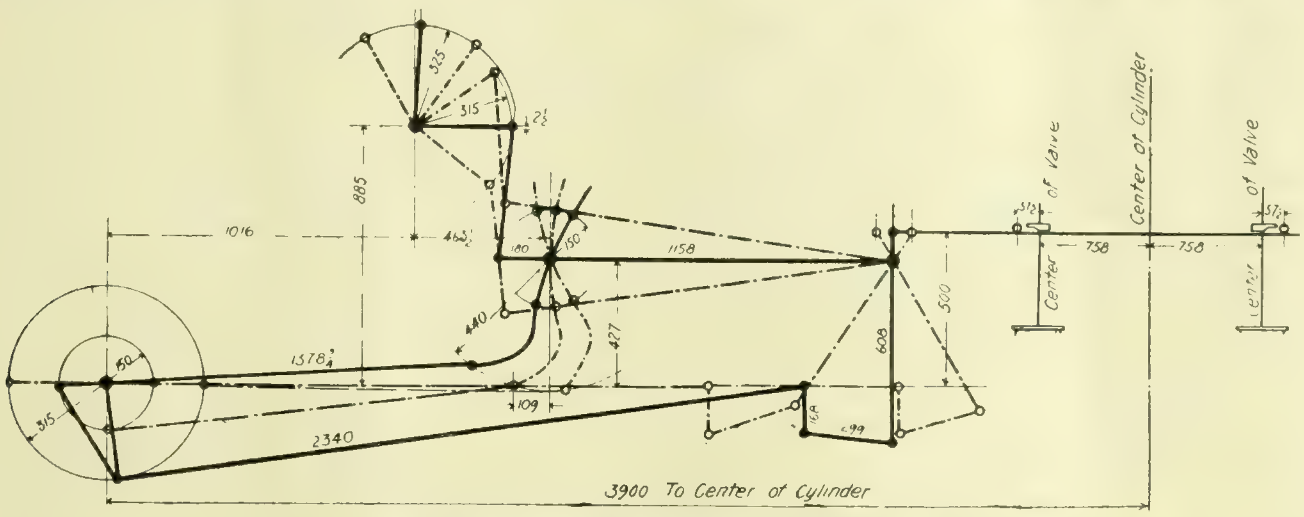
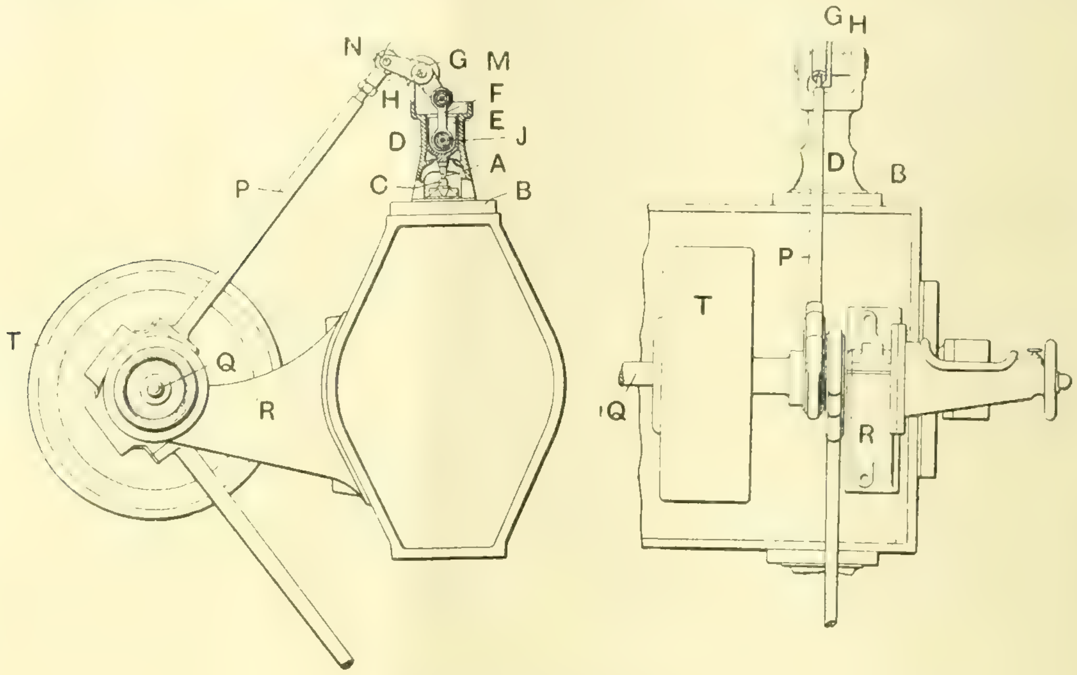


FIG. 6. DIAGRAMMATIC ARRANGEMENT OF VALVE GEAR.

The Whitehead Submarine.—The Whitehead firm at Fiume have recently completed a new type of submarine for the Dutch Navy. In appearance it is, according to a naval correspondent of the "Standard," very similar to our "B" and "C" class type, but is a great deal smaller, being only 150 tons. It has a length of 105ft. and a maximum breadth of just under 10ft., and is fitted with two torpedo tubes, two spare torpedoes, and a double periscope. The contract surface speed was 11 knots with a radius of 500 miles at 10 knots, and an endurance of five hours under water at seven knots, or three hours at eight knots. The above-water propulsion is furnished by a Diesel two-stroke motor of 300 h.p., with a similar horse-power from accumulators for submarine work. On her trials the boat only slightly exceeded the 11 knots on the surface, but her radius of action proved to be nearly double that of the contract. She remained under water at seven knots for nearly $6\frac{1}{2}$ hours instead of 5 hours, and also succeeded in doing one hour under water at 11 knots. These trials took place off the coast of Holland in a gale of "force 6." Very few details as to the internal mechanism of the boat have become known, but it is stated that she maintained exactly any depth that was called for. These extremely satisfactory results go to suggest that considerable submarine developments may be looked for in the early future.

VALVE GEAR FOR STEAM ENGINES.

The accompanying illustrations show a design of distributing valve gear for steam engines of the type in which the distribution of the motive fluid is controlled by means of piston valves, and in which a rocking lever connected directly with an eccentric rod and with the valve spindle actuates the valve. Valves of this type have already been used successfully, actuated generally by a releasing gear and closed by springs if serving as admission valves, but by positive mechanism if serving as exhaust valves. In the case of admission valves the speed at which the valves may work is limited by the speed at which the springs can close the valves successfully, and in the case of exhaust valves the mechanism employed



Valve Gear for Steam Engines.

has been heavy and complicated, and has consequently reduced the speed at which the valves could be operated. In the arrangement under notice, which has been patented by H. W. Morley, of Cole, Marchent, & Morley, Ltd., of Prospect Foundry, Bradford, piston valves are used for admission, and also, if desired, for exhaust.

Referring to the illustrations, Fig. 1 is an end view partly in section of a horizontal steam engine fitted with valves of the piston type, the valves and valve mechanism on the underside of the engine being omitted, and the parts being shown in the position occupied when the valve is just about to open. Fig. 2 is a side elevation. In this type of engine the admission valves are arranged vertically at the top of the cylinders, and the exhaust valves which, together with the mechanism for operating the same, have been omitted from the illustrations are arranged vertically beneath the cylinders. A is the spindle of the admission valve which is contained in a casing B surrounding the cylinder and which passes through the gland C in a bracket D mounted upon the casing. E is a cylindrical valve spindle guide which is connected to the threaded upper extremity of the valve spindle A. The valve spindle guide E is connected by means of a link F to a rocking lever G pivotally mounted at H on the bracket D. The lower extremity of the link F is pivotally connected at J to the valve spindle and the upper extremity is connected to a wrist pin carried by the rocking lever G. At its outer extremity the rocking lever G is connected at N to an eccentric rod P attached to an eccentric upon the lay shaft Q which is mounted in bearings carried by brackets R cast integral with or bolted to the casing. If it be desired to use a shaft governor with automatically variable expansion, a governor T of this type is mounted on the lay shaft Q and controls the admission valve eccentric or eccentrics. The rocking lever G is shown in approximately its mid position, the valve being just about to open by being moved upwardly, and the arcs struck round the pivot H indicate the extent of angular movement of the rocking lever.

By virtue of the design and proportions of the rocking lever G it follows that while the rocking lever moves angularly from the mid point of its travel to the highest point thereof and back again to the mid point (during which period the valve has opened and has just closed) the linear movement imparted to the valve will be greater than the linear movement imparted thereto during the period occupied by the rocking lever G in moving angularly from the mid point of its travel down to the lowest point thereof and back to the mid point (during which period the valve has been inoperative or closed). It will be obvious that the actual shape of the rocking lever will vary according to different requirements, but in order to bring about the foregoing condition it will be necessary that the centre line of that arm of the rocking lever which is connected to the valve spindle link shall not be at right angles to the valve spindle when the arm is in its mid position. In the illustration this angle is shown to be about 130°. The design, it is claimed, is such that the number of parts is reduced to a minimum, and the mechanism being of light construction and having a minimum of movement, the inertia and momentum stresses are thereby lessened. Further, by reducing the total movement of the valve and mechanism, wear is reduced considerably, while the extent of port opening which is necessary for the efficient inlet and outlet of the working fluid is maintained.

Should this mechanism be combined with an eccentric whereof the travel and angular advance is varied by a shaft governor, as mentioned above, the relative movements of the eccentric and valve controlled thereby remain approximately the same, but during the whole of this variation for a given travel of the eccentric the movement of the valve is reduced to a minimum, with comparatively gradual acceleration and retardation of the moving parts.

THE SOOTFALL OF LONDON.

Some interesting figures are published by the "Lancet" respecting the results of an investigation into the amount, quality, and effects of the soot falling annually in London. The experiments were conducted at four stations; two were situated in the S.W. district near Westminster, one in the City area, and the fourth on the borders of the metropolitan area at Sutton in Surrey. The latter station was chosen in order to gain a comparison between the amount and kind of deposit falling in the suburban area and that collected in the metropolis itself. The collections were made each month through the year June-May, 1910-1911, and a soot gauge was installed at each station which caught both deposit and rain. The analysis of these was conducted in "The Lancet" laboratory. The results are summarised in a table in which are set out columns showing (1) rain volume; (2) total deposit fallen on an experimental area of 4 sq. ft. (the soot gauge); (3) insoluble deposit (soot, &c.); (4) total solids dissolved in the rain; (5) soluble volatile solids; (6) soluble fixed solids; (7) sulphates; (8) ammonia; (9) chlorine; (10) lime; and (11) calculated total deposit in the administrative county of London, including the City (117 square miles). The last item of figures deals with some striking facts. If, for example, the City station is taken as the basis of calculation as to the total amount of deposit falling annually upon the administrative county of London, including the City, this deposit amounts to no less than 76,050 tons, in which are present over 6,000 tons of ammonia, about 8,000 tons of sulphates, 3,000 tons of chlorine in chlorides, to say nothing of the carbon and tar. Taking the S.W. metropolitan station as a basis, the total deposit per year over the same administrative area would average 53,820 tons, in which are present over 4,000 tons of ammonia, about 5,000 tons of sulphates, and 4,000 tons of chlorine in chlorides.

Boiler Explosion at Crawley, Hampshire.—The formal investigation ordered by the Board of Trade to be held in this matter is fixed for hearing in the Court Room, Guildhall, Winchester, on Tuesday, the 23rd inst., at 11 a.m.

RECENT DEVELOPMENTS IN STEAM TURBINE PRACTICE.*

BY K. BAUMANN.

ALTHOUGH the principle of the steam turbine is very old, its application only dates from the introduction of electricity, which made it possible to transmit the power developed by turbines at unavoidably high speeds. This necessitated the development of generators of a special construction, which are known as turbo-generators, in conjunction with the development of steam turbines. In view of the intimate connection between the two machines, it is essential that the designers of generators should always be informed with regard to the requirements of the turbine designers, and of the future possibilities of turbine development. Again, electrical engineers in charge of power stations, who are by far the

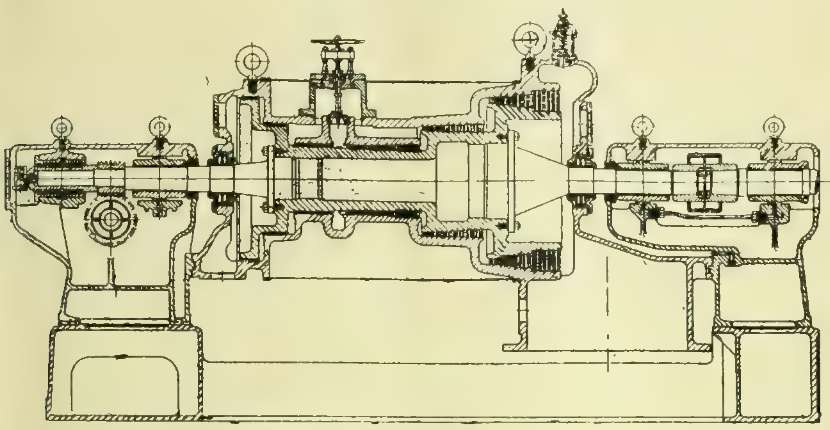


FIG. 1.—PARSONS TURBINE.

largest purchasers of turbo-electric sets, should be well acquainted with the points which are important for reliable running and economy, and should be kept informed on the main facts with regard to the development of the steam turbine, and the performances obtained on these machines. For these reasons this paper, though of a purely mechanical character, may prove of some interest and use to electrical engineers.

Summary of Developments in Steam Turbines up to 1902.—The development of the steam turbine since the first

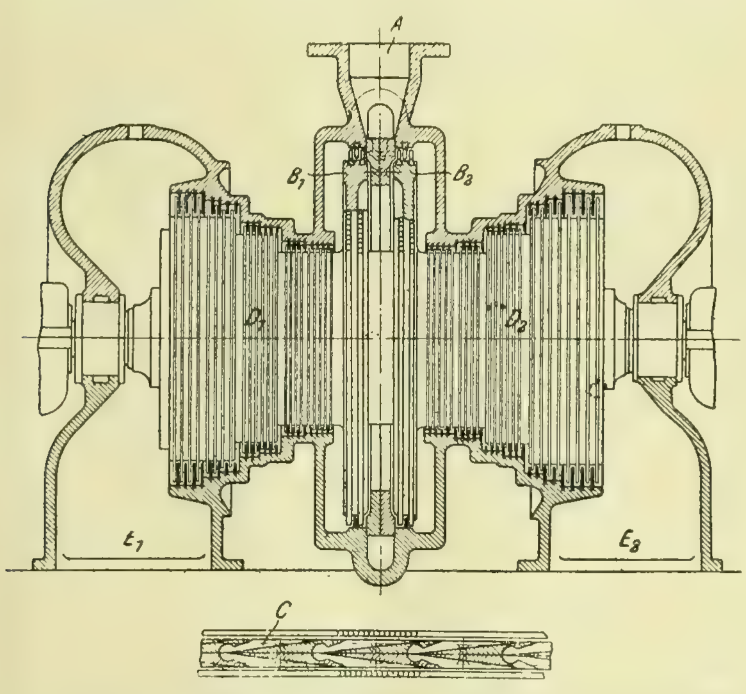


FIG. 2.—WESTINGHOUSE DOUBLE-FLOW TURBINE (PATENT DRAWING, 1904).

machine was built by Parsons in 1884 may be divided into two periods of a more or less distinct character. During the earlier period, which may be called the invention period, new types of turbines different from those built previously were developed. The distinct types introduced during this period are called according to the name of the inventor, Parsons, de Laval, Curtis, Rateau, or Zoelly turbines, and consist, with the exception of the de Laval turbine, of a certain number of elements designed on the same principle. For this reason these types are now always referred to as "pure" Parsons turbines, or "pure" Rateau turbines, &c. The following table gives a summary of the main events during this first period*:—

Parsons Turbines.

Date.

1884. First Parsons turbine built, 10 b.h.p., running at 18,000 revs. per minute, driving direct-current generator.

1888. Parsons reports before the Institution of Mechanical Engineers on a turbine of 50 b.h.p., running at 7,000 revs. per minute, and 200 b.h.p., running at 4,000 revs per minute.

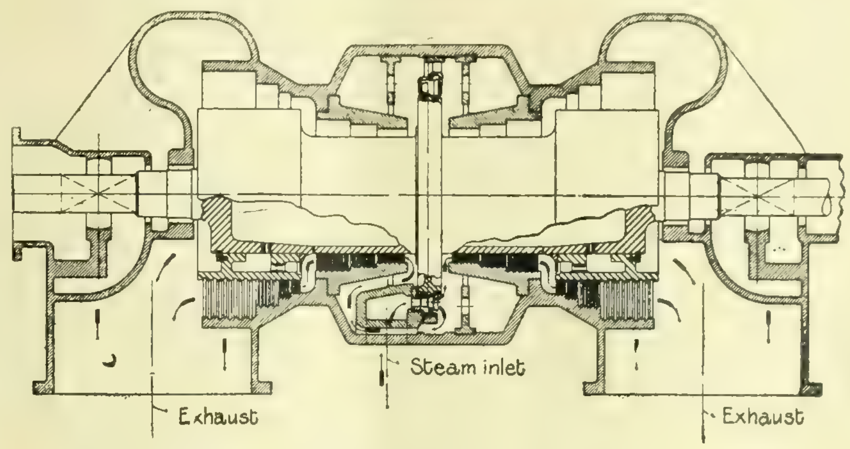


FIG. 3.—SECTION OF MODERN WESTINGHOUSE 15,000 KW. MAXIMUM RATED DOUBLE-FLOW TURBINE, 1,800 REVOLUTIONS PER MINUTE.

1895. Westinghouse Machine Company secures the license for the manufacture of Parsons turbines in the United States. This was the first license granted.

1898. First Parsons machine on the market in America.

1898. First Parsons turbine ordered for Elberfeld, Germany —two turbines each of 1,500 h.p., being the largest of their type running up to this time.

1901. Brown-Boveri secures the Parsons license for the Continent.

de Laval Turbines.

1883. First de Laval turbines with straight nozzles.

1889. First de Laval turbines with divergent nozzles.

1893. de Laval turbines with gears exhibited in Chicago.

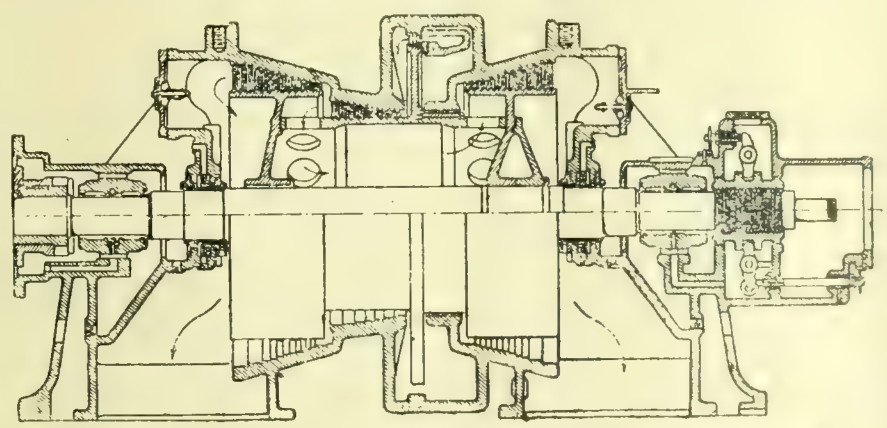


FIG. 4.—COMBINED DISC AND DRUM SINGLE-FLOW, DOUBLE-FLOW TURBINE, WESTINGHOUSE COMPANY, 1906.

Curtis Turbines.

1896. First Curtis patents.

1900. General Electric Company, of Connecticut, takes up the building of Curtis turbines.

1900. First tests on steam turbines made by the A.E.G. Company.

1904. The A.E.G. Company commence the commercial manufacture of A. E. G.-Curtis turbines on a large scale.

Rateau Turbines.

1894. First tests on steam turbine problems made by Prof. Rateau.

* Paper read before the Manchester section of the Institution of Electrical Engineers, January 16th, 1912.

* C. Matschoss, "Die Entwicklung der Dampfmaschine," Berlin, 1908, Vol. II. p. 608.

1898. First Rateau turbines built by Sautter, Harle, & Co., of Paris.
1900 First tests on Rateau steam accumulators.
1902. First commercial use of Rateau accumulators.

Zoelly Turbines.

1903. First commercial Zoelly turbines tested on test-plate.

Development of the Different Steam Turbine Types since 1902.—During the second period, which may be called the development period, the design of the steam turbine has been perfected on the basis of the experience gained on the existing turbines, and of experimental research work founded on the theory of steam turbines. This was made possible to a very great extent by the fundamental work of Prof. Stodola. The year 1902 may be taken as the beginning of the second period of turbine development. During this period not only were great improvements made in the design of the various pure types, referred to above, but further advantages were gained by combining these types in such a manner as to obtain the best results, both with regard to reliability, efficiency, and cost.

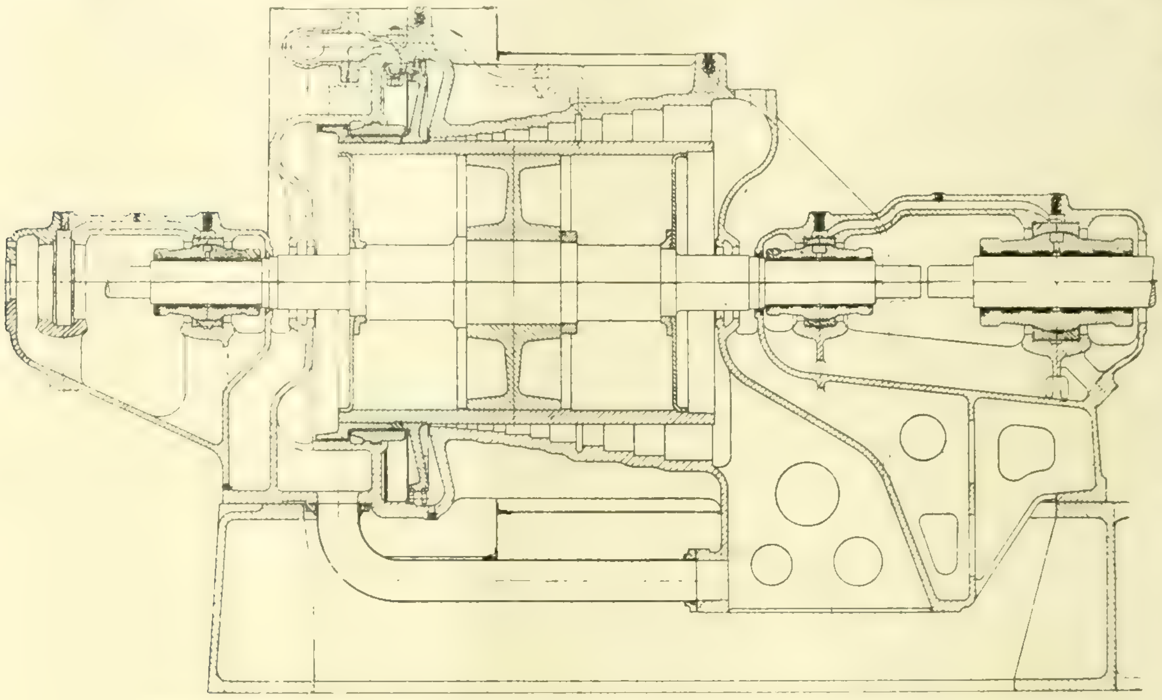


FIG. 5. WESTINGHOUSE SINGLE-FLOW TURBINE. BRITISH WESTINGHOUSE COMPANY, 1905.

In order to follow this development clearly, it is necessary to consider the advantages and disadvantages of the different types These are dealt with below in the following order: (1) Parsons turbine, (2) Curtis turbine, and (3) Rateau and Zoelly turbines.

The de Laval turbine has been excluded from the descriptions, as, owing to its design, it can only be used for small powers, and it has been developed to the highest degree of perfection by the inventor, de Laval, himself. de Laval's work in this connection, in overcoming difficulties of an absolutely novel character, which involved the origination of quite new methods, has proved him to be one of the master minds in engineering

1. Development of the Parsons Turbine.—The Parsons turbine (Fig. 1) is a multi-stage reaction turbine of the drum type, running at a moderate peripheral velocity The fact that until very recently it has been built upon exactly the same principles as the first turbine in 1884, and that it has competed very successfully even with the newest types, reflects the greatest credit on its inventor, to whom, as the originator of steam turbines, we all pay our tribute

The pure Parsons turbine has the great advantage of a moderate peripheral velocity which allows a very simple design of fixing the blading. This, in addition to the relatively small drum and cylinder diameters, enables this type of turbine to be manufactured at a considerably lower cost than steam turbines with discs and diaphragms.

One of the main disadvantages of the Parsons turbine is that the high-pressure part of the cylinder is subjected to the highest steam pressure and superheat, which becomes more accentuated by the necessity of small clearances in that part, and by the growth of cast iron after repeated heating. A further disadvantage is the use of the balance pistons with very small clearances.

The first attempts to overcome these difficulties were made by George Westinghouse, who replaced the high-pressure stages by a Curtis wheel, and overcame the difficulty of the balance piston by using the double-flow arrangement, which had already been used by Parsons on his first turbine in 1884. Fig. 2 gives Westinghouse's patent drawing.

This arangement, which practically means the use of two separate turbines, is too expensive for small units, and is therefore only applied for large outputs. The duplication of the velocity wheel shown in the drawing is, of course, not necessary, as the pressure in front and after the wheel is the same, and a special arrangement for balancing this part is therefore unnecessary. A modern design of such a turbine is shown in Fig. 3, which represents a section of a 15,000 kw. maximum-rated double-flow turbine, running at 1,800 revs. per minute, which was supplied to the City Electric Company, San Francisco, in 1909.

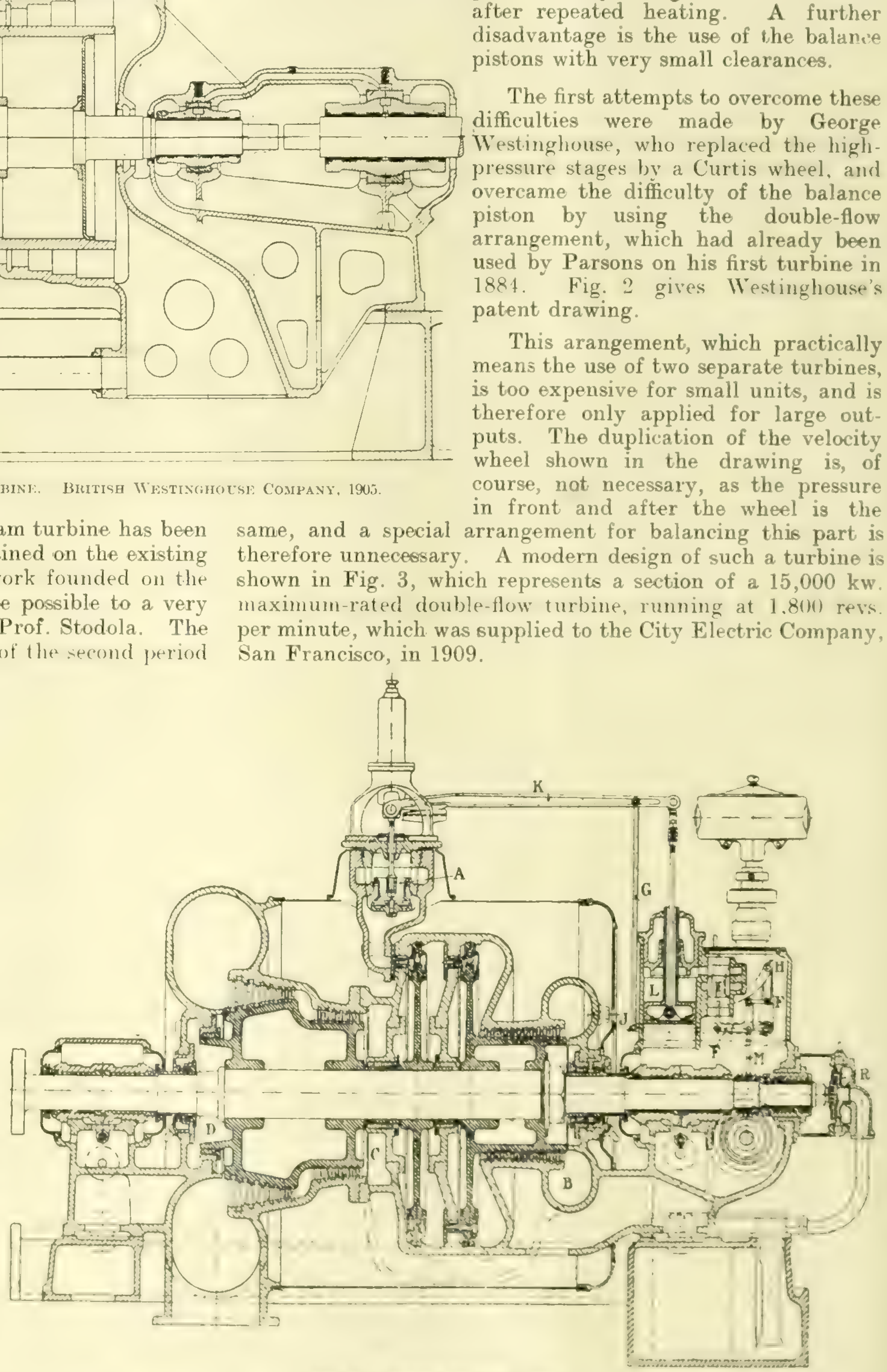


FIG. 6.—SULZER TURBINE, 1909.

For smaller outputs the American and British Westinghouse Companies developed in 1906 the type shown in Fig. 4, which may be called a combined disc and drum single-flow double-flow turbine The high pressure part consists of one velocity wheel and one Parsons drum, and the low-pressure part consists of two drums, through which the steam is flowing in opposite directions This arrangement necessitates, however, a dummy piston in the centre of the turbine.

and therefore cannot be considered as a very perfect solution of the problem.

For small outputs, where a double-flow turbine is too expensive, the British Westinghouse Company developed in the year 1905 a type shown in Fig. 5, which is known as the single-flow disc and drum turbine, consisting of one Curtis wheel in the high-pressure part of the turbine and a Parsons drum of uniform diameter in the low-pressure part, with corresponding balance piston on the high-pressure end.

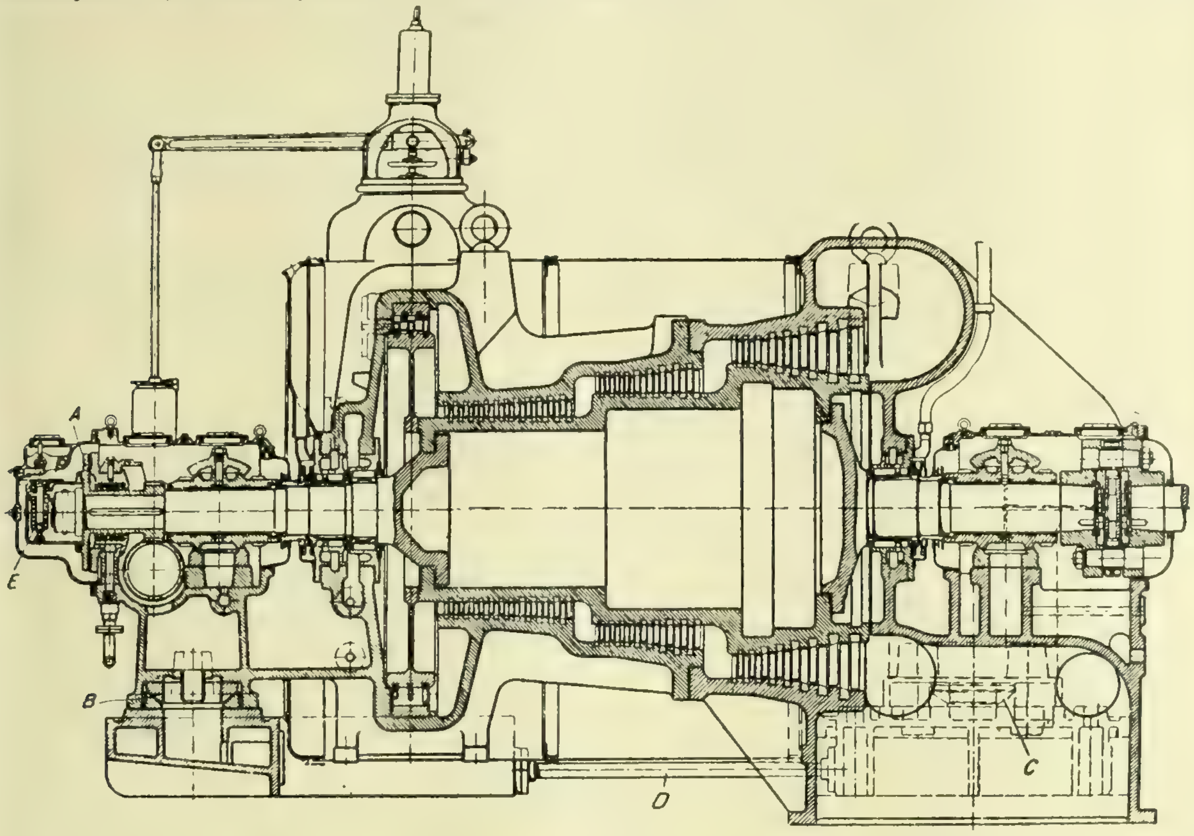


FIG. 7.—SULZER TURBINE, 1906.

One of the first firms to replace the high-pressure part of the Parsons turbine by velocity wheels was Messrs. Sulzer Bros. The first turbine manufactured in 1904* (Fig. 6) consisted of two Curtis wheels in the high-pressure part and two single-flow Parsons drums. The difficulty with regard to the balance piston was overcome by causing the steam to flow through the medium-pressure Parsons drum, in the opposite direction to that through the low-pressure drum. This arrangement necesitates diaphragms with glands in the centre of the turbine and a passage in the cylinder to pass the steam from one end of the turbine back to the centre of the turbine.

For the newer design (Fig. 7) the straight single-flow type† has been used, with one velocity wheel with three rows of blades in the high-pressure part in order to reduce the pressure in the turbine as much as possible (to about 1·5 atmosphere absolute), and three single-flow Parsons drums with increasing diameter towards the low-pressure end of the turbine. The thrust of the Parsons drum is balanced by an automatic oil piston in connection with a thrust bearing, which forms one of the greatest novelties in steam turbine design. Another feature of their newest designs is the governing of the turbine by oil pressure at the discharge side of a centrifugal pump, without the use of a mechanical governor.

* A. Stodola, "Steam Turbines," 3rd edition, p. 313.
† *Ibid.*, 4th edition, page 468.

The attitude of the various firms building the "pure" Parsons turbines towards the development of the combined Curtis-Parsons type was followed with the greatest interest in engineering circles. A report of tests which had been made on a combined turbine of 1,000 kw. at 3,000 revs. per minute, manufactured by Brown-Boveri, was given by Dr. F. Maguerre in August, 1908*, the result of which was summed up as follows: "There are cases where a combined turbine may be of great interest, but in most of the cases the pure Parsons turbine will be superior to the combined turbine with regard to steam consumption and reliability, but not with regard to space required, which condition is, however, of little importance."

Dr. Maguerre claimed that a pure Parsons turbine for that output would be much more efficient, and that a combined Curtis-Parsons turbine would only be equal to a pure Parsons turbine for normal outputs below 500 kw., but that disadvantages with regard to wearing and pitting of the blades would not justify the application of the combined type.

A few months afterwards it was common knowledge that Brown-Boveri had taken up the manufacture of the combined type for smaller outputs. Their design is shown in Fig. 8, which at the present time is made by nearly all manufacturers of Parsons turbines and for all outputs.

This fact can only show that the improvements made in the later designs of the Curtis wheel justified its use, and the competition with other firms forced the manufacturers of pure Parsons turbines to adopt it. The new design, shown in Fig. 8, still retains the use of the balance piston, which, however, becomes much simpler than that on pure Parsons turbines, when used according to Fullagar's patents. The balance piston must, however, still be considered as the weak point of the turbine, and the future will have to decide which of the two methods of balancing is superior—by dummy pistons or by oil pistons, as proposed by Sulzer Bros.

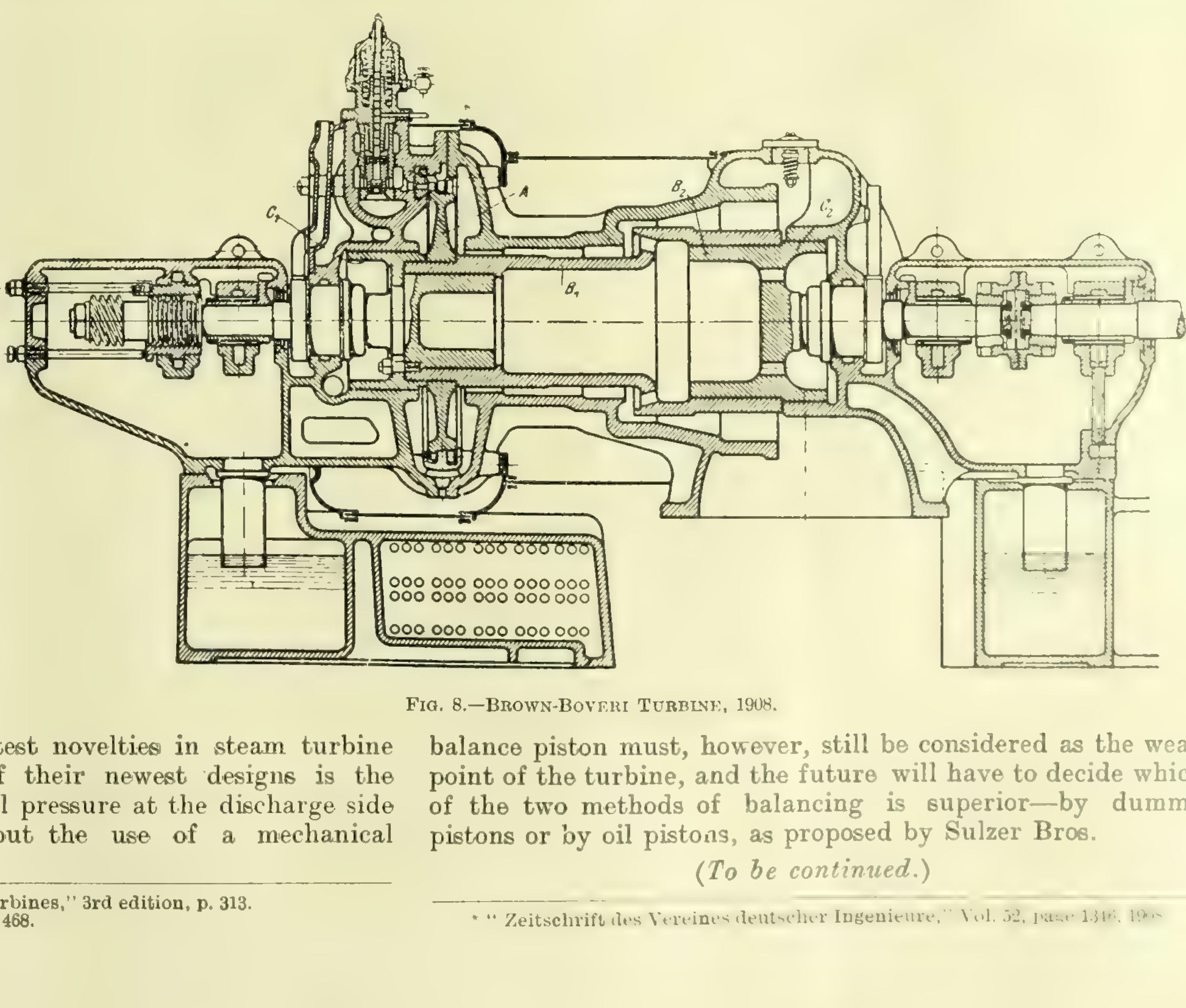


FIG. 8.—BROWN-BOVERI TURBINE, 1908.

(To be continued.)

* "Zeitschrift des Vereines deutscher Ingenieure," Vol. 52, page 1316, 1908.

ENGINEERING SPECIFICATIONS.*

BY MICHAEL LONGRIDGE, M.A., M.INST.C.E.

PRESIDENTIAL addresses I have noticed are usually composed after one of two well-known forms, the one discursive, embodying, like a small scale map, a comprehensive survey of the wide-spread fields which accumulated experience and scientific research have enabled engineers to occupy and conquer; the other circumscribed, reviewing in detail the progress of that particular battalion of the professional army to which the speaker may have been appointed to serve his generation and posterity.

Both forms, as examples of the survival of the fittest, demand the consideration and respect of every writer of a president's address, and yet I find difficulties in following either. I have neither the experience nor has my recent enforced idleness given me time to acquire the second-hand knowledge needed to give an adequate account of present-day engineering practice as a whole. Too many of the most important engineering works, such as roads, railways, canals, harbours, docks, warehouses, ships, telegraphs, telephones, water-works, sewage-works, lie outside the somewhat narrow groove in which it has been my lot to earn my bread and butter. And if I confined myself to a review of my own experience as engineer of a boiler insurance company, I fear I could tell you little that most of you do not already know. The generation and transmission of power, the design of the necessary machinery and its pathology, have occupied the thoughts of most of the members of the Association, as they have my own. The various types of boilers, steam engine, and condensers, the older modes of transmission by spur gears and ropes are familiar to all of us. The principles governing their construction and working and the economic results obtainable are known more or less accurately to most. The newer methods of heat transmission and combustion, investigated experimentally by Dr. Nicolson and Dr. Bone, the more modern prime movers, the steam turbine, the large gas engine, the Diesel oil engine (thermodynamically the most economical heat engine yet materialised in steel and iron) and the transmission of power by electricity, have been ably dealt with in papers which have been or will be brought before us. Therefore, in connection with these subjects there is little left for me to dwell on but technical details which are hardly suitable for an occasion like the present, when we expect less serious entertainment than at our ordinary meetings. I ask permission, therefore, to step outside traditional limits and for the usual retrospective or prophetic, general or special, survey of engineering practice, to substitute some remarks on the specifications for the design, manufacture, and sale of power plants, in which so many of our members are concerned, and incidentally on the mutual relations, duties, and interests of purchasers, contractors, and consulting engineers. Probably everybody in the room (for even an office-boy appreciates the temper of his chief) knows something of the irritation and expense to which the interpretation of these documents so frequently gives rise, especially when they are modified and supplemented by "understandings" which in nine cases out of ten become misunderstandings, leading to the intervention of arbitrators, solicitors, and other gentlemen of the long robe. Indeed, it seems to me questionable whether disputes with men or disputes with customers cause the greater worry and waste of time and temper in an engineering shop.

I therefore allow myself to hope that the reflections of one who has been concerned for many years in the drafting and interpretation of these documents and in the settlement of disputes concerning their true intent and meaning may not be deemed irrelevant to the purpose for which we have met to-night. And first I would say a word about the purchaser, for not only does every contract of the kind we are to consider originate in his necessities, but its harmonious execution and peaceable liquidation are largely in his hands, since he holds the power of the purse. He may be sparsely represented here, but he is not on that account to be ignored. On the contrary, his manifold idiosyncrasies and changing character merit the consideration of all who have business relations with him. Some of our older members can recollect the time when mills and works were largely owned by individuals who devoted their energies to their own trade and neither understood nor pretended to understand the mysteries of engineering. When engineering was required they called in the family engineer with as little hesitation as under other circumstances they called in the family doctor or the family solicitor. They put themselves into his hands, accepted his advice, took what he gave them, paid his bill, and usually were content. Much good work was done in this way, for the engineer was intimately acquainted with the requirements of his customer, his men knew every bolt and key about the customer's mill; time and first cost were not considered as they are now, and the engineering skill required to turn out a good job was less. On the other hand, progress was slow, for engineers, deferred to and uncriticised by their customers, became opinionated, intolerant of change, and antiquated in methods and designs.

Purchasers of this type have practically passed away, and with them, as was inevitable, many of the engineering firms whose prosperity had become dependent on their custom. Municipal committees and joint-stock companies have superseded them. The directors and managers of these companies no longer confine their attention to their own work. They keep observant eyes upon their neighbours. They compare their own methods and costs with their competitors. If chary in giving information, they are seldom backward in asking for it, and they have learnt that the world contains more than one firm of engineers who can do good work. The result is that work is now usually put out to tender, and has therefore to be described in more or less detail in specifications for the protection of both purchaser and contractor.

Now the drafting of a clear, complete, and practicable specification is not by any means a simple matter. It demands not only a theoretical knowledge of engineering, but an intimate acquaintance with workshop methods, and with the requirements of the trade in which the machinery to be tendered for is to be used. It is to careless drafting, and to careless reading of specifications, that most of the disputes between purchasers and contractors are due. Some of the larger joint-stock companies and corporations have in their service engineers of knowledge and experience, capable of drawing specifications and supervising work, but the majority have to depend upon consulting engineers, or upon the contractors who desire to tender for the work, unless, as often happens, their directors elect to manage the business by such light as nature may have vouchsafed to them. In the last case the procedure is generally as follows:—

The object aimed at is explained, so far as it is understood, to the representatives of several contracting firms, who are asked to furnish plans and specifications showing how it is to be accomplished, together with estimates of the cost. Most of these plans are models of concise pictorial exposition, just what are needed to show clearly the main outlines of the schemes proposed, but the specifications are usually extremely vague, abounding in such expressions as "great strength," "ample capacity," "large bearing surfaces," "highest class of workmanship," "best materials," and the like, but containing few dimensions or details of the accessories to be included in the contract price. The consequence is that the directors, who, with the assistance of their manager and enginemen, can generally understand the plans, are quite unable to compare the specifications or to decide (and small blame to them) which gives the best value for the tendered price. Then the contractors are recalled, and after much bargaining one of them is induced to accept the plan and specification which the directors consider most advantageous, at or below the price quoted in the lowest tender.

No doubt under this system orders can be placed at exceedingly low prices, but I question whether, on the whole, those who adopt it get as good value for their money as others who employ and pay professional advisers. The contract prices are too often supplemented by bills for extras, and the completed work marred by makeshifts, especially if it consist of alterations of or additions to existing plant. The guarantees, if any, are found to be elusive because the conditions demanded for the tests are not to be obtained. It can hardly be otherwise when contracts are based on incomplete preliminary plans and specifications of the type I have referred to. Moreover, work done in this way often fails to satisfy, not because contractors are dishonest, but because

* Presidential address delivered before the Manchester Association of Engineers, January 13th, 1912.

purchasers do not know what they really need. The statement may seem exaggerated, but it is true. Provision of insufficient power and the adoption of types of machinery unsuitable for the work to be done, at the instance of men directing engineering work without engineering knowledge, are within the experience of every contractor and consulting engineer. From the contractor's point of view also the practice is unsatisfactory. The preparation of preliminary plans, with the knowledge that, except in rare cases, they will not be paid for, and may even be handed over to a competitor to be carried out, takes all the pleasure out of the work, and the too frequent quarrels over extras and final reductions of already cut prices, to get a settlement after the completion of the job, create disgust.

In other cases the directors send the plans, specifications, and tenders they have received from the contractors to a consulting engineer. They do not ask him to study the circumstances of the case and prepare a plan and specification of his own, but simply to advise which of the plans and tenders submitted is the most advantageous. If the engineer keep within the limits of his instructions, I do not think his employers benefit much. He can certainly tell them which of the plans submitted is the best from a purely engineering point of view, but whether that plan be the most suitable having regard to the local and trade conditions and possible future requirements of his employer he cannot tell. To decide these points usually requires information which contractors' plans and specifications do not give. He probably has sufficient experience of the work of each contractor tendering to form a rough idea of the general character of the design and workmanship of the plant likely to be supplied, but in appraising the exact significance and scope of specifications of the vague character usually submitted he is nearly as helpless as his employers. If he be wise, he will explain the difficulty to them and suggest that he should go into the matter himself, decide what ought to be done, and draw up his own specification for the work. Modesty, however, may prevent him from offering services which he has not been asked to render, and pride from risking an intimation that they are not required.

In that case he does the best he can with the material available and advises the acceptance of one of the specifications and tenders, in most cases with some alterations and additions. The directors then make their bargain with the contractor selected and a more or less formal contract follows. Usually the contract provides that the consulting engineer shall inspect the plant during construction and certify that it is in accordance with the specification, but very often it is agreed that he shall also settle all details of the design. Sometimes the question of inspection is only raised after the contract has been signed. This I think is hardly fair, for even when the specification is perfectly definite and the inspector reasonable, his presence causes some expense, and when the specification is indefinite and the inspector faddy the expense may be very great. The remedy, fortunately, lies in the contractor's hands. He can always find out if his work is to be inspected before he signs a contract, and if his specification be so indefinite that an inspector can put him to any great unforeseen expense he has no one but himself to blame.

As an inspector under such a contract the position of the engineer is delicate and difficult. Some people seem to think that it is his duty to become a mere tool for squeezing the contractor by interpreting the specification and contract solely in their own interest, by twisting every ambiguous expression to their advantage and using every pretext their ingenuity can suggest for extracting work or money from him. I hope that no consulting engineer belonging to this Association will suffer his authority to be prostituted in this way. I maintain that it is his duty to hold the scales of justice fair, to see that his employer gets the thing the contractor has tendered for in workmanship, material, and design, but not to force the contractor into expenditure which he never contemplated when he made his tender, because the indefinite wording of the specification might be stretched to cover such expense.

I think an engineer inspecting under an indefinite and ambiguous specification should have some regard to the price at which the work was taken, and the style of design and finish customary at the shop at which the work is done. Let me not be misunderstood. No consideration of this kind should induce an engineer to pass bad material, dangerous designs, or obviously insufficient strengths, but there are many matters of design and finish which are held to represent the best practice in some shops, while classed as second-rate in others. These are the cases in which doubts arise in the mind of any man anxious to be fair.

Let me put a hypothetical case by way of illustration. Suppose two firms tender for a steam engine of the best material and workmanship. One is in the habit of fitting all joints in the valve gear with box ends, bronze steps, and wedge adjustment; and the other uses plain gun-metal bushes. In both specifications the valve gear is described only by the words "of extra strength." The purchaser drives his bargain with the firm accustomed to use plain bushes, and when the contract has been made and the work is in progress, tells the consulting engineer to compel the contractor to substitute box ends, bronze steps, and wedge adjustments for the plain bushes, on the ground that the words "best material and workmanship" entitle him to have them. Or, again, suppose the order given to a contractor who is in the habit of fitting the piston-rod crosshead with a slipper without any means of adjustment, except a liner, and of casting the slide as part of engine bedplate. The only stipulation in the specification as regards these parts is "that the crosshead shall be fitted with a cast-iron slipper of ample surface." But after the contract has been signed the purchaser requires the consulting engineer to insist on a screw or a wedge adjustment for the crosshead slipper, and a slide cast separately from the bedplate and fitted into the latter.

In cases like these, which crop up every day, what ought the engineer to do? Should he enforce his employer's demands? I think not. I think in such cases the maxim *caveat emptor* spells "equity as well as law," and a man who signs a contract without ascertaining exactly what he is going to get has no right to feel aggrieved if he gets not everything he thinks he ought to get. But if it is difficult for the engineer merely to interpret an indefinite and ambiguous specification fairly, what is his position when he is held responsible for all details of the designs? I have been forced into that position more than once, and I say that it is intolerable. To do justice to the contractor and to give satisfaction to his employer and to himself is well nigh impossible. His experience, or, if you prefer, his fads, which are the outcome of his interpretation of his experience, may constrain him to call for alterations of the contractor's usual designs, which may involve the latter in expenses never contemplated when he estimated for the work, and at the same time lead to mistakes and mishaps in execution which may seriously affect the efficiency of the plant, or even lead to its total failure, for a manufacturer forced out of his beaten track may easily lose his way. In every path the engineer may tread are pitfalls so carefully concealed that he who traverses the road for the first time is almost certain to stumble into one of them. Experience as well as knowledge is needed to ensure success in engineering. If any doubt this aphorism, let me advise him to defer attempting to "show his faith by his works" until he has had opportunities of watching the experiment tried by others. On the other hand, if the engineer accept the contractor's designs and workmanship as complying with a fair and honest interpretation of the specification, he may render himself responsible for work which his own judgment condemns as second-rate, and later on be compelled to take the blame for any mishap which he may have to tell his employers might not have occurred had some design, other than that sanctioned, been adopted.

I hope I have said enough to make it clear that, in my opinion, such methods of doing business are not for the advantage of the purchaser, and are most unsatisfactory for the engineer or the contractor, and sometimes for both of them. I think others are coming to the same conclusions, for there is, in my experience at least, a growing minority who believe that it pays to employ an experienced engineer to advise what should be done, to draw up the specification and contract, to supervise the work during construction, and test it when complete. When thus employed the engineer's first duty is to find out exactly what his employer needs. This is not always easy, for, as I have stated, many would-be purchasers do not know definitely what they want, much less what they need. Others again are so stupid as wilfully

to mislead or at least refuse to help the engineer. More than once I have myself been told that it was my business to find out what my employer wanted, and not to try to transfer my responsibility to him.

When all the information available has been collected, it should be set out in writing and sent to the employer for confirmation or correction. Only after a written statement has been agreed to should the engineer begin to plan the work required, and, when planning, he should always look ahead. To hear a sermon once a week is generally regarded as a necessary refreshment in a well-ordered life. I have no doubt we all enjoy it at church, chapel, or street corner. If so, we must have heard that in the spiritual life there is no standing still: man always progresses or retrogrades. Businesses are subject to the same law, and the engineer who fails to provide, whenever possible, for extensions is presupposing decadence rather than prosperity for his client—which is hardly fair. Who here has not heard of slow speed on Monday mornings, of struggles with insurance companies for higher pressures, of over-burdened engines, springing shafting, and broken gear, all because the plant when it was put down was only sufficient for the immediate requirements of a business that increased. The provision of means of escape from these inconveniences should receive the most careful consideration of every designer of a power plant.

Having thought out one or more schemes and laid down their main features on paper, the engineer should take the drawings to his employer and discuss them on the site of the intended work to see that they are practicable, to decide which is the most suitable, and to make sure that all necessary work, especially all connections to existing machinery, have been considered. Thus only will makeshift alterations during the progress of the work and bills for extras on completion be avoided.

This work completed, he may proceed to draw his specification. Now specifications for power plants, and many other things as well, may be divided, as regards their technical clauses, into two classes:—

(1) Those which describe the plant and its accessories in detail, the dimensions of the principal parts, the materials to be used, the methods of manufacture to be adopted, the tests to be applied, and the conditions under which these last are to be carried out; and (2) those which state only what the plant or machinery has to do and what tests it will be required to pass, leaving the contractor free to obtain the specified results in his own way.

I cannot say that either meets the needs of the present time. A specification drawn in great detail may add unnecessarily to the cost of manufacture, and therefore to the price charged to the purchaser by compelling the contractor to make new drawings and patterns where old, but for the restrictions of the specification, would have served. It is also perplexing to the estimator in the office and harassing to the foreman in the works. It is a source of anxiety and risk to the contractor and often lays an unfair burden on the shoulders of the engineer, for the contractor will certainly attribute every mistake and imperfection of workmanship to its prescriptions rather than to faults of his draughtsmen, artisans, and machinery. It is quite right that a consulting engineer who forces an unwilling contractor to adopt a design not distinctly described in his specification should be responsible for the consequences, but when a specification is clear and a contractor has accepted it without demur, he has no right to throw back his responsibility upon the engineer. If he objects to the specification he should state his objection before tendering, or refuse to tender.

On the other hand, if the consulting engineer specify only the results required and leave the contractor to obtain them how he will, he is inviting his client (unless he be dealing with the standard designs of well known makers) to open his purse and shut his eyes and take the contractors' ability and honesty on trust. Well, gentlemen, like Disraeli, I am on the side of the angels. I am proud of the loyalty of Lancashire engineers to their engagements, but I also remember that the garments of civilised life leave little room for wings to grow, and that even angels living in an atmosphere of unrestricted competition, and under the supervision of the shop steward, are sorely tempted to turn their feathers into gold, and may, under temptation, fall. To hold a falling angel up is a troublesome and thankless, sometimes even a cruel task. Few can undertake it without provoking feelings of resentment and accusations of injustice, which react upon the relations between the contractor and the purchaser, turning into a bone of contention that which should have been the seal of a covenant of mutual appreciation and respect.

There is also a third method. It consists in inviting would-be contractors to send in specifications and drawings for the work required, and making use of these without acknowledgment or remuneration to compile a specification embodying selections from the originals, with additions from the inner consciousness of the engineer. The new specification is put forward as the engineer's, and contractors are asked to tender to it, and sometimes to pay for the privilege of tendering. Many of these specifications, like the nostrums of a mediæval leech, are made up of the most incongruous ingredients, and are apt to disagree with the contractor who accepts them; also the fee to be paid for them is often in proportion to their complexity. The only difference is that while the old leech had to find materials at his own cost, the modern practitioner steals his from his patients. I do not think the method is one which members of this Association will commend.

Of the other two methods, except when dealing with standard designs, I think the first, viz., specification in detail, is much to be preferred, but I fear that, as the child of the consulting engineer, it is unlikely to survive. It is an exotic, too costly in time and money for the present industrial conditions. There seems, however, no good reason why it should not be adopted by the contractor, and if it were I feel confident that the trouble expended in licking it into shape would amply repay its foster-father.

Let manufacturers of power plants, engines, boilers, gas producers, and the like issue their own specifications, not as so many do now, in the vague language I have quoted, but in full detail, in greater detail than can be attempted by any consulting engineer, and let them illustrate their descriptions by photographs and drawings in such a way that the engineer who reads may understand the thing that is described as accurately and completely as if he had examined the thing itself. Of course, the preparation of such specifications implies standardisation, not necessarily of dimensions, for that is not always practicable commercially, but rather of typical designs and permissible stresses. The specification accompanying a contractor's tender would then consist of two distinct parts—one variable, defining the special characteristics of the particular plant to be supplied, the other standard containing the description and illustrations of the designs and finish adopted by the contractor for every plant of the same kind.

Let me give one short example of my meaning. Take the case of an ordinary vertical air pump. The variable part of the specification would merely state that the particular pump tendered for would be vertical, of n inches diameter and m inches stroke, driven in such and such a way, and requiring q gallons of water per minute at t degrees to maintain a vacuum of p per cent. of the barometer with the rated load upon the engine. The standard part of the specification would show the characteristics common to all vertical air pumps made by the contractor, and would explain by illustrations and descriptions all details of design, such as the method of fastening the bucket to the rod, the type of foot bucket and delivery valves adopted, the means of securing their grids and guards, the kind of snifting valve, injection cock, and vacuum breaker supplied, the maximum stresses permitted on bucket rods, the precautions taken to prevent splashing from the hot well and to preserve the foundations from oil and water, &c. If such description were furnished by contractors, consulting engineers could curtail their specifications of air pumps to statements of the type of pump preferred and the temperature of the cooling water available. They would know exactly what contractors intended to supply, and could arrange any modification in the designs presented before accepting tenders.

In opposition to these proposals, it is said that standardisation would be useless because consulting engineers would ignore the manufacturers' designs and insist upon the substitution of their own. So far as I can judge from the assistance I have received from the printed descriptions and illustrations of standard articles issued of late years with their tenders by many of the larger manufacturing firms, I feel convinced that as soon as these descriptions and illustrations are made sufficiently complete consulting engineers will

cease to compile the elaborate documents they are compelled to issue now, and will limit their specifications to descriptions of the type of plant required, the work to be done, the tests to be passed, the conditions under which the tests are to be made, the nature of the guarantees required, and the penalties to be exacted for non-fulfilment.

It is also said that standardisation is undesirable, because it has a tendency to stereotype designs and to retard progress. A national system of standards, unless carefully restricted, is extremely likely to have this effect, but sectional standardisation by individual firms coupled with publication will have just the opposite effect. For the competition of other firms and the criticisms of purchasers and consulting engineers will keep designing and modification of standards up to date.

Publication also is objected to, on the ground that it enables a man's competitors to copy his designs and reap the harvest of his labours. I should not be sorry if this were true, but in my opinion it is not. The law of England says that the drawings in a patent specification must be such that a competent man can manufacture from them. I wonder how many machines manufactured from a patent specification alone would find a sale! So it is with other drawings and descriptions. They must be supplemented by experience to have a marketable value. But even if copying be possible, who suffers? If a man's competitor can appropriate the good points of his designs, he can appropriate the good points of his competitors.

The only result worth consideration is that progress is accelerated, and, with Lancashire importing steam engines, gas engines, and electrical machinery from the Continent, the acceleration cannot be too rapid. I have heard that engineers in by-gone times were wont to add odd inches and eighths to 6ft. for the stroke of the beam engine, and to use screws with curious threads to hinder repairs of their engines by any but themselves. I suppose the 6ft. stroke and Whitworth thread were deemed subversive to private interest then. In holding out for secrecy in engineering in 1912, are we any wiser than our fathers were?

And now I must bring my reflections to a close. When I decided on the subject of this address I intended to have said something about tenders and contracts as well as specifications, but I find I have already detained you long enough. Nevertheless, the astounding agreements sometimes entered into by contractors and the unexpected interpretations sometimes put upon them by purchasers and their engineers clearly indicate that these important documents are often prepared and signed without proper consideration of the liabilities they entail. Let me only quote two cases in support of my assertion.

The first is an instance of a reckless contract. Here a contractor undertook to replace an existing steam engine by a new one for the value of the fuel to be saved during a certain number of years, without any stipulations as to the means to be adopted for ascertaining the coal consumption or the horse-power either before or after the replacement, or as to the date when payment contingent upon the realisation of a saving over a number of years would become due, without even settling whether the saving should be reckoned on the total fuel bill at the mill or only on the value of the coal burnt in raising the steam used by the engine. Naturally the contract led to a dispute.

The second is an instance of unexpected interpretation of a very ordinary guarantee and penalty clause. The contractor guaranteed rates of steam consumption under penalties at full load, three-quarter load, half-load, and one-quarter load, and failed to obtain the guaranteed rates. The engineer, whose decision under the specification was to be final, claimed the sum of the four penalties and obtained legal opinion to support him. A pretty quarrel ensued.

In conclusion, I must I fear plead guilty to having said some things which will displease some because they will regard them as impracticable, and other things which will displease others because they will regard them as stale platitudes. Let me suggest a rule of conduct with which neither purchasers, contractors, nor consulting engineers can quarrel. I take from the "de contemptu mundi" of St. Bernard, to which church and chapel alike owe some of their best loved hymns, and from a card hung up in an office for the edification of the clerks and callers. The language of the two is somewhat different, but the meaning is the same.

St. Bernard, asking who shall gain

> "The peace of all the faithful,
> The calm of all the blest,
> Inviolate, unvaried,
> Divinest, sweetest, best,"

answers: They

> "Who do the work that lies before them,
> Who mean the thing they say."

The office card enjoins each reader "to live so that he can look every damned man in the eye and tell him to go to hell!"

TECHNICAL "ROT" IN THE NON-TECHNICAL PRESS.

THE literature of engineering does not offer much that is humorous save when writers in popular periodicals essay to provide sensational matter for the general public, and then it not infrequently happens that accounts intended to harrow and startle the general reader only make the technical expert laugh. We do not, as a rule, undertake to provide amusement for our readers, and we trust they will excuse the slight trespass on our space involved in the reproduction of the following choice specimen from a recent issue of that popular periodical "Answers." Those who have any practical knowledge of steam boilers will probably think with us that if the effusion is devoid of accurate information it is at least funny.

BEWARE THE BOILER!

DANGERS ENCOUNTERED BY THE MAN WHO GETS UP STEAM.

The men who are employed in the boiler house of any big steam works are always working under conditions of considerable danger to their lives.

Between 30 and 40 lives are lost every year in this country as the result of boiler explosions, and hundreds are badly injured.

The bursting of a valve is one of the commonest of boiler accidents.

In a large steam dye-works in the North of England a boiler-minder met a fearful death in this way last year.

He was standing close to the huge boiler, when a valve burst: the steam rushed out with an immense roar, catching the luckless minder full in the face. He was killed instantly.

Sometimes bad boiler accidents are caused by the plates of the firebox becoming so eaten away by corrosion that they are unable to bear the pressure on them, and burst.

A bad accident of this sort occurred in the boiler-house of a large cement works a few years ago. The back and side plates of the huge firebox burst, with the result that an immense quantity of blazing fuel was blown out and hurled in a solid mass into a corner of the house. Two men who were near were caught up like feathers in the blast made by the explosion, and hurled with the blazing fuel into a corner of the boiler-house.

Every boiler-minder knows that when the slightest sign of leakage shows between the joint plates of a boiler that it is a danger signal, and he communicates at once with the works manager, who has the steam let out, and the leakage repaired straight away.

But sometimes a few drops of water may show at the joint plates as the result of what is known as outside evaporation. This may happen with a boiler that is in perfect order; but great care has to be taken when drops do appear at the joint plates, to make certain that the water is not coming from a leakage.

In a big melting works in the North of England a short time back a boiler-minder called the works manager's attention to a couple of drops of water showing between the joint plates. The manager, who was a careful man, had the steam shut off, and sent the boiler repairer to caulk the leak. Three hours later one of the minders observed another drop of water showing at the same spot, and showed it to his mates.

"It must be evaporation" said the man. "Anyway, we will finish the work with it as it is."

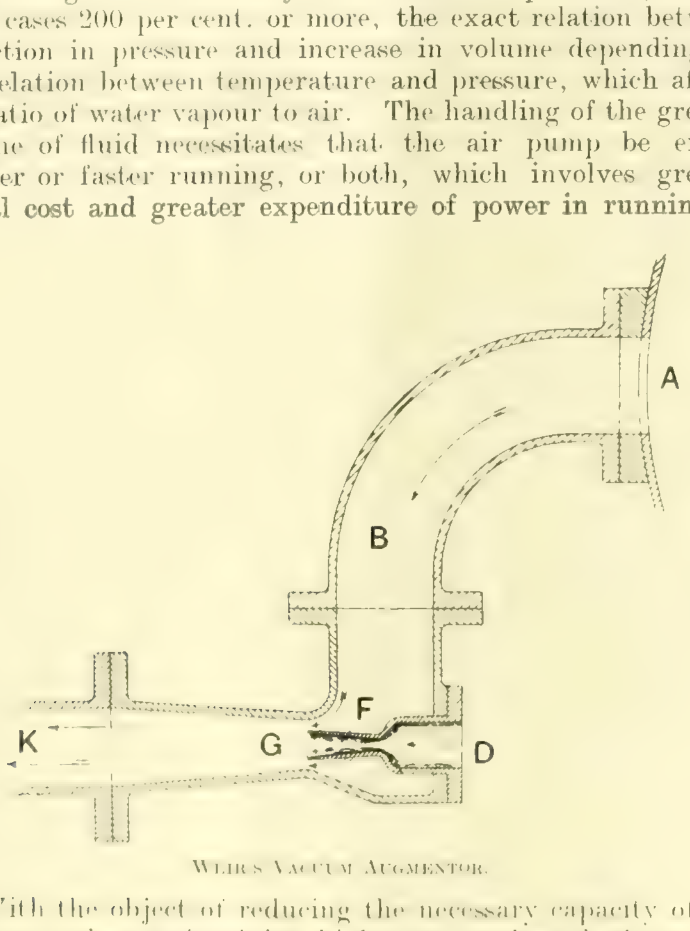
Hardly had he ceased speaking when the boiler exploded where the leak had been showing, a leak that had not been properly repaired.

A huge plate, 5ft. in circumference and a couple of inches thick, was blown across the boiler house as if discharged from a cannon. It hit the minder in the chest, and he was killed instantly. His mate escaped with a bad scalding from the out rushing steam.

Boiler accidents often occur when the boiler is being filled but an accident of this sort is usually due to the minder's neglecting to keep the pipes of the boiler clean and properly drained.

WEIR'S VACUUM AUGMENTOR.

AIR pumps are commonly employed to withdraw air and water vapour from condensers receiving the exhaust steam from steam turbines, the relative proportions of the air and water vapour depending on the pressure and the temperature. For a fixed temperature, a reduction in pressure increases the volume of the air, and, if the air were dry, the increase in volume would be exactly proportional to the reduction in pressure. The weight of water vapour which can be carried by a given weight of air is, however, increased by reduction of pressure (the temperature remaining constant) so that the increase in volume of the air and vapour with reduction of pressure is always greater than would be the case with dry air. It therefore follows that the lower the absolute pressure at the air pump suction, the greater must be the capacity, or piston displacement, of the air pump, in order that the pump may deal with the increased volume of fluid; and, in fact, the halving of the absolute pressure at the air pump suction requires of the air pump capacity or piston displacement being increased always more than 100 per cent., and in some cases 200 per cent. or more, the exact relation between reduction in pressure and increase in volume depending on the relation between temperature and pressure, which affects the ratio of water vapour to air. The handling of the greater volume of fluid necessitates that the air pump be either heavier or faster running, or both, which involves greater initial cost and greater expenditure of power in running.



WEIR'S VACUUM AUGMENTOR.

With the object of reducing the necessary capacity of the air pump when maintaining high vacua or low absolute pressures in the condenser, vacuum augmentors have been used or proposed consisting of nozzles fed with steam or water under pressure and adapted to discharge the steam or water into the air pump suction pipe and so to produce a difference in pressure between the condenser and the air pump suction. The air pump capacity can then be less than would otherwise be necessary to maintain any given high vacuum in the condenser. The use of water in such augmentors has the disadvantage that it necessitates a considerable increase in the capacity of the wet air pump or other water-discharge pump; and, moreover, the obtaining of the requisite quantity of fresh cold water often involves difficulties or complications; and in steam turbine-propelled ships, especially warships, any increase of weight is to be avoided. The employment of steam jet augmentors increases the steam or water vapour in association with the air in the air pump suction to such an extent that an auxiliary condenser has usually to be employed between the augmentor and the air pump, thus adding to the weight and complication of the system.

In the arrangement illustrated, the invention of G. & J. Weir, Ltd., Cathcart, Glasgow, and J. Petermoller, air at atmospheric pressure is employed in place of steam or water in the augmentor nozzle. If a given weight of air is expanded from atmospheric pressure to a low absolute pressure, say P, in a suitable nozzle, the kinetic energy obtained from the expansion is sufficient to compress an equal weight of air from a certain lower absolute pressure to pressure P, even when allowing for considerable losses due to eddies and due to the conversion of kinetic energy into heat energy.

By placing a suitable nozzle in the air pump suction pipe and allowing air at atmospheric pressure to enter this nozzle, a substantial difference in pressure is obtained between the condenser and the air pump suction. The amount of air with which the pump has to deal is, of course, increased by the amount which enters through the nozzle; but the water vapour is not increased, and, owing to the increase in the pressure, the resulting volume of fluid admitted to the air pump is less than would be the case without the air jet. The net reduction in volume is, of course, greatest in cases where the ratio of water vapour to air is great at the exit from the condenser. It is thus possible to obtain a reduction in the necessary air pump capacity without any consequential complications or increases in weight.

The air and vapour to be suctioned come from the condenser A through the passage B into the nozzle apparatus. The admission of atmospheric air is at D; and in the nozzle F this air expands and acquires high velocity, its available heat energy being transformed into kinetic energy. This air mixes at G with the air and vapour coming from the condenser, in sucking and compressing which it gives up its acquired kinetic energy; and the mixture passes to the air pump by way of the divergent nozzle and pipe K. It is not, of course, necessary that the air passed through the nozzle should be equal in weight to the air drawn from the condenser; and the best ratio to employ in any case will depend on the conditions of working.

SOME LARGE DIESEL ENGINES.

IT is not generally known, says "The Times" Engineering Supplement, that Messrs. Krupp have for some considerable time past been engaged on the question of the development of the double-acting Diesel engine for marine work. They were one of the first firms to take up the construction of Diesel engines, and have manufactured a very large number of two-cycle motors up to 1,000 h.p. working on the single-acting principle, most of which have been supplied to the Russian Government. Some time ago they built a single-cylinder double-acting two-cycle engine, and this has now been running successfully in the shops without giving any trouble, either with the glands or with the bottom cover, which has been the cause of some of the difficulties experienced with double-acting engines. It is worthy of note that up to the present there seems to have been no confirmation of the generally expressed view that double-acting Diesel engines would involve trouble with the glands, but the matter cannot of course be considered as settled until sea experience has been obtained. The single-cylinder engine of Krupp's was designed for 2,000 h.p., and actually developed 2,800 h.p.; and an engine is now being constructed in the Kiel works which will be suitable for a battleship, and will be of 12,000 h.p. It is anticipated by the builders that, at any rate for the present, cylinders will not be constructed of greater power than the one already running—nominally 2,000 h.p.—owing to the difficulties of getting rid of the heat. In point of fact, there does not seem any immediate necessity for larger sizes, since a six cylinder engine develops well over 12,000 h.p., so that a triple screw battleship would be provided with approximately the power necessary. The Diesel locomotive, which has been constructed by Messrs. Sulzer, is now undergoing its preliminary trials; but nothing is likely to be heard about the results for some little time yet.

The Old and the New Lathe.—At a recent meeting of the Glasgow Association of Foremen Engineers a lecture was delivered by Mr. William M'Chesney on "The Old and the New Lathe: A Friendly Criticism." The purpose of the lecture was to show that, notwithstanding all the improvements embodied in the new tools, much of the adaptability of the old was lost, and that the tendency of the present day tool makers was to elaborate. What was wanted, the lecturer said, was a simple, effective tool.

HOME OFFICE REGULATIONS OF HUMIDITY IN WEAVING SHEDS.

THE following regulations respecting humidity in weaving sheds have just been issued by the Home Office under the Factory and Workshops Act:—

These regulations shall come into force on April 1st, 1912, provided that paragraphs (*c*), (*d*), (*e*) and (*f*) of Regulation 6 shall not come into force until June 1st, 1912.

Provided further that the Chief Inspector of Factories may by certificate in writing suspend the operation of Regulation 1 (*a*) in respect of any *humid shed* for a period not exceeding two years from April 1st, 1912, if satisfied, after an enquiry at which the occupier and persons employed shall be heard, that all reasonably available means to keep down the temperature have been adopted, and that by reason of the circumstances of that *humid shed* it is not at all times practicable, notwithstanding the full use of such means, to prevent without cessation of *artificial humidification*, the wet-bulb reading of the *hygrometer* from exceeding 75°. Any such certificate shall be subject to the condition that the arrangements for cooling the shed shall be kept in efficient working order, and used whenever necessary, and in the event of any contravention of this condition the certificate may at any time be revoked by notice in writing from the Chief Inspector of Factories.

Definitions.

For the purposes of these Regulations,—

Humid shed means any room in which the weaving of cotton cloth is carried on with aid of *artificial humidification*.

Artificial humidification means humidification of the air of a room by any artificial means whatsoever, except the use of gas or oil for lighting purposes only. Provided that in a room in which there are no distributing pipes or ducts, the introduction of air directly from the open air outside through mats or cloths moistened with cold water shall not, if adopted solely at times when the temperature of the room is 70° or more, be deemed to be *artificial humidification*.

Dry shed means any room, other than a *humid shed*, in which the weaving of cotton cloth is carried on.

Degrees (of temperature) mean degrees on the Fahrenheit scale.

Hygrometer means an accurate wet-and-dry-bulb *hygrometer*, conforming to such conditions, as regards construction and maintenance, as the Secretary of State may prescribe by order.

Regulations.

1. There shall be no *artificial humidification* in any *humid shed*—

(*a*) at any time when the wet-bulb reading of the *hygrometer* exceeds 75°; or

(*b*) at any time when the wet-bulb reading of the *hygrometer* is higher than that specified in the Schedule of this Order in relation to the dry bulb reading of the *hygrometer* at that time; or, as regards a dry-bulb reading intermediate between any two dry-bulb readings indicated consecutively in the Schedule, when the dry-bulb reading does not exceed the wet-bulb reading to the extent indicated in relation to the lower of those two dry bulb readings; or

(*c*) at any time, after the first half-hour of employment in any day, when the dry-bulb reading of the *hygrometer* is below 50°; or

(*d*) at any time, within the first half-hour of employment on any day, when the wet-bulb reading of the *hygrometer* is less than 2° below the dry-bulb reading.

2, No water which is liable to cause injury to the health of the persons employed, or to yield effluvia, shall be used for *artificial humidification*, and for the purpose of this Regulation any water which absorbs from acid solution of permanganate of potash in four hours at 60° more than 0·5 grain of oxygen per gallon of water, shall be deemed to be liable to cause injury to the health of the persons employed.

3. In each *humid shed* two *hygrometers*, and one additional *hygrometer* for every 500 or part of 500 looms in excess of 700 looms, shall be provided and maintained, in such positions as may be approved by the inspector of the district.

A copy of the Schedule appended to this Order shall be kept affixed near to each *hygrometer* provided in pursuance of this Regulation.

4. In every *humid shed* the readings of each *hygrometer* provided in pursuance of Regulation 3 shall be observed on every day on which any workers are employed in the shed, jointly by representatives of the occupier and of the persons employed, between 7 and 8 a.m., between 11 a.m. and 12 noon, and (except on Saturday) between 4 and 5 p.m.

The prescribed Humidity Register shall be kept in the factory. If any readings taken as above are such as to indicate contravention of Regulation 1 or Regulation 5, the persons who have taken them shall forthwith enter and sign them in the prescribed Humidity Register, and a copy of each such entry shall also be sent forthwith, in the prescribed form, to the inspector of the district.

At the end of each week the persons appointed to take the readings shall enter and sign in the prescribed Humidity Register a declaration that during the week the readings have been duly taken by them as required by this Regulation, and that (subject to any exception recorded as above) no readings have been such as to indicate contravention of Regulation 1 or Regulation 5.

The entries in the Humidity Register shall be *primâ facie* evidence of the temperature and humidity of the air of the *humid shed*.

5. In every *dry shed* and in every *humid shed* the arrangements shall be such that (1) during working hours the temperature shall not at any time on that day be below 50°, and (2) no person employed shall be exposed to a direct draught from any air inlet, or to any draught at a temperature of less than 50°.

Provided that it shall be sufficient compliance with the requirement marked (1) in this Regulation if the heating apparatus be put into operation at the commencement of work, and if the required temperature be maintained after the expiration of half-an-hour from the commencement of work.

In a tenement factory it shall be the duty of the owner to provide and maintain the arrangements required for the purpose of the requirement marked (1) in this Regulation.

6. In a *humid shed* in which steam pipes are used for the introduction of steam for the purpose of *artificial humidification* of the air-

(*a*) the diameter of such pipes shall not exceed 2in., and in the case of pipes hereafter installed the diameter shall not exceed 1in.;

(*b*) such pipes shall be as short as is reasonably practicable;

(*c*) such pipes shall be effectively covered with insulating material kept in good repair, in such manner that the amount of steam condensed in the covered pipe shall not exceed one-fifth of the amount of steam condensed in the bare pipe under the same conditions; and there shall be kept attached to the General Register a certificate from the manufacturer of the covering to the effect that a sample of the covering has been tested by an authority approved by the Chief Inspector of Factories, and has been found to conform to the above standard.

(*d*) all hangers supporting such pipes shall be separated from the bare pipes by an efficient insulator not less than ½in. in thickness;

(*e*) no uncovered jet from such a pipe shall project more than 4½in. beyond the outer surface of such covering;

(*f*) the steam pressure shall be as low as practicable, and shall not exceed 70lbs. per square inch

7. In every *humid shed* hereafter erected—

(a) the average height of the shed shall not be less than 14½ft., nor the height of the valley-gutters from the floor less than 12ft.;

(b) the lights shall as far as possible face true north; or if this be impracticable, between north-east and north-north-west;

(c) the glass of the lights shall be at an angle of not more than 30° to the vertical, except in the case of flat concrete or brick roofs;

(d) the boiler-house and engine-room shall be separated from the shed by an alley-way, not less than 6ft. wide, and either open to the outside air or provided with louvre or roof ventilators capable of being opened in summer, and of an area equal to one-quarter of the floor area of the alley-way;

(e) no boiler flue shall pass under the shed, or within 6ft. horizontally from the wall of the shed.

8. In every *humid shed* and in every *dry shed* the whole of the outside of the roof (windows excepted) and the inside surface of the glass of the roof windows shall be whitewashed every year before the 31st May, and the whitewash shall be effectively maintained until the 15th of September.

Provided that the above requirements of this Regulation, so far as regards roof windows, may be suspended by certificate in writing from the inspector of the district, if it is shown to his satisfaction that the roof windows are so placed, or are so shaded by adjacent buildings, that the direct rays of the sun can never impinge upon them at any time during any day; which certificate shall be kept attached to the General Register.

9. In every *humid shed* and in every *dry shed* the arrangements for ventilation shall be such that at no time during working hours shall the proportion of carbon dioxide in the air in any part of the shed exceed the limit specified below for that shed, namely:—

for *humid sheds* eight
for *dry sheds* eleven
{ parts by volume of carbon dioxide per 10,000 parts of air in excess of the proportion in the outside air at the time.

Provided that

(1) during any period in which it is necessary to use gas or oil for lighting purposes, and

(2) before the end of the dinner hour on any day in which gas or oil has been so used,

it shall be sufficient compliance with this Regulation if means of ventilation sufficient to secure observance of the above requirement during daylight are maintained in full use and in efficient working order.

SCHEDULE.

Humidity Table, for the Purposes of Regulation 1.

Dry Bulb Readings	Wet Bulb Readings	Dry-Bulb Readings	Wet Bulb Readings
(1)	(2)	(1)	(2)
50°	48°	66°	64
51°	49°	67°	65
52°	50°	68°	66
53°	51°	69°	67
54°	52	70°	68
55°	53	71°	68·5
56°	54	72	69°
57°	55	73	70
58	56	74	70·5
59	57	75	71·5
60	58	76	72
61°	59	77°	73
62	60	78	73·5
63	61	79	74·5
64	62	80	75·0
65°	63		

10. In every *humid shed* erected after 2nd February, 1898, sufficient and suitable cloak room or cloak rooms shall be provided for the use of all persons employed therein, and shall be ventilated and kept at a suitable temperature.

In every *humid shed* and *dry shed* to which the above provision does not apply, and in which a suitable and sufficient cloak-room is not provided, suitable and sufficient accommodation within the shed shall be provided for the clothing of all persons employed, within a reasonable distance of the place of employment, and consisting of a sufficient number of pegs, not less than one for each person employed, and not less than 18in. apart, and of a covering of suitable non-conducting material spaced not less than ½in. from the wall or pillar and so arranged that no moisture either from above, or from the wall or pillar, can reach the clothing.

R. McKENNA,
One of His Majesty's Principal
Secretaries of State.

Home Office, Whitehall,
21st December, 1911.

MAGNETIC APPARATUS FOR TESTING THE ENDURANCE OF METALS.

AT a recent meeting of the Birmingham Local Section of the Institution of Electrical Engineers Prof. Gisbert Kapp gave a demonstration of his magnetic machine for testing the endurance of steel and other metals, a description and illustration of which appeared in our issue of October 27th, 1911 (see p. 513, vol 28). Prof. Kapp, in the course of his remarks, said that ever since Woehler's time, now half a century ago, it was known that metals became fatigued, *i.e.*, their strength was diminished if subjected to rapid repetition of stress. Steel might support quite safely a load of 15 tons to the square inch if continuously applied, but if such a load were repeatedly put on and taken off the steel would become fatigued and finally break. Machines for putting alternating loads on test pieces were also well known; but in the machine hitherto used the application of the test load was purely mechanical, and could therefore only take place at a moderate frequency. If the problem was to find the effect of some millions of applications of stress the process naturally took a very long time. In the author's machine the application of the stress was by means of an electromagnet energised by an alternating current at the rate of 100 stresses per second, and it was thus possible to subject the test piece to one million stress applications in about three hours. The time required to ascertain whether or not a material was suitable for machinery where high speed and great mechanical stresses occur was thus considerably shortened. By testing samples of steel, iron and copper for strength, Prof. Kapp found that in only two samples of common iron could any fatigue be discovered when the stress was kept within the moderate limits of five to six tons (three to four tons for copper) per square inch, although some of the samples were subjected to as many as 15 million stresses. If, however, the stresses were raised to the values which in modern high-speed and lightly built machinery prevailed, the effect of repeated application became very noticeable, in other words there was fatigue. A test piece of steel was shown which, in a length of 3in., had under the repeated applications of a stress of only 15 tons to the square inch lengthened by ¼in., and would, if left in the magnetic machine, have undoubtedly broken under that stress. The machine was just stopped in time to prevent actual rupture. Yet only 180,000 stresses had been applied to this test piece. A test piece of the same steel which had not been treated in the magnetic machine broke in an ordinary testing machine with a load of 26 tons per square inch. It was thereby clearly demonstrated that fatigue is a real danger if the material is subjected to fairly high and often repeated stresses of five or six tons per square inch, although there is practically no change in the strength of the metal, no matter how long it has been in service.

Flying at a Speed of 88 Miles an Hour.—M. Vedrines made a remarkable flight on Saturday last. He flew a distance of 150 kilometres (93 miles) in 1h. 2min. 13sec., covering a distance of 142 kilometres 130 metres (88 miles 468 yards) in the hour.

PETROL RAIL MOTOR COACHES.*

BY T. F. CHARLTON AND H. GRINSTED.

THE employment of the internal-combustion engine in the propulsion of railway vehicles is a comparatively recent development, and most of the work done hitherto may be regarded as of a pioneer description. There is a considerable future for vehicles of this description, and that it is the legitimate field of those who have brought the small internal-combustion engine to its present high state of efficiency and reliability is perfectly clear.

The creation of rail motor services by the railway companies in this country was mainly due to two causes: In the first place, to the keen competition set up by the increased facilities for rapid transit in large towns and their suburbs provided by the electric tramcar and the motor omnibus. The railway companies, to combat this serious drain on their ordinary suburban traffic, began to reorganise the train services, replacing them by the greatly accelerated rail motor services. The success of this arrangement led them to extend the system to local lines, in provincial districts in which the maintenance of a reasonably frequent service of ordinary trains was not possible except at a considerable loss.

The early rail motor vehicles consisted of a single large coach drawn by a small tank engine. The advantages of this arrangement are not far to seek. Small tank engines they had in plenty. All that remained was to provide a trailer coach with through communication for the conductor, it being part of the scheme for accelerating the services that tickets should be issued and collected by the conductor en route, thus saving both the passengers' and the companies' time; and a means of driving the combination of coach and locomotive from either end, the compartment at the rear end of the coach containing a duplicate regulator and brake control gear, the regulator operating that on the locomotive by a system of rods and levers. Here then we have the germ of the rail motor service, a combination of locomotive and coach which can be driven from either end like a tramcar, thus obviating the time-wasting operation of shunting and turning; also a vehicle of vastly improved acceleration, and of which the saving in the cost of operation is considerable. So many advantages had this arrangement at the outset that there was no considerable call for a special vehicle to serve the purpose. The rolling stock they already had; their men were used to it, and no outlay of any consequence was necessary to effect the conversion.

As soon as the success of the new services was assured, however, a vehicle was designed specially for the purpose, consisting of a coach and locomotive in one unit, and of this description there are a number in use. It is an arrangement, however, which is not susceptible to much improvement and lacks certain advantages which only the internal-combustion engine can give. These may be briefly enumerated as follows: The engine and running gear require far less attention than is needed by the ordinary steam locomotive. All that the internal combustion requires is a periodic supply of oil and an occasional inspection, and the grinding in of mushroom valves is not to be compared with the troublesome processes of packing steam glands and cleaning out boiler tubes. No fireman is required, in itself a saving of about 7d. an hour. For the same power, the petrol engine is much smaller and lighter than the steam engine and boiler, and the weight of petrol and cooling water required is much less than that of the coal and feed water required by a steam engine to enable it to travel an equal distance. Petrol or paraffin as a fuel is much more easily handled and stored than coal and water, and enough can be carried for a complete day's run. Any steam railway vehicle is an ever-present source of inconvenience and annoyance to passengers and others on account of the smoke and cinders emitted from the funnel, a disadvantage entirely absent in the case of the internal-combustion engine. The control of a petrol rail motor can be made as simple as that of a tramcar.

Turning to the question of design, this resolves itself into the choice of one out of three different methods of transmission: Purely mechanical; electro-mechanical combinations; purely electrical.

* Paper read before the Coventry branch of the Graduates Section of the Institution of Automobile Engineers, January 11th, 1912.

Considering the purely mechanical system first, the arrangement of the mechanism is influenced in the first place by the size of the coach and the number of passengers to be carried. For a coach to carry not more than about 45 passengers a rigid wheelbase construction can be used, which considerably simplifies the design. A very simple design of small car and one that is really a connecting link between the commercial road vehicle and the railway vehicle proper is a petrol tramcar manufactured by Leyland Motors, Ltd., for use in South America. The car can be driven from either end, the motor being a 30 h.p. 4-cylinder engine. A 3-speed gearbox is fitted, being coupled up to the clutch by means of a short shaft and universal joint. From the gearbox the drive is transmitted to the live axle by means of a cardan shaft. By means of bevels and a sliding-claw clutch pinion, the direction of rotation of the driving axle can be changed. Both axles are coupled together by means of a heavy roller chain, as it is necessary to drive on all four wheels to enable the car to climb a gradient of about 14 per cent. with a full load of 20 passengers. There is a radiator at each end of the tram, and a large tank of water in addition, which also serves the purpose of counteracting the weight of the engine at the opposite end. The tram works about 16 hours a day and does about 80 or 90 miles, making a series of short journeys one kilometre each way, the petrol consumption being about 16 galls. per day. The brakes are the usual standard mechanical brakes for tramcars, operating on all four wheels. The weight of the car complete with body is about 3½ tons.

Turning to railway cars proper, it is evident that this design requires considerable modification, and the possible arrangements of mechanism will now be considered. One arrangement of drive is that in which the frame carrying the engine and gearbox is slung from the axles themselves. This arrangement permits of a lighter truck frame, as it is not subject to stresses due to the power plant, and has the further advantage that the engine vibrations are not transmitted directly to the floor of the coach. Although all ordinary adjustments can be made from the sides or through trap doors in the coach floor, a periodic overhaul of all gear is necessary. This method of suspension renders this exceedingly convenient, as the coach can be lifted and placed on trestles, and the underframe run out complete on the axles. When travelling even at ordinary speeds the shocks produced by inequalities of rails, points, and crossings are very considerable; it is therefore advisable that the engine and gearbox should be spring-supported on the underframe. This can be most conveniently accomplished by having a subsidiary frame carried on springs on the underframe.

The design of the engine is limited by two important considerations. It is not desirable that the rail clearance should be less than 7in., whilst at the same time the height of the engine is limited by the coach floor. In the case of the 4ft. 8½in. gauge, the standard in this country, the total height available for the engine is about 3ft. 4in. Therefore, unless a small and consequently high-speed engine be used it will be necessary to fall back upon the horizontal type. Although the efficiency of the high-speed engine is undoubted, the wear and tear consequent on running at full power practically continuously must considerably shorten its life and reduce its reliability. This wear and tear is not confined to the engine alone, but must also be shared by the gearbox, &c. Further, in order to allow an engine to run at a high speed, the reciprocating parts must be lightened to such an extent that their ability to withstand the stresses incurred at full load for continuous periods is greatly reduced. On the other hand, the horizontal engine is not limited in its main dimensions by the vertical space available. It is therefore possible to use an engine of large bore and stoke and comparatively low speed, say from 500 to 600 revs. per minute, there being no need to cut down the weight in this class of work.

The question of transmission is perhaps the most difficult of all on a vehicle of this description. Clash gears are out of the question on account of the large masses involved. The gears, then, must be always in mesh, and brought into action by some arrangement of clutch, dog clutches again being equally undesirable. Consequently some form of friction clutch must be used, and of these there are several types which could be adopted. The engine can be placed with its

crank shaft either on the centre line of the coach, or parallel to the axles. The latter arrangement does not necessitate the use of bevel gears or universal joints, the final drive being by silent chain to the axle. A silent chain reduction on all speeds could also be used. In the first place, a propeller shaft drive can be adopted, with the gearbox either coupled to the engine or mounted on the axle, the final drives being by bevels contained in a case on the axle. With this arrangement universal joints must be used, which, unless made of exceptional size, are certain to give trouble by wear due to the impossibility of keeping them properly lubricated. On the other hand, the bevel drive can at the same time have incorporated with it a simple reversing device consisting of two bevels engaging with the same pinion and alternatively clutched up to the axle. This permits the use of a non-reversible engine. The propeller shaft could be eliminated by the use of a cross shaft in the gearbox with a silent chain final drive.

Another arrangement is one in which the engine and gearbox are rigidly attached to the under side of the truck frame. The power plant can be arranged in any of the ways mentioned above. There are, however, distinct disadvantages. The vibration is directly transmitted to the body; the gear is exceedingly inaccessible by reason of the necessary supporting members, and the removal of any portion of the mechanism is a matter of considerable difficulty. For coaches carrying more than 45 passengers, the increased length necessitates the use of bogies, as it is not desirable that a rigid wheelbase should exceed 18ft. in length. This introduces a new factor, as the drive, unless completely mounted on the bogie, must compensate for both horizontal and vertical movement of the driven axle.

Considering the attachment of the power plant to the coach frame first, there are several reasons which render this undesirable. A propeller shaft drive is imperative. The long space between the points of support on the bogies necessitates a particularly heavy type of frame to carry the weight of the engine and gearbox without liability to excessive vibration. What has previously been said with reference to inaccessibility when the mechanism is rigidly suspended from the coach frame applies also here, although the use of a horizontal engine with opposed cylinders improves matters somewhat, as the cylinder heads and valves would be accessible from the sides of the coach. A long propeller shaft is necessary to decrease its angularity when the bogies are curving, and lessen the movement and consequent wear in the universal joints. A long propeller shaft also means an exceedingly heavy one, to prevent any tendency to whip. Another serious objection to propeller shaft drives of this description is the varying angular velocity of the bevel shaft due to the angularity of the universal joint, and causing uneven pressures on the bevel teeth and probably reversing stresses in the propeller shaft. Universal joints, unless exceedingly well balanced, are liable to put undue loads on the bearings supporting the shafts to which they are connected, owing to the unbalanced force acting at so great a distance from those bearings.

The only alternative is to mount all gear on the driving bogie. This forms a compact power plant which can be easily run out complete for overhaul or inspection by lifting one end of the coach frame. A further advantage is that the engine vibrations are not directly transmitted to the body. In addition, a spare motor bogie can be always in readiness to replace any one which may need repair or attention. This enables a reliable service to be maintained at the expense of an additional motor bogie only instead of a complete spare coach.

In the McKeen motor-car, an American design of this description, a 6-cylinder engine developing 250 b.h.p. at 400 revs. per minute, and capable of propelling a 70ft. coach carrying 150 passengers, at 70 miles per hour, is mounted on the front bogie. There are only two speeds, the reduction on the lower being through a train of large open-spur gear always in mesh and operated pneumatically by plate clutches, and a silent chain transmission to the axle. On the top speed the spur reduction is out of action. The cylinder heads and valve chambers of the engine project upwards through the floor of the driver's compartment, thus at the same time simplifying the control and improving the accessibility for ordinary adjustments. The engine is cooled by water circulated by a pump through a coil tube radiator hung beneath the coach. The water can also be utilised for heating the interior of the body. 120 galls. of petrol is carried, and delivered by pressure to a small tank in the engine-room, whence it flows to the carburetter by gravity. The engine-room is separated from the main body of the car by a fireproof bulkhead. As these vehicles are used in America for main-line express services, provision for driving at either end is unnecessary. The car is constructed completely of steel, the sides, floor, and roof of the body being of steel sheet stiffened by vertical and diagonal steel members. This gives a remarkable stiff construction for the weight.

The engine is started and reversed by air pressure supplied from a tank which is normally charged by a compressor driven from one end of the crank shaft. To raise pressure for starting when the tank is empty, a small auxiliary petrol-driven compressor is provided, being placed in the engine-room and started by hand.

It may here be stated that owing to the large size of engine on vehicles of this description provision for automatic starting is an absolute necessity. This is most conveniently effected by compressed air, as a compressed-air installation is required for operating the brakes. An auxiliary valve system to admit air to the cylinders must be provided unless the air compressor, which would be mounted at one end of the crank shaft, be arranged to act as an air motor for starting the engine. The auxiliary valve arrangement is preferable, as it is not desirable to complicate the compressor. An auxiliary air compressor driven by a small petrol engine, as was mentioned in the case of the McKeen car, is advisable, to enable pressure to be raised in the reservoir before the large engine is started. It is undesirable to use this type of auxiliary compressor for maintaining pressure at all times, as the demands on the reservoir are intermittent, and the frequent hand starting would be most inconvenient. In the event of an electric lighting installation being provided, an electrically driven compressor is the best way out of the difficulty, a simple switch mounted beside the pressure gauge in the driver's compartment controlling the compressor motor. This arrangement is preferable to that in which the compressor is mounted on the main engine, as in the latter case it would be always working and an automatic relief valve would be needed, and a considerable and unnecessary waste of power occasioned.

The tappet valve engine permits of a simple reversing mechanism in the form of a sliding camshaft on which two sets of cams are mounted. A small cylinder containing a double-acting piston connected to the end of the camshaft and operated by compressed air can be made to give the necessary end movement. If compressed air is not available, a simple system of rods and levers can be substituted. A form of mechanical reversing gear which may be adopted in conjunction with a bevel drive has already been mentioned, namely, two crown bevel wheels which are always in mesh

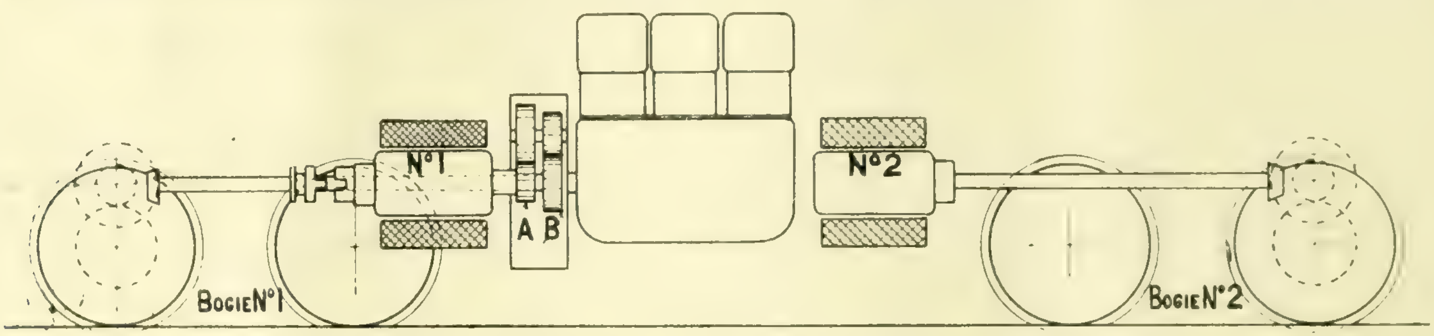


DIAGRAM OF THOMAS TRANSMISSION AS FITTED TO THE LEYLAND RAIL MOTOR COACH.

with the driving bevel pinion, being alternatively clutched up to the axle, or cross shaft, as the case may be. In the case of a bogie driven in this manner, the only convenient method of manipulating the reversing clutch is by compressed air, since it is exceedingly difficult to compensate for the motion of a bogie in a system of rods and levers. The ordinary reverse embodying an intermediate shaft in the gearbox cannot be considered, as the coach must be capable of running equally well in either direction.

Any of the forms of electrical transmission can be applied to self-propelled railway vehicles, but the considerations which give preference to any one of them differ from those which determine the choice of the design in an ordinary commercial vehicle, as weight is not of great consideration and the mechanism is not subject to such shock as on a road vehicle. Electrical transmissions fall into two classes, namely, those in which the electrical gear is utilised to supplement the engine torque at low coach speeds, and those which embody a complete generating set with electrical transmission only.

Of the first class the best known is perhaps the "Automixte." In this system the engine is mechanically connected to the road wheels through the armature of a direct-current electrical machine capable of acting as a generator or a motor. A battery of accumulators is connected across the armature, so that, so long as the voltage at the dynamo terminals exceeds the potential difference across the battery, the excess energy above that required to propel the vehicle is stored in the cells. When, however, the torque required to move the vehicle is greater than that which the engine is capable of supplying at that speed, the speed of the latter falls, and the accumulators discharge through the armature of the electrical machine which then becomes a motor and assists the engine. As soon as the vehicle attains the critical speed of the electrical machine the engine takes up the full load, and at higher speeds the accumulators are recharged, as explained above. On account of its dual function, the electrical machine is commonly known as the "Dynamotor."

At first sight this system appears to be a complete solution of the vexed question of transmission. A perfectly smooth speed variation is obtained, and at the highest speeds the engine torque is transmitted to the road wheels with no more loss than is the case with a mechanical transmission with so-called direct drive. By means of the dynamotor the engine can be infallibly started in either direction. The accumulators are available for lighting the coach and for any auxiliary purpose such as heating, ventilating, driving the air compressor, &c. A rheostat in the dynamo field circuit provides a speed control, the throttle lever being used in the ordinary way. In the practical working of this system the accumulators are liable to become a constant source of trouble owing to violent alternations in the direction and value of the current, and especially the constant danger of giving excessively heavy momentary charging currents. The expense of the equipment is considerably in excess of that required for a purely mechanical drive, as the gearbox is replaced by a more expensive electrical machine, the bevel or other final drive is retained, and in addition a set of accumulators, of a probable cost of from £200 to £500 is required. The engine, if the coach is intended for a service necessitating frequent stops, must be considerably larger than would be otherwise required, as the periods during which it attains the speed necessary for charging the accumulators will not be of sufficient duration to replace the energy given up during the frequent periods of acceleration. It is evident from the length of the combined engine, generator, and clutch unit that only a propeller shaft drive is possible with this system.

Rail motor coaches on this principle have been constructed by the Daimler Company, who were amongst the pioneers of this class of work, their first vehicles anticipating the services for which they were intended. The coaches can be driven from either end, a mechanically-operated bevel reverse being provided.

The only other electro-mechanical transmission of any importance at the present time is the Thomas system, which has been embodied in a rail motor-car constructed by Leyland Motors, Ltd., for the C.S.A.R. The system as employed in road vehicles has been modified somewhat in order to obtain a driving effort at starting, on two axles. The engine is coupled direct to the planetary gear cage which forms the flywheel of the engine; the small sun pinion A is connected to dynamotor No. 1, whilst the larger sun pinion B is connected to one of the axles of bogie No. 1. The second dynamotor is connected to the other driven axle. No. 1 driving axle is gear driven, whilst No. 2 driving axle is driven electrically. The effect of the introduction of the epicyclic gear between the engine and the first dynamo is as follows: When the flywheel of planetary gear cage is rotated in a clockwise direction, the larger of the two sun pinions B, by reason of its connection with one of the driven axles is prevented from rotating, and, as a result, the smaller sun pinion A, which is coupled to the armature of the first dynamotor, is driven in a counter clockwise direction. At low speeds, the engine will continue to rotate without the dynamotor fields becoming excited, but when the engine is accelerated the field magnets become excited, and current is transmitted to the second dynamotor, the armature of which is constantly coupled to the driving axle of No. 2 bogie, and once the static resistance of the car has been overcome, the sun pinion B will commence to turn in the same direction as the engine, but at a lower speed, and transmit power to the driving axle of No. 1 bogie. It will be seen, therefore, that the epicyclic gear has a differential action, and causes one-third of the engine's power to be transmitted electrically to the driving axle of No. 2 bogie, whilst two-thirds of the engine's power is transmitted mechanically to the driving axle of No. 1 bogie. When the rail car has attained its normal speed, the armature spindle of No. 1 dynamotor, and the propeller shaft for the driving axle of No. 1 bogie, are coupled so as to give a direct drive; No. 2 dynamotor then becomes inoperative, or it may be employed to charge a battery of 18 secondary cells. Each of the two dynamotors is capable of giving 50 b.h.p. at 500 revs. per minute and each weighs approximately $12\frac{1}{2}$ cwts.; they are specially designed for this particular work, and unlike the usual practice of tramway or railway engineers, the dynamotors are not suspended from the axle, but are slung direct from the main frame.

The Leyland engine has 6 cylinders, with a bore and stroke of 7in., developing 120 b.h.p. at 670 revs. per minute, whilst it may be accelerated to give 200 b.h.p. The cylinders are cast in pairs with the valves all on one side. There is a main bearing between each throw of the crank. The crank shaft can be given endwise motion so as to bring into operation a second set of cams which permit the engine to be run in a reverse direction. The radiator, which is built up in three sections, any one of which may be cut out of circuit if found to be faulty, is mounted upon the roof of the car, and over each section are a couple of sheet-metal shields which serve the double purpose of preventing the hot rays of the sun from bearing directly upon the radiator tubes, and inducing a current of air between the coils when the vehicle is in motion. The speed variation is effected by means of a controller with contacts breaking in oil, operated by a hand lever in the ordinary way, and providing for: Starting the engine from the battery; propelling the vehicle in either direction at any speed from zero to top speed; charging the battery while running at top speed; propelling the vehicle by means of dynamotor No. 2 which is supplied with current from the accumulators; applying the electrical brakes.

The accumulators are placed under two seats which back up to the central luggage compartment, and they are of sufficient capacity to propel the car in case of emergency for a distance of 8 miles at a speed of 4 miles per hour. The engine is placed midway on the vehicle, and stands less than 2ft. above the level of the frame. It is cased over and enclosed in a compartment which is reserved for the conveyance of luggage. The seats provide accommodation for 42 passengers; they are divided into two sections by the luggage compartment, so that two classes of passengers may be carried if desired. The length over the body is 37ft. 6in., the centres of the bogie bolsters are 22ft. 6in. apart, the wheelbase of each bogie is 5ft., and the wheels themselves are 30in. diam. Each axle runs on Hyatt roller bearings. The approximate weight of the complete rail car in running order is 21 tons 5 cwts., of which the petrol-electric equipment accounts for 7 tons, the 6-cylinder engine alone weighing about 35 cwts. Tests with this rail car have shown that when the wheels are just upon the point of slipping on the rails, the power applied to the driving axles is sufficient to maintain a steady drawbar pull of $1\frac{3}{4}$ tons. The advantages of this system are:—

(1) That at no time is more than one-third of the power

transmitted electrically, whilst the remainder is transmitted mechanically.

(2) There is no electrical loss on top gear.

(3) As the dynamotors transmit only a small portion of the total power, and that only at starting and during periods of acceleration, they may be made much smaller and lighter than the motors for any other system.

(4) The engine may be stopped every time the vehicle is stopped, and re-started through one of the motors, for which current is supplied by the accumulators.

(5) The system provides current for electric lighting, ventilating, and braking.

The coach is guaranteed to maintain a speed of 30 miles per hour on a gradient of 1 in 25. It attains a speed of 30 miles per hour in the space of 30 seconds, this rate of acceleration, namely, 1·3ft. per second, being with a full load on the level. The car is capable of attaining a speed of 50 miles per hour.

In what may be called the pure petrol-electric system, the engine drives a dynamo, which is electrically connected through controllers of the ordinary tramway and railway type, to electric motors mounted upon the axles, the transmission being always purely electrical. All things being considered, this appears to be the best solution of the whole problem. The engine and generator can be placed in the driver's compartment at one end of the coach, where they are perfectly accessible, and are not exposed to damp and dirt, and can be flexibly supported, thus at the same time insulating the coach from engine vibration and also preventing track shocks from reaching the machinery. The engine runs at a constant speed, irrespective of the speed of the car, the throttle being controlled by an electrical governor regulated by the output of the dynamo. The entire control of the coach is effected by a standard type of electrical railway or tramway controller. The only connections to the electric motors are by means of cables, and in the case of a bogie coach these obviate the necessity for any compensation for the curving motion, and the drive can be transmitted to more than one axle without complication. An ordinary electric railway bogie of proved reliability can be used, and no special design of coach frame is necessary. The engine is perfectly accessible, and the reliability of electrical machinery is well known. The engine is working under the best conditions, and would need no more attention than a stationary engine.

With electrical transmission the engine always runs in the same direction, the reversing of the car being accomplished by the controller which reverses the motors in the usual manner, without stopping the engine, complicated mechanical reversing gear being avoided. For switching, shunting, and yard work, coupling, &c., this ability to reverse the motors instantly without changing the direction of rotation of the engine or stopping it greatly adds to the safety and convenience of operation, and, moreover, also furnishes a means, independent of air or hand brakes, of stopping the car in cases of emergency. This transmission is perhaps not so effective as a purely mechanical transmission; the entire electrical transmission, from engine to axles, if properly designed should give an efficiency of at least 80 per cent., whereas the efficiency of a mechanical transmission on direct drive might be as high as 95 per cent. Another slight disadvantage lies in the fact that the space available for carrying passengers is slightly curtailed. It must be admitted, however, that for general convenience this system is greatly superior to any of the others, and a small percentage of efficiency may well be sacrificed in view of the advantages obtained.

Good examples of this type are the coaches manufactured by the General Electric Company, of America, of whom the British Thomson-Houston Company are the representatives in this country. The power plant consists of an 8-cylinder engine of the V-type, running at 550 revs. per minute, and directly coupled to an 8-pole 600-volt generator. The bore is 8in. and the stroke 10in., giving about 200 b.h.p. The exhaust and inlet valves and air starting valves are mounted in the cylinder heads, and the cylinders are provided with auxiliary exhaust ports which are uncovered by the pistons at a point near the bottom of the stroke. The valves are operated by two camshafts placed one on either side of the engine. The engine is cooled by thermo-syphon water circulation through radiators of the gilled tube type placed on the cab roof. The fuel is pumped from a 150-gallon tank suspended under the car. The ignition system consists of two low-tension magnetos and magnetic make and break plugs, the magnetos being provided with automatic centrifugal switches to preclude the possibility of the engine exceeding a safe speed. The engine is started by air taken from the main reservoirs of the air-brake system, which are made of extra large capacity for this purpose. Air is led to the engine through a valve mounted on the controller and interlocked with the throttle, and thence to distributing valves driven by the camshaft. The air reservoirs are charged by a single-cylinder 4¾in. by 4in. air compressor, driven from the crank shaft of the main engine, and provided with an automatic governor which maintains a constant pressure.

A 4-cycle 2-cylinder petrol engine, direct coupled to a single-cylinder air compressor and lighting generator, is supplied to provide an initial charge of air for starting the engine and to furnish power for lighting the car. The generator has a capacity of 1½ kw. at 125 volts. The cylinders of the petrol engine and compressor are made in a single casting and provided with a common water jacket. The two engine cylinders are of 4¾in. bore by 6in. stroke, and the air cylinder is placed between them. A centrifugal governor is provided to maintain a constant speed of 600 revs. per minute. The set is started by hand and the ignition consists of a low-tension magneto with magnetic make and break plugs and an accumulator-starting attachment. The armature of the lighting generator is bolted to a flange on the end of the crank shaft. By means of a special controller the driving motors are placed progressively in series and parallel; the voltage is governed by varying the strength of the generator field; this is accomplished by the movement of a single handle on the controller; separate handles are provided for reversing the car and for throttling the engine, and both are conveniently placed on the controller. A hot water heater, coal fired, is installed for heating the car. This heater may be connected to the engine-cooling system to prevent freezing when laying up at night in cold weather.

The trucks are of the swing bolster type with elliptic bolster springs and coil equaliser springs. The forward truck is equipped with two standard 600 volts, box frame, oil lubricated, commutating pole railway motors of 100 h.p. each. These are mounted directly on the axles and are nose suspended and equipped with the General Electric Company's standard gears and gear cases.

In conclusion, it is evident that much greater progress has been made abroad than in our own country, which is probably chiefly due to the conservatism of English railway companies, who are inclined to look askance at any recently-developed form of motive power or anything which is not a direct descendant of the works of Watt and Stevenson. This is the more to be regretted, as much experimental work must be carried out by the makers before a sufficiently reliable vehicle can be offered for tender.

VARIABLE HYDRAULIC DRIVING AND REVERSING MECHANISM.

THE change speed and reversing gear shown diagrammatically in the accompanying cuts is based on adding together two speeds, whose ratio is variable, by means of a compensating gear. The two speeds, which are to be added together, are derived from hydraulic motors. By means of this gear, which has recently been patented by the Internationale Rotations Maschinen Gesellschaft m.b.H., 6, 7, Schiffbauerdamm, Berlin, it is claimed that a gradual change of speed between a given maximum speed of forward motion and a given maximum speed of reversing motion is obtained.

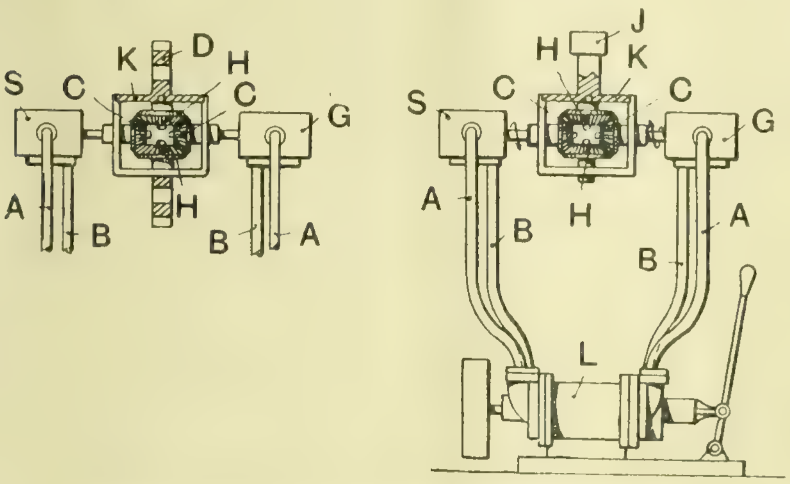
Fig. 1 shows an example of construction embodying the general principle of the arrangement, while Fig. 2 illustrates a particular application. According to Fig. 1 two hydraulic motors G and S, which are connected with supply conduits A, and outlet conduits B, for the propelling liquid, actuate the bevel wheels C of the compensating gear, which are in gear with the driving wheels H, mounted in the gear box K. A toothed wheel D is mounted on the gear box for transmitting the resulting motion and speed. The motors are driven in such a way that, for example, the one G runs always in one and the same direction at a constant speed, while the other motor S is driven at a variable speed and in the same or in

the opposite direction of rotation to that of motor G. The speed of the gear-box, resulting from this arrangement, will consequently always be the arithmetic mean of the two separate speeds, when indicating the speed of forward motion of motor S (that is the motion in the same direction as the motion of motor G) with the plus sign, and that of the reversing or opposite motion with the minus sign.

If it be assumed that motor G works at constant speed $v = n$ and that the speed v^1 of motor S varies between $+n^1$ and $-n^1$, then in case of $v^1 = v = n$ the speed V of the gear box will also be n, that is to say, the compensating gear will revolve as a rigid whole.

If $v^1 = +n^1$, then $V = \frac{n + n^1}{2}$, or if $v^1 = o$, then $V = \frac{n}{2}$; or if $v^1 = -n$, then $V = \frac{n - n}{2} = o$, or if finally $v^1 = -n^1$, then $V = \frac{n - n^1}{2}$.

If n is larger than n^1, forward motion at half the difference between the two speeds results, whereas if n is smaller than n^1, reverse motion at corresponding speed follows. It



VARIABLE HYDRAULIC DRIVING AND REVERSING MECHANISM.

is therefore possible to run the driven object at an infinitesimal speed, without, however, working the motor itself at a correspondingly low speed, and it is even possible to bring the driven object to a full stop, notwithstanding that motor G continues running at full speed, while motor S runs at an equal speed in the opposite direction.

The pressure liquid for working the motors G and S may be drawn from a common pressure reservoir. But the motors may also be connected with separate pressure pumps, of which the one for motor G would require to have a constant delivery, while the delivery or output of that for motor S would be variable both as to quantity and to direction. The regulation of motor S might, however, with constant delivery of its pumps, be effected by means of a controlling slide. Finally both motors G and S may be worked at varying speeds, in which case, when the motors are running in opposite directions, a change of speeds for the driven object would be obtained within a range corresponding on the one hand to the maximum speed of one motor for forward motion and on the other hand to the maximum speed of the other motor for reverse motion.

The two motors may also, as shown in Fig. 2, be driven by a rotary pump L with revolving piston drum, the two sides of which pump work independently, but may be conjointly regulated with regard to their respective capacities by an axial adjustment of the piston drum, in such a way that the aggregate capacity of the two sides remains constant, so that, for example for the maximum delivery of one side the delivery of the other side drops to zero, whereas in the middle position, which corresponds to the rest-position of the driven object, the two sides of the pump deliver equal quantities of liquid, but in opposite directions. The casing or gear box of the compensating gear might also be connected with a belt pulley. Or, according to Fig. 2, it may act on a lever J, adapted to be turned forward and backward.

DETERIORATION AND SPONTANEOUS HEATING OF COAL IN STORAGE.

BY HORACE PORTER AND F. K. OVITZ.

NOT many years ago, coal was commonly regarded as an extremely unstable material, subject to very serious alteration and losses on exposure to the elements. E. C. Pechin, in 1872, speaking before the American Institute of Mining Engineers, says: "Fuel suffers materially by . . . storage; especially with bituminous and semi-bituminous coals is the loss heavy, an exposure of only two weeks causing a loss of carbon to the extent of 10 to 25 per cent." Similar views have been held in much more recent times. For example, in a paper before the United States Naval Institute in 1906 we find the statement: "The pressure of the weight of coal causes gases to be evolved; . . . these gases constitute the chief and only value of the coal in that they furnish the heat units. It is claimed that if a ton of fine bituminous coal be spread out on a concrete pavement . . . in the open air in this climate for one year, it will lose all its calorific properties. The gases are simply free to escape, and when the coal has lost all its gas it will have lost all its heat units and be simply coke." This was only five years ago.

In 1907 a German gasworks engineer claims to have found that moist fine coal sustained an average loss per week of 1·7 per cent., this loss being due to gas. The 1889 edition of Groves & Thorp's "Chemical Technology of Fuels" says: "In some places coal is known to lose 50 per cent. of its heating value in six months." Other statements like these are to be found in recent literature, but probably the great majority of chemists and engineers to-day hold no such exaggerated ideas on the subject. There is, on the other hand, a well-defined suspicion in the minds of many that sufficient loss of volatile matter and sufficient deterioration by oxidation does occur in coal to be of industrial importance; and for that reason the investigations described in this paper were undertaken by the Bureau of Mines to determine accurately the extent of the deterioration in different types of coal.

First, a study was made in the laboratory of the loss of volatile matter from crushed coal during storage. A number of samples (20lbs. each) representing a variety of types from widely separated fields, were broken to about ½in. size and immediately placed in glass bottles in the mine. At the laboratory the accumulated gas was withdrawn, and a free continuous escape of the volatile products permitted at atmospheric pressure and temperature. The results of these experiments have been published in Technical Paper No. 2, Bureau of Mines, entitled "The Escape of Gas from Coal," and will therefore not be given here in detail. Suffice it to say that while several coals evolve methane in large volumes, especially in the early period after mining, the coal suffered in one year a loss in calorific value from this cause of but 0·16 per cent., as a maximum. It seems, therefore, that the loss due to escape of volatile matter from coal has been greatly over-estimated.

At the instance of the Navy Department, however, which is a large purchaser of coal, and stores large lots in warm climates for long periods of time, more elaborate tests were undertaken to determine the total loss possible in high-grade coal by weathering. The extent of the saving to be accomplished by water submergence as compared to open-air storage was a point to be settled, and there had also arisen the question as to whether salt water possessed any peculiar advantage over fresh water for this purpose.

In brief outline, the tests by the Bureau of Mines were carried out as follows: Four kinds of coal were chosen: New River, on account of its large use by the Navy: Pocahontas as a widely used steaming and coking coal in the eastern section, and as being also the principal fuel used in the Panama Canal work: Pittsburg coal as a type of rich coking and gas coal; and Sheridan (Wyo.) sub-bituminous or "black lignite"—a type much used in the West. With the New River coal, 50lb. portions were made up out of one large lot, which had been crushed to ½in. size and well mixed. These portions, confined in perforated wooden boxes, were

* Abstract of paper presented [illegible] Society, American Ele[illegible] November 10th, 1911.

submerged under sea-water at three Navy yards, differing widely from each other in climatic conditions, and 300lb. portions from the same original lot were exposed to the open air, both out of doors and indoors, at the same places.

With the Pocahontas coal, test was made only at one point, the Isthmus of Panama, run-of-mine coal being placed in a 120-ton pile exposed to the weather. Pittsburg coal was stored as run-of-mine in open outdoor bins, five tons' capacity, at Ann Arbour, Mich., also in 300lb. barrels submerged under fresh water. The Wyoming sub-bituminous was stored at Sheridan, both as run-of-mine and slack, in outdoor bins, holding three to six tons each.

Every test portion was sampled each time in duplicate, and in all cases except the outdoor pile at Panama and the 300lb. open-air piles of New River coal, the sampling was done by re-handling the entire amount. In the excepted cases mentioned it was not thought fair to disturb the entire lot, and therefore at Panama a vertical section of 10 tons only was removed each time (eight samples being taken from the 10-ton section), while in the case of the outdoor lots at the Navy yards, a number of small portions, well distributed, were taken from each pile, mixed, and quartered down. Small lots and a fine state of division were conditions purposely adopted with the New River coal, so as to make the tests of maximum severity.

Moisture, ash, sulphur, and calorific-value determinations were made on each sample, the latter by means of the Mahler bomb calorimeter and a carefully calibrated Beckman thermometer. The calorimetric work on all except the Sheridan tests has been done throughout by one man, Mr. Ovitz, and with the same instrument. All the calorific values in the tables have been calculated to a comparable unit basis, viz., that of the actual coal substance free of moisture, sulphur, and corrected ash.

The results show, in the case of the New River coal, less than 1 per cent. loss of calorific value in one year by weathering in the open. There was practically no loss at all in the submerged samples, and fresh water seemed to "preserve the virtues" of the coal as well as salt. There was almost no slacking of lump in the run-of-mine samples, and the crushed coal in all cases deteriorated more rapidly than run-of-mine.

The Pocahontas run-of-mine, in a 120-ton pile on the Isthmus of Panama, lost during one year's outdoor weathering less than 0·4 per cent. in heating value, and suffered little or no physical deterioration of lumps.

The Pittsburg gas coal, during six months of outdoor exposure, suffered no loss whatever of calorific value, measurable by the calorimetric method used, not even in the upper surface layer of the bins.

The Wyoming coal lost as much as 5·3 per cent. in one of the bins during 2¾ years, and 3·5 per cent. even in the first three months. There was bad slacking and crumbling of the lumps on the surface of the piles, but where the surface was fully exposed to the weather this slacking did not penetrate more than 12in. to 18in. in the 2·75-year period.

No outdoor weathering tests have been made by the Bureau on coal of the Illinois type. Thorough tests, however, on this type have been reported by S. W. Parr, of the University of Illinois, and B. A. Bement, of Chicago, both of whom find from 1·0 to 3·0 per cent. calorific loss in a year by weathering. Mr. Bement reports a slacking of lumps (in tests on small samples) of over 80 per cent. in one case and about 12 per cent. in another. It is probable that in this type, as in the Wyoming, the slacking in a large pile would not penetrate far from the surface.

Storage under water unquestionably preserves the heating value and the physical strength of coal. But it practically necessitates firing wet coal, and therefore means the evaporating in the furnace of an amount of moisture varying from 1 to 15 per cent., according to the kind of coal. This factor is an important drawback to under water storage with coals like the Illinois and Wyoming types, which mechanically retain 5 to 15 per cent. of water after draining, but in case of the high grade eastern coals, if firemen are permitted, as is ordinarily the case, to wet down their coal before firing, "so as to make," as they say, "a hotter fire," then the addition during storage of the 2 or 3 per cent. moisture which these coals retain would be of little consequence. Submergence storage is an absolute preventive of spontaneous combustion, and on that account alone its use may be justified with some coals, but merely for the sake of the saving to be secured by avoidance of weathering there does not seem to be good ground for its use.

Losses in coal due to spontaneous heating are a much more serious matter. Oxidation, probably in the main an absorption of oxygen by the unsaturated chemical compounds in the coal substance, begins at ordinary temperature in any coal, attacking the surfaces of the particles, thus slowly developing heat. In a small mass of coal this slowly developed heat can readily dissipate itself by radiation, and no rise in temperature results. If radiation is restricted, however, as in a large pile densely packed, the temperature slowly rises. Now, the curve of oxidation rate plotted against temperature rises with great rapidity, and when the storage conditions are such as to allow a certain point (near 100° C.) to be passed, the rate of oxidation is great enough ordinarily, so that the heat developed overbalances the heat radiated and the temperature will rise to the ignition point if the air supply is adequate. The importance, therefore, can be seen of guarding against even moderate heating in the coal either from internal spontaneous causes or by radiation from external sources. Increased loss of heating value and of volatile matter occurs at moderately increased temperatures, even though the ignition point is not reached.

The amount of surface exposed to oxidation in a given mass depends on the size of the particles, and increases very rapidly as the fineness approaches that of dust. Dust is therefore a dangerous thing in a coal pile, particularly if it is mixed with larger-sized coal which forms air passages to the interior. Spontaneous combustion is brought about by slow oxidation in an air supply sufficient to support the oxidation, but insufficient to carry away all the heat formed. There is a wide variation among coals in friability. In comparative rattler tests under certain standard conditions, Pocahontas, New River, and Cambria County (Pa.) coals produced nearly twice as much (through ¼in. screen) as a sample from the Pittsburg seam. This is a large factor in spontaneous combustion. Mixed lump and fine, *i.e.*, run-of-mine, with a large percentage of dust, and piled so as to admit to the interior a limited supply of air, make ideal conditions for spontaneous heating.

High volatile matter does not of itself increase the liability to spontaneous heating. A recent circular letter of enquiry on spontaneous combustion, sent by the Bureau to more than 2,000 large coal consumers of the United States, has brought 1,200 replies, of which 260 report instances of spontaneous combustion, 220 of them naming the coal. Of these 220, 95 are in semi-bituminous low-volatile coals of the Appalachian region, and 55 in western and middle western coals. This result shows at least no falling behind on the part of the "smokeless" type, and no cause for placing special confidence in these coals for safety in storage.

A serious fire in cinder filling under a manufacturing plant in Pittsburg was recently investigated by the Bureau, and all the evidence pointed to spontaneous combustion as the cause, induced by external heat radiated from a furnace. The cinders contained 40 per cent. of carbon. A similar fire occurred two years ago in cinder filling under a smelting plant on Staten Island, in which case the cinders contained 33 per cent. of carbon. Damage amounting to £4,000 was done. The cause was not definitely determined, but from the reports of the insurance adjusters, spontaneous heating appears to be the most plausible explanation. The volatile matter in the material could not have been a factor in these causes.

Pocahontas coal gives a great deal of trouble with spontaneous fires in the large storage piles at Panama. It is reported also by several large by-product coke concerns to be more troublesome in this respect than their high volatile gas coals. The high volatile coals of the West are, to be sure, usually very liable to spontaneous heating, but they owe this property to the chemical nature of the substances which compose the coal rather than to the amount of volatile matter. Strange as it may seem, a high-oxygen content in coal appears to parallel its avidity for oxygen and to promote, therefore, its tendency to spontaneous combustion.

The influence of moisture and that of sulphur upon spontaneous heating of coal are mooted questions much discussed, not very much actually investigated, and certainly not yet

settled. Richters has shown that, in the laboratory, dry coal oxidises more rapidly than moist, but the weight of opinion among practical users of coal is that moisture promotes spontaneous heating. The observation by the Bureau of many actual cases has not developed any instances where moisture could be proved to have had such an effect. Sulphur, on the other hand, has been shown by these investigations to have, in most cases, only a minor influence. In a number of actual cases, samples of the heated coal from areas where the heat was greatest have been analysed both for the total sulphur and that in the sulphate form. The difference between these, or, in other words, the unoxidised sulphur, was in no case less than 75 per cent. of the average total sulphur in the original. In other words, not more than one-fourth of the total sulphur has entered into any heat-producing reaction. The possibility remains, however, that all of the sulphur which was oxidised was concentrated in one pocket of moist flaky pyrites, and thus sufficient heat was developed in one spot to act as an igniter. On the other hand, a Boston company, using Dominion (Nova Scotia) coal of 3 to 4 per cent. sulphur, has much trouble with spontaneous fires in storage, but a number of samples taken by the Bureau from exposed piles of this coal in which heating had occurred showed that 90 per cent. of the sulphur was still unoxidised. Experiments in the laboratory, passing air over coal at 120° C., have developed enough heat to ignite the coal, and no change was found in the form of the sulphur. While not entirely conclusive, these results point to a very minor contribution, if any, on the part of sulphur to spontaneous heating in coal.

Freshly-mined coal, and even fresh surfaces exposed by crushing lump coal, exhibit a remarkable avidity for oxygen, but after a time become coated with oxidised material, "seasoned," as it were, so that the action of the air becomes much less vigorous. It is found in practice that if coal which has been stored for six weeks or two months and has even become already somewhat heated, be rehandled and thoroughly cooled by the air, spontaneous heating rarely begins again. A large power plant in New York crushes its coal to pass a 4in. screen immediately after unloading from barges, the fines and dust, 50 per cent. or more, being left in the coal to be stored. This freshly-crushed coal is elevated to iron hopper-shaped bunkers directly over the boilers, and the air temperature in these often reaches 100° Fah. As the coal hangs on the sloping sides sometimes three or four months at a time, it seems hardly surprising that some of the bunkers are on fire practically all of the time.

With full appreciation of the fact that any or all of the following recommendations may under certain conditions be found impracticable, they are offered as being advisable precautions for safety in storing coal whenever their use does not involve an unreasonable expense.

(1) Do not pile over 12ft. deep nor so that any point in the interior will be over 10ft. from an air-cooled surface.

(2) If possible, store only lump.

(3) Keep dust out as much as possible; therefore, reduce handling to a minimum.

(4) Pile so that lump and fine are distributed as evenly as possible; not, as is often done, allowing lumps to roll down from a peak and form air passages at the bottom.

(5) Re-handle and screen after two months.

(6) Keep away external sources of heat even though moderate in degree.

(7) Allow six weeks' "seasoning" after mining before storing.

(8) Avoid alternate wetting and drying.

(9) Avoid admission of air to interior of pile through interstices around foreign objects such as timbers or irregular brick work; also through porous bottoms such as coarse cinders.

(10) Do not try to ventilate by pipes, as more harm is often done than good.

New Japanese Railway.—The line from Nagoya, Japan, to Hachioji, near Tokyo, has been opened to traffic. According to the "Railway Gazette," this line is 224 miles long and represents an outlay of £3,500,000. There are 95 tunnels, 350 bridges, and 47 stations on the line.

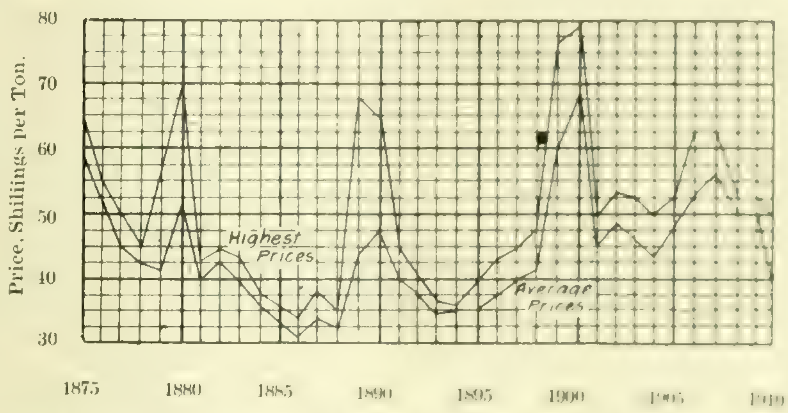
INDUSTRIAL AND TRADE NOTES.

German Pig Iron Production.—The pig iron output in Germany during 1911 was 15,334,000 tons, as compared with 14,793,000 tons in 1910, 12,918,000 in 1909, and 11,814,000 in 1908.

Clyde Shipbuilders and Steel Rebates.—The Scottish Steelmakers' Association has received from the Clyde Shipbuilders' Association a letter on the subject of rebates on prices of steel material. The shipbuilders point out that in certain respects the rebate scheme is unfair to them, and ask the steelmakers to meet a deputation in order to discuss the points at issue. A meeting will probably be held shortly.

Platinum Production in New South Wales.—Up to the end of 1909 the total Commonwealth production of platinum was only 11,578ozs., valued at £21,000, and nearly the whole of it was contributed by New South Wales. In 1910, 332ozs., valued at £1,380,

Fluctuations in Price of Cleveland Pig Iron, 1875-1910.

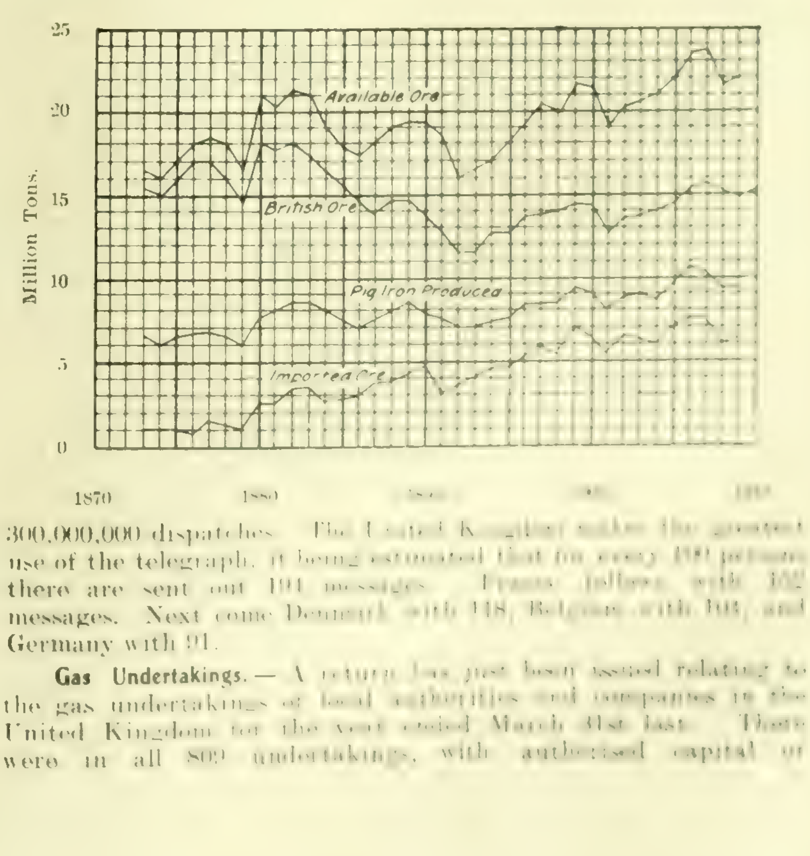


were won in New South Wales. For some years the price of the metal abroad has been rising, until at the end of June, 1911, it had attained the record price of £9 per ounce. This high price will probably lead prospectors in New South Wales to investigate more carefully the possibilities of platinum mining.

Amalgamation of Trade Unions.—In the January report of the Boilermakers' Society, Mr. John Hill, the general secretary, says that towards the end of last year the society was moving closer towards their fellow unionists in allied trades. They had had meetings with the Shipwrights' Society and with the Amalgamated Society of Engineers and the Liverpool Shipwrights, while their vote on closer unity with other shipbuilding and engineering trades had shown a large favourable majority. Many of the schemes were yet indefinite, but during 1912 they would see a linking up of trade union forces beyond anything in their experience.

Telegraphs of the World.—It is about 60 years since the introduction of the electric telegraph, as the system was known in this country up to its acquisition by the Post Office. The lines now in existence, so we learn from a Paris contemporary, are sufficient to go round the world 138 times. The total number of offices is given at 130,000, with 100,000 apparatus, which send out annually

Fluctuations in British Ore and Pig Iron Production, 1873-1910



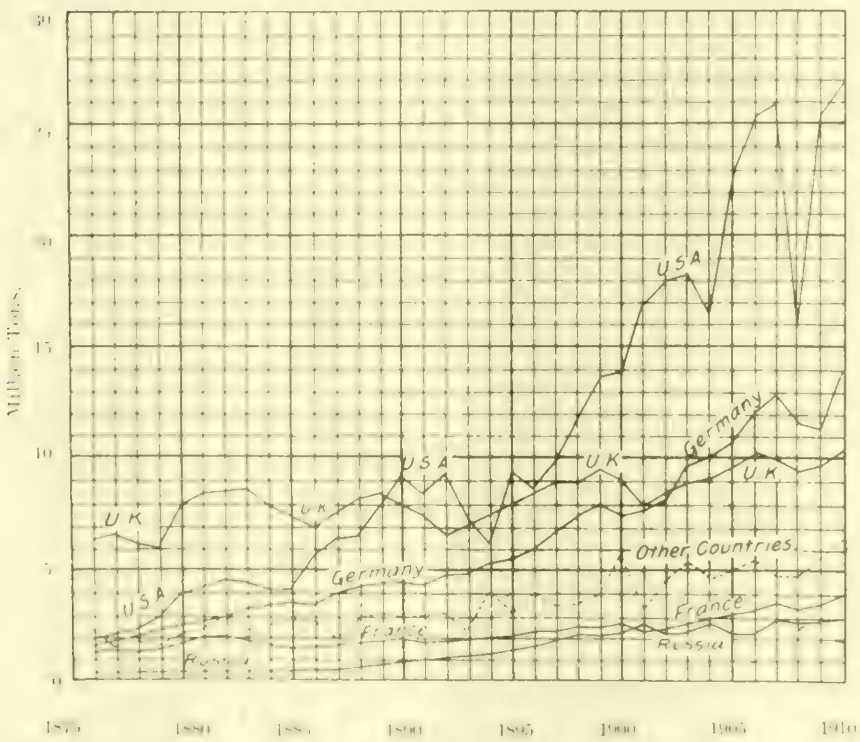
300,000,000 dispatches. The United Kingdom makes the greatest use of the telegraph, it being estimated that for every 100 persons there are sent out 191 messages. France follows with 152 messages. Next come Denmark with 118, Belgium with 108, and Germany with 91.

Gas Undertakings.—A return has just been issued relating to the gas undertakings of local authorities and companies in the United Kingdom for the year ended March 31st last. There were in all 809 undertakings, with authorised capital of

authorised loans of £157,341,047. The receipts for the year amounted to £31,276,196, while the expenditure was £23,211,379. The number of tons of coal carbonised was 15,397,703, and 198,733 million cubic feet of gas was made, and 182,833 million feet was sold. The total length of gas mains was 36,122 miles; there were 6,417,849 consumers. The number of local authorities included in the return is 298, and the receipts of the undertakings amounted to £10,829,758, while the expenditure was £7,902,451, and the total number of consumers supplied was 2,666,146.

Electricity in the Celluloid Industry.—The necessary heat for forming the various articles composed of celluloid has usually been supplied by high pressure steam, and as this material becomes soft at a temperature of about 250 Fah. and ignites at about 30 beyond that temperature, it is necessary to exercise a careful control over the heat. An electrical method is being tried in the

Pig Iron Produced in Principal Countries of the World, 1876-1910



United States in which the heat is applied by hot plate elements. In the manufacture of celluloid combs, for example, the blanks are placed on the plate successively, and are removed one by one by the workman as they are softened. A large electrical manufacturing house has placed on the market a special heating element for this purpose, measuring 18in. by 30in., and provided with quick starting connections, taking 450 and 900 watts in order to heat the plate rapidly. The normal consumption amounts to about 225 watts.

Lloyd's Register.—The following have been chosen to represent the shipbuilding and engineering interests on the general committee of Lloyd's Register: Mr. Thomas Bell, of Messrs. John Brown & Co., Ltd., Clydebank; Mr. James Denny, of Messrs. William Denny & Brothers, and Messrs. Denny and Co., Dumbarton; Mr. Harold R. Dixon, of Sir Raylton Dixon & Co., Ltd., Middlesbrough; Mr. Stephen W. Furness, M.P., of Irvine's Shipbuilding and Dry Docks Company, Ltd., West Hartlepool, and Messrs. Richardsons Westgarth & Co., Ltd., Middlesbrough and Hartlepool; Mr. Alexander Gracie, M.V.O., of the Fairfield Shipbuilding and Engineering Company, Ltd., Govan; Mr. George B. Hunter, of Messrs. Swan, Hunter & Wigham Richardson, Ltd., Wallsend-on-Tyne, and the Wallsend Slipway and Engineering Company, Ltd.; Mr. Andrew Laing, of the Wallsend Slipway and Engineering Company, Ltd.; Mr. James [illegible], of Messrs. Russell & Co., Port Glasgow; Mr. James Readhead, of Messrs. John Readhead & Sons, Ltd., South Shields.

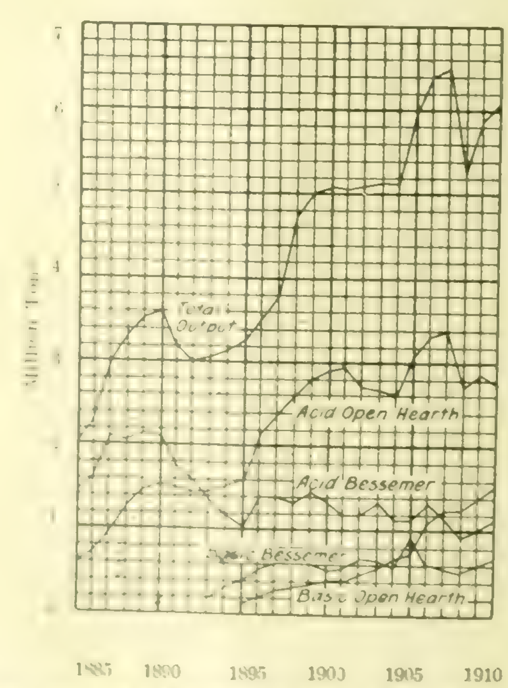
Germany's Industrial Insurance Scheme.—Details concerning the working of the German Imperial Insurance Laws are given by the American Consul at [illegible]. He states that the German Imperial Insurance authorities have brought out the first of a series of special reports made since the enactment of the Insurance Law of June 30th, 1900, setting forth the effects of these laws, and [illegible] that accidents may be avoided [illegible]. The [illegible] covers a period up to 1907. Accidents caused by the negligence of workmen, [illegible] decreased from [illegible] per cent. in 1887 to [illegible] per cent. in 1897, and to [illegible] per cent. in 1907. On the other hand, accidents resulting from negligence of employers decreased from [illegible] per cent. in 1887 to [illegible] per cent. in 1897, and [illegible] per cent. in 1907. In 1908 damages were paid in respect of the following who were insured: 9,212 killed, or 0·34 per thousand of those insured; 1,110 permanently wholly injured, or ·04 per thousand; 52,707 permanently partly injured, or 1·94 per thousand; temporarily injured, 74,735, or 2·75 per thousand; total, 137,764, or 5·07 per thousand of those insured.

Trade Unions and the Working of Machines in Engineering Works.—Trouble is threatening in the engineering trades respecting the employment of labourers for operating machine tools. Several conferences have recently taken place between the Engineering Employers' Federation, and the principal engineering trade unions concerned as to the class of labour to be employed on certain machines, and the interpretation to be placed on clause 7 of the terms of settlement arranged after the great engineers' lock-out in 1897 will be discussed. The employers claim that this clause gives them the right to employ whom they think fit on any machines. The trade unions claim that the clause only gives the employers the right to do this on certain almost automatic machines, reserving the others to skilled and trained journeymen. Another conference on the matter is to be held early next month. At the last central conference the trade unions threatened to break off all local negotiations on such points and recommend a national engineering strike unless the special conference to discuss the whole position was agreed to by the employers.

Some Trade Figures for the British Empire.—The 48th volume of the statistical abstract for the British Dominions and Colonies, from 1896 to 1910, has just been published as a Blue Book, and contains some interesting information with reference to the Empire. According to this, the total imports of the self-governing Dominions, Crown Colonies, Possessions, and Protectorates in 1910 amounted to £426,066,000, compared with £366,524,000 in 1909. The total exports were £444,479,000 in 1910, compared with £403,792,000 in 1909. The length of railway line open in 1910 was: British India, 32,099 miles; Australia, 15,467 miles; New Zealand, 2,753 miles; South Africa, 7,586 miles; Canada, 25,780 miles. The total for all the Colonies, &c., was 91,039 miles. India had 72,746 miles of telegraphs; Australia, 43,492 miles; New Zealand, 11,316 miles; the Cape, 8,166 miles; Canada, 36,317 miles; and Newfoundland, 3,382 miles. Australia had 220,173 miles of telephone; New Zealand, 1,384 miles; and the Cape of Good Hope, 6,002 miles. British India in 1910 produced 573,120ozs. of gold; Australia, 2,720,748ozs.; New Zealand, 446,431ozs.; Transvaal, 7,527,108ozs.; Southern Rhodesia, 609,955ozs.; Gold Coast, 183,691ozs.; and Canada, 490,000ozs. India produced 12,047,413 tons of coal; Australia, 9,758,994 tons; New Zealand, 2,197,362 tons; Natal, 2,294,746 tons; Transvaal, 3,548,550 tons; Canada, 11,425,457 tons.

The Decimal Association.—A circular just issued by this association sets forth the progress made towards securing the adoption of the metric system. The circular states there has been a very notable increase generally in the attention given to the subject in non

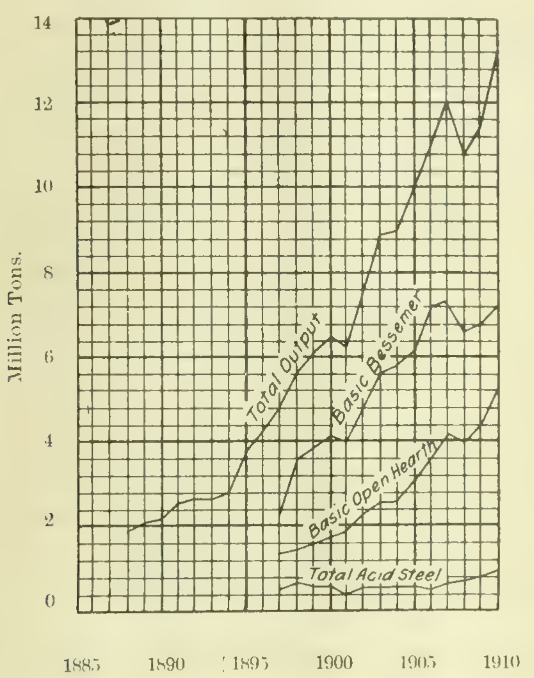
British Output of Steel, 1885–1910.



metric countries, and claims credit for the stimulus it has given. In August, 1910, a resolution in favour of the compulsory adoption of the metric system throughout the Empire was introduced in the Australian House of Representatives by Mr. G. B. Edwards, and the resolution was passed by 35 votes to two. More recently a resolution on the same lines was introduced at the Imperial Conference in London, but it was withdrawn in consequence of the opposition of the Board of Trade. In Malta a Bill for the com-

pulsory adoption of the metric system has been passed, and will come into force on January 1st, 1912. It is also announced that the Central American Republics of Nicaragua, Honduras, Costa Rica, San Salvador, and Guatemala have passed the necessary measures to enforce the metric system as from January 1st, 1912. The Commercial Intelligence Department of the Board of Trade has announced that an Act rendering the metric system compulsory in Bosnia-Herzegovina has been passed by the Government of that country, and will come into force on September 1st, 1912.

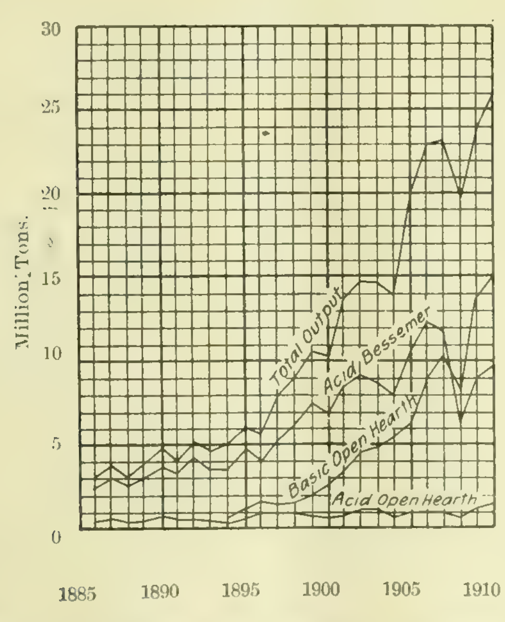
German Output of Steel, 1888–1910.



The Danish Weights and Measures Act was passed in 1907, and will come into force in April, 1912. There is no doubt, the circular adds, that the metre and the kilogram are gaining ground in every direction, and that the number of non-metric countries is being steadily reduced.

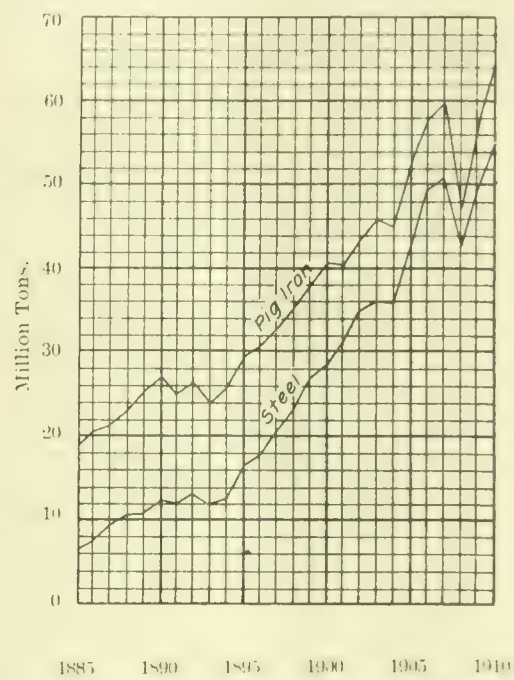
The World's Coal Production.— A report on coal production and coal consumption in the principal countries of the world has just been published by the Board of Trade. According to this report, the output of coal in the five principal coal-producing countries in 1910 was as follows: United Kingdom, 264,433,000 tons; Germany, 150,372,000 tons; France, 37,254,000 tons; Belgium, 23,332,000 tons; United States, 447,837,000 tons. In each of these countries, with the exception of the United Kingdom, the production in 1910 exceeded that of any previous year, the aggregate being 923 million tons, or an increase of 42 million tons on the output of 1909, and 27 million tons more than in 1907, when

United States Output of Steel, 1886–1910.



the highest previous total was reached. Except in the United States and Germany, the increases were small, the former country accounting for over 36 million tons, and the latter for 4 million tons of the increase over 1909. In the United Kingdom the output in 1910 fell short of that of 1907 by nearly $3\frac{1}{2}$ million tons. Of the remaining countries included in the tables, Russia alone has a production exceeding 20 million tons. The total known coal production of the world (exclusive of brown coal or lignite) in 1910 was about 1,035 million tons, of which the United Kingdom produced more than one-fourth. As compared with its population, the production of coal in the United Kingdom still surpasses that in the United States. It amounts to nearly 6 tons per head, whilst in the United States it is under 5 tons per head. In Belgium it amounts to $3\frac{1}{4}$ tons; in Germany to about $2\frac{1}{4}$ tons; and in France to under 1 ton per head. The average value per ton produced in the following countries in 1910 was: United Kingdom, 8s. 2d.; Germany, 9s. $11\frac{3}{4}$d.; Belgium, 11s. $10\frac{1}{2}$d.; United States, 5s. $10\frac{1}{4}$d. The average value per ton has increased considerably during the last 25 years in each of the European countries mentioned above. In 1909 the number of persons employed in coal mining above and below ground in each of the principal producing countries was as follows: United Kingdom, 992,300; United States, 666,600; Germany, 613,200; France, 187,200; and Belgium, 143,000. As regards the output per person employed, which is affected to a certain extent by the methods of operation, and by the accessibility of the seams, the United States took first place, with an output in 1909 of 617 tons per person employed; the United Kingdom second place, with 266 tons; followed by Germany, France, and Belgium, with 239 tons, 195 tons, and 162 tons, respectively. In the United Kingdom

World's Production of Pig Iron and Steel, 1885–1910.



and Germany the output per person employed has considerably increased during recent years. The exports from the United Kingdom in 1910 were less than in 1909 by nearly $1\frac{1}{2}$ million tons. The United Kingdom imported only 18,000 tons in 1910, her exports amounting to 84,512,000 tons. In 1909 the United Kingdom imports totalled only 8,000 tons, and the exports 86,037,000 tons. The total consumption of coal in the United States is now considerably more than twice as great as that in the United Kingdom, which has the next largest consumption.

Electro-deposition on Metals.— Mr. A. Price, in a lecture recently delivered before the Sheffield Electro-Metallurgical Society on "General preparatory methods previous to electro-deposition," said the demand for the electro-deposition of several metals, other than silver, had during the past few years increased to such an extent that the deposition alone of one metal—nickel—was responsible for the employment of more labour than all the other metals put together. In the several processes of metal colouring where certain desired finishes, known as oxidised and relieved, must be produced upon inferior basis metals, the need of a practical electro-plater having a wide experience in the deposition of all metals upon all basis metals, became more important every day. Much information was yet needed in regard to the preparation of surfaces in order to secure anything like perfect adhesion. For want of knowledge the most skilful operator sometimes failed in producing adhesion, especially upon zinc, cast iron, steel, Britannia metal and high percentage nickel-German silver. Mr. Price explained the various methods adopted for dealing with different metals, and urged the importance of thoroughly cleaning all articles before immersing in the plating bath, otherwise the deposit would not adhere no matter how good and correct the condition of the electrolyte.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1910.

Slide valves for fluid pressure engines. Say. 21579.
Rotary furnace or firebox. Smallwood. 22495.
Machines for making twist drills. Wilt. 27226.
Fluid meters. Kent & Hodgson. 27332.
Apparatus for the interchange of heat. Still, and Still's Tube Syndicate. 27772.
Couplings for railway wagons. Jones & Roberts. 29791.
Apparatus for the even distribution of liquids. Newton. 29902.
Arrangement and working of condensers. Mueller. 29903.
Devices for automatically applying brakes to railway vehicles. Becht. 29913.
Driving belts. Dunlop Rubber Company, and Worthington. 30009.
Automatic belt shifters. Bauer. 30025.
Construction of bolts. Dobbie & Dobbie. 30072.
Apparatus for cooling water by evaporation. Cunningham. 30089.
Nut locks. Robson & Harvey. 30141, 30142, and 30143.
Railway vehicle coupling. Wende & Höber. 30187.
Treatment of melted metals, alloys, and steels. Baraduc Muller. 30198.
Flexible metallic tubing. Berryman & Camus. 30199 and 30200.
Carburetters for internal combustion engines. Grove. 30252.
Rolling profile iron. Gewerkschaft Deutscher Kaiser Hamborn. 30279.
Automatic railway couplings. Lanzlort. 30308.
Interchangeable device for automatic railway coupling. Hebblewhite. 30312.
Vertical coke ovens. Jones. 30374.

1911.

Workmen's time recorders. Llewellin. 23.
Petrol gas generators. Wilson. 931.
Admission valve gear for steam engines. Eastwood. 1013.
Manufacture of smokeless fuel briquettes. Cowper Coles. 2003.
Filter presses for use in connection with hydro metallurgical processes. Merrill. 2802.
Motor road vehicles. Joteh & Moody. 2884.
Generation of gas from liquid fuel. Southey. 2954.
Rotary engine. Lindley & Schreier. 3082.
Portable hoist. Pinchbeck. 4116.
Relief or surplus pressure valves. Auld & Graham. 4657.
Winding apparatus for mines and lifts. Randall. 6422.
Propelling mechanism for mechanical flying machines. Short, Short, & Short. 8108.
Boiler flue baffles. Musgrave. 8429.
Apparatus for distributing liquids. Naylor & Naylor. 8464.
Locking devices for screws and nuts. Timmis. 8777.
Controlling valves for steam brakes of locomotives. Robson and Lewis. 8812.
Control of the overload or by-pass valves by means of the ordinary regulating valves in steam turbines. Kilburn. 8977.
Carburetter. Williams. 9285.
Apparatus for grinding milling cutters. Herbert & Allen. 9416.
Means for coupling and connecting metal tubes. Arnold. 11395.
Reducing valves. Hopkinson, Murgatroyd, and J. Hopkinson and Co. 12054.
Train controlling mechanism for railways. Jones & Jones. 12089.
Explosion turbines. Castelli. 12218.
Striking gear for power transmitting belts. Bertall & B[illegible]. 12634.
Steam boilers. Parker. 13[illegible].
Process and apparatus for silencing and deodorising the exhaust of explosion motors. Felsk. 13917.
Valves. Leadbeater. 14025.
Blowers for cleaning boiler tubes. Mattsson. 14[illegible].
Internal combustion engines having rotary distributing valves. Fornaca. 14944.
Valve gear for 2-cycle internal combustion engines. Fornaca. 15[illegible].
Process and apparatus for roasting ores containing sulphides. Mathonet & Pietsch. 15[illegible].
Steam boilers. Parker. 1531[illegible].
Casing of centrifugal compressors. Allgemeine Elektricitäts Ges. 15[illegible].
Safety devices for lifting appliances for use in connection with [illegible]. Siemens Bros. & Co. 16[illegible].
Apparatus for swelling and grinding tubes. Bodge. 16[illegible].
Speed[illegible] gear of traction engines. Bramall & [illegible]. 16844.

Device for preventing a sudden excessive increase in the speed of internal combustion engines with rotary cylinders. Windhoff. 17302.
Pipe testing apparatus. Crisandt. 17404.
Lubrication apparatus. Wakefield. 17906.
Superheaters. Schmidt, & Thomsen. 17959.
Water tube boiler. Ward. 18646.
Screw propellers. Mahodeau de Villethiou. 18854.
Steam jet cleaning apparatus for boiler tubes. Grunwald. 19662.
Internal combustion turbines. Whiteside. 19926.
Firebar. Smith & Rees. 20428.
Permanent way rail joint. Cook. 22004.
Hoisting winch. Kelly. 22591.
Lubricating means for ball bearings. Benz & Co. 24353.

ELECTRICAL, 1910.

Circuit for use with automatic telephone systems. Western Electric Company. 24995.
Methods of and means for clearing faults on high tension alternating current systems. Taylor. 27312.
Brush holders for dynamos. J. L. Manufacturing Company, and Reed Cooper. 27419.
Telephones. Climent. 29685.
Multiplex telephony and telegraphy. Squier. 30003.
Magnetic lifting appliances used with cranes. Steel, Peech, and Tozer, Ltd., and Bowen. 30075.
Flaming arc lamps. Dinsmoor. 30319.
Portable electric cluster lamps. Kirby. 30343.

1911.

Electric lamp signalling apparatus. Stewart & Stoodley. 2690.
Dynamos. Lancashire Dynamo and Motor Company, and McLeod. 2867.
Electric motor starting and protective devices. British Thomson Houston Company. 6188.
Electric meters. British Thomson Houston Company. 7669.
Electric time relays. British Thomson Houston Company. 7896.
Electric wall plugs and sockets. Hirst & Chapman. 8375.
Process for the electrolytic production of metallic antimony from antimony ores or compounds. Whitfield. 9968.
Electric switches. British Thomson Houston Company. 10254.
Switch holders for electric incandescent lamps. Downton & Kibblewhite. 10527.
Electric radiation furnaces. Marks. 11932.
Conductor points of electric railroads on the overhead conductor system. Nicholson & Nicholson. 13970.
Liquid electric controllers. Allen West & Co., and Moggridge. 16871.
High pressure current distributors for electric ignition apparatus. Heyer. 16968.
Make and break device for the primary circuit of electro magnetic ignition. Heyer. 17053.
Circuit arrangements for automatic telephone systems. Siemens and Halske Akt. Ges. 19187.
Electrically controlled railway signals. Siemens & Halske Akt. Ges. 21873.
Automatic regulating apparatus for electric supply systems. Siemens Bros. Dynamo Works, Ltd. 24105.
Means for use in automatically regulating the timing in magneto electric apparatus. Wiehl. 24970.

METAL QUOTATIONS.

TUESDAY, JANUARY 16th.

Aluminium ingot ...	63/- per cwt.
,, wire, according to gauge, &c. ... from	102/- ,,
,, sheets ,, ,, ... ,,	120/- ,,
Antimony ... £27 10 to	£28 -/- per ton
Brass, rolled ...	7¾d. per lb.
,, tubes (brazed) ...	9¼d. ,,
,, ,, (solid drawn) ...	8d. ,,
,, ,, wire ...	7¾d. ,,
Copper, Standard ...	£62 5/- per ton.
Iron, Cleveland ...	49/3 ,,
,, Scotch ...	55/3 ,,
Lead, English ...	£15 17 6 ,,
,, Foreign (soft) ...	£15 10/- ,,
Mica (in original cases), small ...	6d. to 2/- per lb.
,, ,, medium ...	2/6 to 4/- ,,
,, ,, large ...	4/6 to 8/6 ,,
Quicksilver ...	£8 -/- per bottle.
Silver ...	25[illegible] per oz.
Spelter ...	£26 15 - per ton.
Tin, Straits ...	£190 ,,
Tin plates ...	13/6 ,,
[illegible] (Siemens) ...	£30 10 ,,
,, (Siemens [illegible]) ...	£30 15 ,,

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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

The Corrosion of Condenser Tubes.

It will be remembered that one of the first collective efforts of the Institute of Metals was to initiate an enquiry into the subject of corrosion, and as a first step in their investigation they selected the wasting of brass condenser tubes by sea water. The subject is one to which a good deal of theorising has been devoted, and in the mercantile marine has given rise to considerable trouble and inconvenience. It seems clear, however, from the paper which was presented by Mr. Arnold Philip, Admiralty chemist, at the meeting of the Institute last week, and which we reproduce in another part of this issue, that the causes and methods of prevention are well understood in the Navy, and that the wider dissemination of this knowledge would do much to dissipate the troubles experienced in the mercantile marine. To those whose acquaintance of sea-water condensers is confined to marine practice it will be a surprise to learn that, notwithstanding some millions of tubes are in use in the Navy, the number of cases in which localised corrosion occurs is very rare, and further, that this immunity is secured simply by close adherence to a particular chemical composition of metal (viz., 71 copper, 1 tin, 28 zinc) for the tubes, and to the consistent use of steel, iron, or zinc protectors to guard against galvanic action. The efficacy of such protectors, although recognised in a general way, is by many engineers in the mercantile marine regarded as uncertain—owing to corrosion of the brass tubes being met with even where these protective agents are employed. It seems more than probable, however, that such cases could be fully accounted for, were the facts fully known, by imperfect electrical connections between the tubes and the protector metal. Admiralty experience has repeatedly shown that any defect in the electrical connection renders the protective action of iron, steel, or zinc upon the condenser tubes quite useless and, on the other hand, that where the electrical connection is perfectly maintained corrosion does not occur. It is essential

also for the protector metal and the condenser tubes to be immersed in the same electrolyte. Too often in the mercantile marine when protective agents are used they are attached in a way that fails to maintain electrical contact and they are then useless. This form of protection was adopted by the Admiralty and proved completely satisfactory years ago when the bodies of condensers were of cast or wrought iron and sea water passed outside the tubes instead of through them. Corrosion of the casing was then common, but corrosion of the tubes was practically unknown. In present practice, with water passing through the tubes, the protecting agent is used sometimes in the form of slabs attached to the inside of the condenser doors or on the tube plates, or in other cases in the form of rods fixed in the place of certain of the condenser tubes, while more recently it has become customary to make condensers with steel bodies. As evidence of the immunity from corrosion of condenser tubes in the Navy, Mr. Philip cites many cases in which they have lasted from 10 to 12 years. In the few rare instances where corrosion has been met with in horizontal condenser tubes the wasting has almost invariably been confined to the bottoms of the inside surface, and has been found to be due to local galvanic action set up by particles of coke, coal, or ferric oxide deposited from the cooling water. In only one case could the chemical composition of the tube be held responsible for the corrosion which ensued, and in that particular case it was discovered that the one per cent. of tin specified in the metal had been omitted. The deposition of particles of coke or coal is of course facilitated when a condenser is not in use and the tubes remain full of sea water, and such particles are more likely to obtain entrance when vessels are coaling or ash ejectors are in operation. It might be suggested that under such conditions it would be advantageous to drain the condenser, but this, as Mr. Philip observes, would introduce the possibility of corrosion of a somewhat similar kind, since the bottom of the tube would be the last part to be drained and the longest exposed to the joint action of air and salt water, and, having regard to the few cases of corrosion actually met with, it would appear best to let well alone and treat them as unavoidable incidents of wear and tear, seeing that the main trouble experienced from corrosion of brass condenser tubes can be avoided by the exercise of reasonable care

The Nomenclature of Non-ferrous Alloys.

In a brief note presented to the Institution of Metals last week, Dr. Rosenhain urged a reform in connection with the naming of non-ferrous alloys which, we are sure, will meet with wide approval. At present the names "brass," "bronze," "German silver," &c., are applied with a laxity that is confusing and even misleading to those not acquainted with the actual composition of the alloys. He suggests the matter should form the subject of investigation at the hands of a representative committee of members of the Institute, and without formulating a uniform nomenclature, such as is adopted in chemistry, he makes a suggestion which might at least serve as a rational basis. He proposes that all alloys should be regarded as essentially binary alloys, i.e., as consisting of two metals principally, to which one or more other metals may have been added in certain cases. To each of these groups of binary alloys he would apply a general class name, and distinguish the various members of the class containing a third or fourth metal by the addition of certain words or syllables to the class name. On this basis all copper-zinc alloys with their ternary and quaternary derivatives would be termed "brasses," and all copper-tin alloys and their derivatives would be termed "bronzes," following in this respect recognised custom, though these terms would exclude compounds consisting in the main of copper and aluminium, to which the misleading term "aluminium bronze" is now often applied, and to which the more distinctive class name "cupro-aluminium" might be applied; copper-nickel alloys and their derivatives being similarly designated "cupro-nickels." In the majority of commercial alloys the classification indicated would not present any difficulty, since their approximation to the binary type in most cases is fairly definite, nor need it interfere with certain current designations with which engineers are already familiar; such, for example, as "naval brass," though, under the nomenclature proposed, this would be more accurately designated "tin-brass," just as brasses containing iron or lead could be designated as "iron-brass" or "lead-brass"; while similar distinctions could be applied to the bronzes. It is not pretended that the system of classification proposed would permit of sharp, clear division in all cases, because there are many alloys which contain two metals in nearly equal proportions, in addition to copper, but a consideration of their characteristics would permit, as a rule, of designations having some approach to scientific consistency. No interference would, of course, be made with trade designations where fancy names are employed for selling purposes, or to alloys having special properties, but some restraint would at least be laid on the haphazard way in which such terms as brass or bronze are at present employed, and if the Institute of Metals can formulate a clear and unambiguous set of names by which the general types of alloys can be distinguished, it will undoubtedly prove helpful to engineers in drafting specifications, as well as to chemists in testing materials, and by so doing promote the interests of all concerned.

Pit-cage Accidents.—At a recent sitting of the Royal Commission on Metalliferous Mines and Quarries, Sir Henry Cunynghame presiding, Mr. N. Trestrail, of the Phœnix Mine, Carn Brea, Cornwall, gave evidence, in the course of which he submitted that engine drivers and hoisting men in mines should be certificated, and subject to an annual medical examination, in addition to being tested for sight and hearing. There should also be an age limit. Other provisions urged by the witness were: Safety catches to be used where men were hoisted, poppet heads to be a certain minimum height between landing stage and pulley, the adoption of a universal code of signals for hoisting enginemen, a standard or approved lubrication to be used in air-compressor cylinders, air reservoirs to be thoroughly cleaned out every six months, and regulations for the use, delivery, and return of dynamite not used. Mr. B. Angwin, of Carn Brea, favoured a general code for signalling in respect of winding engines, but he preferred to rely on a good rope rather than automatic safety catches. "A satisfactory safety catch for cages," he added, "has yet to be found."

Cleveland Institution of Engineers.—At a meeting of this Institution, held at Middlesbrough on the 22nd inst., Mr. H. G. Stedman, A.M.Inst.E.E., read a paper on "The Electric Furnace Process, as Applied to the Metallurgy of Steels." He said that the total number of electric furnaces in existence was not far short of a thousand. Those were mainly employed in the manufacture of steel, iron, and other metals. The use of electricity for metallurgical purposes was now an established commercial process abroad. In some respects the progress made by the latest source of heat had been rapid, more so than most of the important processes recently developed, and many well known steel manufacturers had gone in for electric refining on a large scale, both in America and England. Continuing, Mr. Stedman said it was incorrect to assume that the installation would be a financial failure if there were not water power, but, if they excepted Canada and Scandinavia, there was nowhere in the world where current could be obtained cheaper than on the North-east Coast.

AUXILIARY MACHINERY FOR INTERNAL-COMBUSTION ENGINED VESSELS.

AT the Institute of Marine Engineers on Monday, January 15th, a paper on "Auxiliary Machinery for Internal-combustion Engined Vessels," by Mr. W. R. Cummins, was read, in the unavoidable absence of the author, by the Hon. Secretary. Mr. F. M. Timpson (member of council) occupied the chair. The author first considered the question of the starting engine. There were two methods, he said, of applying a starting force to the crank shaft, the first being to utilise the power cylinders themselves, air or gas under pressure being distributed by the ordinary or special valves. In the second method the starting engine might be coupled to the engine shafting mechanically, hydraulically, or electrically during the manœuvring periods. The first system was most in favour at the present time. There were, generally speaking, many disadvantages in using the power cylinder as a starting cylinder, as, while it was employed in starting, it could not undertake its normal functions. In the system patented by the writer, the bottom end of the power cylinder was closed, and used as a scavenging and cushioning cylinder. The starting air was admitted at this bottom end of the cylinder, thus leaving the top end free to take up its normal functions immediately the engines were started. Dealing next with the various pumps required, the author said it would be noticed that, with the exception of the hydraulic pumps for the water-tight doors and the fire pumps, all delivered at a comparatively small head. For this duty, electrically-driven, direct-coupled, single-stage centrifugal pumps would be the most efficient combination. He also advocated the electrical drive for the ventilating fans. The present-day steam steering engines were very reliable, but were not economical. An easy solution of the problem would be to use compressed air in place of steam, thus utilising the present standard engines. It was a sign of the times that many engineering firms who made a speciality of ships' auxiliary machinery were now devoting their attention to electrical and hydraulic driving. The author then dealt with the cargo winches, cranes, hoists, and other auxiliaries, and concluded by a consideration of the merits of the electrical, compressed-air, and hydraulic systems of power transmission.

In opening the discussion, the Chairman stated that compressed air had been used for auxiliaries on the oil-engined vessel "Vulcanus," but the owners of that vessel had reverted to the use of steam, with oil fuel fired boilers in later boats. It appeared to him that it would be a good practice for steamship lines to fit motor-driven auxiliaries, as this would give the engineers good training for the internal-combustion engines of the future. Mr. W. P. Durtnall said there had been many attempts to utilise compressed air for various purposes, but the compression losses were such as to make the overall efficiency very unfavourable as compared with internal-combustion engines, and even, in some cases, with the steam engine. Hydraulic gear was fairly efficient for the handling of cargo. Recently he had assisted in making a three days' test on a 7,000-ton steamer, with eight winches, and it was shown that the consumption was 29·2lbs. of coal for every ton of cargo lifted out of the hold. This figure included radiation and other losses. The owners had decided to put in apparatus for electrical driving. The system was a continuous-current one, and it had been entirely successful in the experimental stage. It was a balance system, with seven different voltages varying from 50 to 350 volts. The variable voltage got over the difficulty of having resistance weights. He considered that electrical driving could be shown to be better, commercially speaking, than any other system. Mr. E. Shackleton thought there were many difficulties in the way of adopting electrically-driven auxiliaries on smaller boats, such as trawlers. He agreed that the use of compressed air was not economical in practice, although it seemed all right in theory. He thought it would mean unnecessary complications to have an electrical motor for starting the main engines or for the auxiliary engines. Mr. W. McLaren considered that deck machinery, winches, windlass, capstan, &c. should be operated by electrical gear. For the steering gear, however, he did not see why either hydraulic or compressed air apparatus should not be used, and the power applied direct on to the rams. It was agreed that the discussion be adjourned till Monday, February 5th. The meeting concluded with the usual votes of thanks.

ELECTRICITY IN COLLIERIES: PROSECUTION UNDER THE FACTORY ACTS.

ON the 17th inst. the Alfreton magistrates had before them an important case dealing with alleged breaches of colliery rules. The prosecution was directed by Mr. W. H. Pickering, the chief mines inspector for the district, and the defendants were Mr. Henry Stevenson, the agent and general manager of the Pinxton Collieries, and Mr. James Strachan, the manager of the collieries. They were charged with three separate offences and breaches of three special rules. The first charge was that for the installation and use of electricity, unenclosed fuses in the Brookhill Colliery shaft pump room were placed more than 2ft. from the floor, and were not otherwise suitably protected. The second charge was that the exposed ends of the cables in the pump room were not properly protected and finished off. The third offence alleged was that the motor in use in the shaft pump room was not provided with an ammeter to indicate the load put on the machine. There was a private consultation before the case was heard between the defending solicitors and Mr. Pickering, who afterwards intimated to the Bench that as he had been assured that all the electrical appliances had now been put right, he would withdraw the charges on payment of costs, and conditionally that the defendants admitted a violation of the rules. At the same time, not only must the appliances comply with the present regulations, but they must be placed in first-class order. The defendants accepted Mr. Pickering's conditions, and said they did not complain of the inspector's attitude. The delay in complying with his requisition was due solely to the delay of the firm who had the order to supply the necessary appliances. The Bench allowed the cases to be withdrawn on the payment of costs.

THE CHURWELL STEAM-PIPE EXPLOSION.

A BOARD of Trade formal enquiry into the circumstances of a fatal steam-pipe explosion which occurred on March 20th last, at the woollen mills of Messrs. C. Scarth & Sons, Ltd., Churwell, near Leeds, was held on the 17th and 18th inst. at the Leeds Town Hall, before Commissioners Mr. A. B. Bence-Jones and Mr. J. Melrose, C.B.

The steam pipe, which was situated in the boiler-house, burst at a joint which had just previously been repaired by the insertion of a rubber ring, and at the time six workpeople were taking advantage of the warmth of the room to smoke and chat, and one was scalded to death.

Giving the judgment of the court, Mr. Bence-Jones said they were satisfied that at the time of the explosion the steam pressure in the boiler was not excessive. Answering the questions put to them by Mr. G. C. Vaux, who represented the Board of Trade, the Commissioners found that the condition of the material of the rubber ring could not, as the result showed, have been good at the time, although apparently there was nothing in the appearance of the ring to indicate that it had either undergone decay with long keeping, or that it was originally made of faulty material.

As to whether the joint had been properly tightened, they said if anything the screwing up process had been carried too far, and the rubber ring torn to pieces.

The cause of the explosion was the defective nature of the rubber ring, which had failed to withstand the steam pressure. They found that Messrs. Scarth, their manager, and engineman were not to blame, and further, they were of opinion that no order should be made upon them for payment of any of the costs of that enquiry.

The Commissioners also drew attention to the Board of Trade report respecting a similar enquiry in Staffordshire in 1894, and they concurred in the views of the Commissioners on that occasion that a less perishable material than india rubber should be used for making steam-pipe joints.

HERRINGBONE GEARS.*

WITH SPECIAL REFERENCE TO THE WUEST SYSTEM.

BY PERCY C. DAY.

THAT the helical principle in toothed gearing is ideal from a theoretical point of view is well known. From a practical standpoint herringbone gears have been less satisfactory than straight-cut spur gears because, until recently, no method was devised for producing them with the requisite speed and accuracy. Within the last six years a method has been found and developed, in England, to a high degree of perfection. Herringbone gears made by this method are called Wuest gears, after the name of the inventor, and can be produced with even greater accuracy than cut gears of the spur type (see Fig. 1).

The distinction between these gears and those of the ordinary herringbone type is that the teeth of the former, instead of joining at a common apex at the centre of the face, are stepped half the pitch apart and do not meet at all. This arrangement of the teeth does not affect the action of the gears, but it facilitates their commercial production and admits the use of the precision methods in their manufacture.

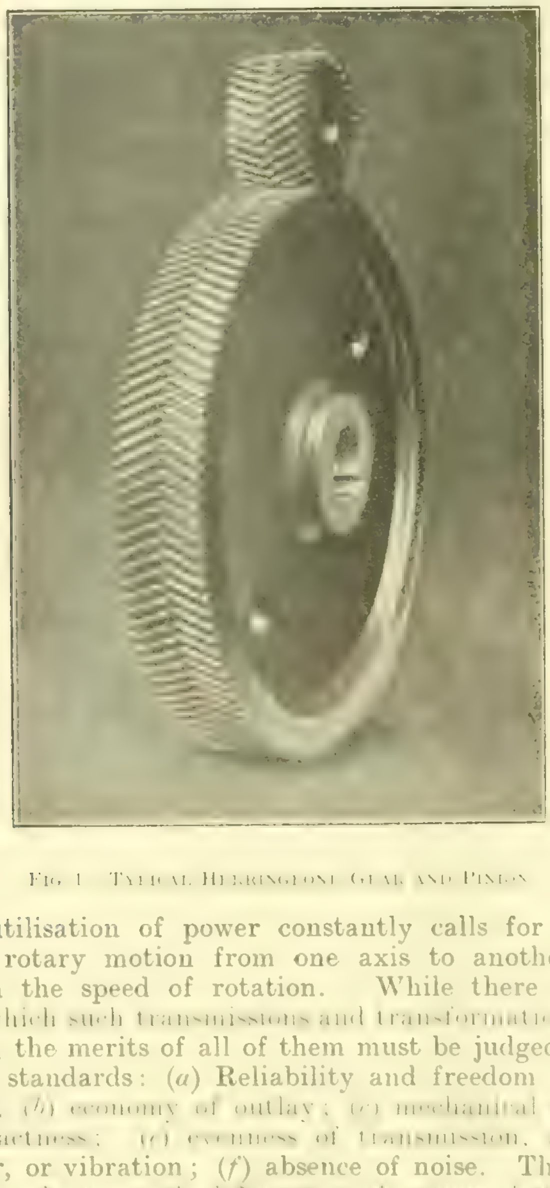


FIG. 1.—TYPICAL HERRINGBONE GEAR AND PINION.

The utilisation of power constantly calls for means to transmit rotary motion from one axis to another and to transform the speed of rotation. While there are many ways in which such transmissions and transformations may be produced, the merits of all of them must be judged from the following standards: (*a*) Reliability and freedom from wear and tear; (*b*) economy of outlay; (*c*) mechanical efficiency; (*d*) compactness; (*e*) evenness of transmission, absence of shock, jar, or vibration; (*f*) absence of noise. The order of merit may change with different applications, but the same standards obtain for all transmissions. The various methods employed are so well known that they need no discussion here. Let it suffice to say that the spur gear, which satisfies only the first four conditions, is used to such an extent that all other appliances are relatively unimportant.

Action of Spur Gearing.—The aim of all designers of gearing is to transmit rotary motion from one axis to another in a perfectly even manner without variation of angular velocity. Let us consider the action of a straight spur pinion driving a gear. There are three distinct phases of engagement:

(*a*) First phase: The root of the pinion tooth engages the point of the gear tooth.

(*b*) Second phase: The teeth are engaged near the pitch line.

(*c*) Third phase: The point of the pinion tooth engages the root of the gear tooth.

Let us assume that the teeth are accurately cut to involute form, so that if the pinion moves with even angular velocity it will produce corresponding evenness of motion in the gear. Also that the pinion has sufficient teeth to allow the engagement of successive teeth to overlap. At the beginning of the first phase, while the load is carried near the point of the gear tooth, that tooth is subjected to a maximum bending stress along its whole length. During the first phase, the portion of the pinion tooth near the root is sensibly sliding over the outer portion of the gear tooth: that is to say, two metallic surfaces of small area are sliding under heavy compression. The action during the second phase more nearly approaches ideal conditions. The teeth are engaged near their respective pitch lines and very little sliding takes place. During the third and final phase the pinion tooth is subjected to a maximum bending stress, while the tooth surfaces again slide over each other, this time with the outer portion of the pinion tooth engaging the gear tooth near its root.

The point to be noted is that while those portions of the mating teeth which are near the pitch lines transmit the load with rolling contact, those which are more remote have to transmit the same load with sliding contact. The inevitable result is that the points and roots of all the teeth tend to wear away more rapidly than the portions near the pitch lines, so that the involute tooth curves, necessary to the preservation of even angular velocity, lose their form and the motion becomes uneven.

It may be suggested that the sliding action can be got rid of by shortening the teeth so that they engage only the phase of rolling contact. This has been tried with a certain measure of success in the stub-toothed gear, but it cannot be carried far enough without curtailing the arc of contact so that continuity of engagement is lost, thereby introducing more serious trouble than that which it is desired to avoid.

Distortions of gear teeth from involute form, whether due to inaccurate cutting or subsequent wear, give rise to all kinds of trouble. The average angular velocity may be uniform, and yet the passage of each pinion tooth through its brief engagement with the mating gear may be accompanied by successive retardation and acceleration which, though small in itself, takes place in such a short interval of time that it may cause interacting stresses many times greater than the average working load on the teeth. These internal stresses are very difficult to deal with, because they are indeterminate. They cause noise, vibration, crystallisation, and fracture.

Action of Herringbone Gears.—Herringbone gears completely overcome all these difficulties, but only when they are accurately cut. The writer will first assume the accuracy and describe the action, afterwards he will endeavour to show how the system under discussion has special features which ensure the production of accurate herringbone gears on a commercial scale.

If we take two exactly similar pinions with straight teeth and place them side by side on one shaft, with the teeth of one pinion set opposite the spaces of the other, then we have what is known as a stepped-tooth pinion. If this pinion is meshed with a composite gear made up in a similar manner, the action is modified so that there are always two phases of engagement taking place simultaneously. Such gears are commonly used for rolling mill work, because they stand up to heavy shocks better than the plain type. Still better action can be secured by assembling a number of narrow pinions with the last of the series one pitch in advance of the first and the others advanced by equal angular increments. As a practical proposition, however, gears made on these lines would be costly and difficult to produce.

The helical gear is the logical outcome of the stepped gear carried to its limit, and built up from infinitely thin laminations. Since the steps have merged into a helix, there must be an axial component of the tangential pressure on the teeth, producing end thrust on the shafts. To obviate end thrust, the helical teeth are made right hand on one side of the face and left hand on the other. Such gears, with double helical teeth, are known as herringbone gears. The fundamental principle of the action of herringbone teeth lies in the circumstance that all phases of engagement take place simultaneously. This holds good for every position of pinion and

* Paper read before the American Society of Mechanical Engineers.

gear, provided only that the relationship between pitch, face width, and spiral angle is such as will ensure a complete overlap of engagement.

Since all phases of engagement occur together, it follows that the load is partly carried by tooth surfaces in sliding contact and partly by surfaces in rolling contact. The result is curious and interesting. Those portions of the teeth farthest from the pitch line, which engage with sliding action, tend to wear away more rapidly than the portions nearest the pitch line. But the pitch line portion is always carrying part of the load, and the effect of wear on the ends of the teeth merely tends to throw more load on the centre portions; in other words, there is a tendency to concentrate the load near the pitch lines. The ends of the teeth, instead of wearing away to an ever-increasing extent from their original involute form, are relieved of some of the load from the moment that wear commences to take place. As soon as the load on these ends has been partially relieved and transferred to the middle portion, the wear becomes equalised all over the teeth and they do not tend to distort further from their original shape.

It is quite clear that an unmeasurable amount of wear on the tooth ends will be sufficient to relieve them of all the load, so that the distortion from original form will be practically nothing. The minute extra wear that does take place at the ends is only the amount necessary to transfer such proportion of the load near the pitch lines that the wear is equalised all over the surface of the teeth, those portions in sliding contact carrying less than those in rolling contact. Thus the teeth keep their involute form, and motion is transmitted from pinion to gear in a perfectly even manner, without jar, shock, or vibration. Although herringbone teeth may not be intrinsically stronger than straight teeth, the elimination of all shock and indeterminate internal stresses renders them capable of dealing with far heavier transmitted loads. The concentration of the major portion of the load on the parts of the teeth in rolling contact eliminates friction to a marked extent.

Since all phases of engagement occur simultaneously, the transference of the load from one pinion tooth to the next takes place gradually instead of suddenly. This is the second principle of herringbone gearing, and may be termed continuity of action. In straight gears the continuity of action is a function of the number of teeth in the pinion. Straight pinions with less than 12 teeth are seldom made, and more than that number must be used if the drive is to be even moderately satisfactory.

In herringbone gears continuity depends on the relationship between the face width and the number of teeth in the pinion. Pinions with as few as five teeth have been used with success by merely increasing the face width to suit such extreme conditions. This feature, which is peculiar to herringbone gears, has made practical the adoption of extremely high ratios of reduction hitherto considered impossible.

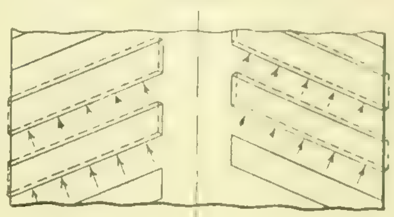
The third principle of herringbone gearing is that the bending stress on the teeth does not fluctuate from maximum to minimum as in straight gears, but remains always near the mean value. This feature is of special importance in rolling-mill driving and work of a similar nature.

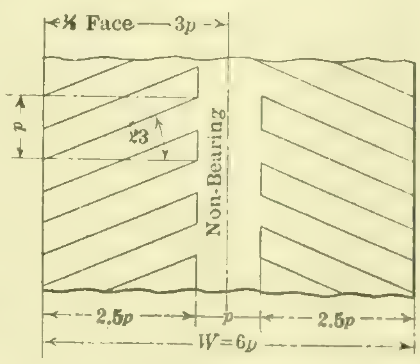
To summarise the foregoing arguments: The action of herringbone gears is continuous and smooth; there is no shock of transference from tooth to tooth; the teeth do not wear out of shape; the bending action of the load on the teeth is less than with straight gearing and does not fluctuate to anything like the same extent; the gears work silently and without vibration; the phenomenon commonly termed back-lash is absent; friction and mechanical losses are reduced to a minimum; herringbone gears can be used for higher ratios and greater velocities than any other kind. These advantages are limited to gears which can be produced with a degree of accuracy which will ensure the practical realisation of the principles involved.

The Production of Herringbone Gears.—Herringbone gears may be produced in a variety of ways which differ from each other as widely as the character of the product. Until a few years ago all gears of this type were moulded. The limitations of moulded gearing are analogous to those which would be experienced if a journal were set to run in a moulded bearing. Just as the bearing would touch the shaft only in spots, so moulded gears utterly fail to give the intimate contact all along the teeth which is necessary to secure the realisation of true helical gear action. It is obvious that if the teeth touch only in a few high places, they will be subjected to all the evils of shock, stress, and inequality of motion which it is desired to avoid. If the gears are particularly well moulded, some mitigation may be expected when they become well worn, but initial wear is accompanied by a departure from correct tooth shape. For slow speeds a well-moulded helical gear is no better than a straight gear with cut teeth, and for high speeds it is not as good. The natural smoothness of helical action does no more than compensate for the inaccuracies of tooth form and spacing.

The modern herringbone gear must have cut teeth if its advantages are to become real. Cut herringbone gears may be broadly divided into two classes, two-piece and one-piece gears. The difficulty in the way of cutting double helical teeth in a single blank gave rise to the two-piece variety. The same methods of cutting may be used for both kinds. The disadvantages of the two-piece type are fairly obvious. There is the expense of two complete gears, the difficulty of assembling the gears so they are in accurate register with each other, and the necessity for very complete fixing if they are to perform hard service without getting out of register.

Fig. 2.





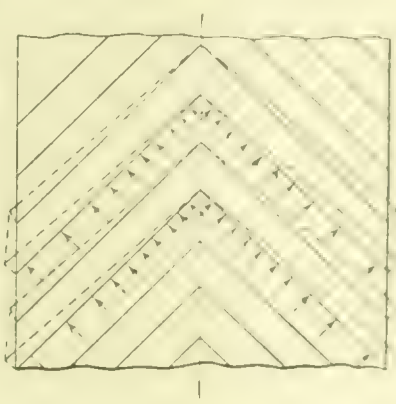


Fig. 4. Fig. 3.

DIAGRAMS SHOWING TOOTH PRESSURES AND ANGLE NECESSARY FOR CONTINUITY OF ACTION.

High ratios, perhaps the strongest feature of the one-piece type, are not within the scope of the built up gear, because the pinions must be assembled on a separate shaft and the pitch line must be far enough from the surface of the shaft to allow room for the necessary bolts or rivets used in fastening the two portions together. The one-piece pinion, however, may be cut solid with its shaft, so that its pitch diameter need be but very little larger than the latter

The known methods of cutting helical gears may be divided into four classes: (*a*) Milling by formed disc cutters; (*b*) milling by end mills; (*c*) generating by shaping or planing methods; (*d*) generating by hobs

Milling by formed disc cutters is unsatisfactory because, in addition to the usual errors of step-by-step division, there is the difficulty of making the cutters to the normal tooth shape with sufficient accuracy to ensure correct circumferential shape for the gears cut. This difficulty is increased by reason of the fact that a disc cutter cannot cut its own shape in a spiral groove. Let it be noted that the cutters must be formed empirically, that their number must be very large to meet the requirements of a general gear business, and that the accuracy of each gear turned out depends on the combined efforts of the toolmaker and draughtsman who produced the cutter. Worst of all, two different cutters must be used for a gear and pinion. This method will produce indifferent herringbone gears which may be built up with teeth in register or made in one piece with staggered teeth.

The use of end mills is open to all the objections given

with regard to disc cutters, with the single exception that the cutter does leave a fair approximation to its own shape in the groove which it cuts. The end mill has a host of disadvantages peculiar to itself which render it even less efficient than the disc cutter for general work. In the first place, it is a small tool with very little wearing surface and no capacity for dissipating the heat generated at its cutting edges. The great variation in diameter between point and base renders it difficult to arrive at a cutting speed which will satisfy the conditions at both ends of the cut. When used for any but the largest pitches, outside the range of general gear practice, the mills quickly become clogged with cuttings, overheat, and burn. A burnt end mill, clogged with cuttings, produces a wider groove than a good mill. This is a fruitful source of spoiled work. To complete one fair-sized gear by the end-mill process requires quite a number of cutters. This not only makes the expense heavy, but must necessarily result in an inaccurate gear.

Every cutter used must be formed to gauge and hardened. After being hardened, it will run out of true a little in most cases, thereby cutting a shape different from that for which it was designed. In end mill gears it is not merely a case of getting accurate conjugate tooth shapes in gear and pinion made with different cutters, but the teeth in a single gear may have a dozen different shapes. The process is so slow that it cannot compete with other methods, quite apart from the doubtful quality of the gears produced.

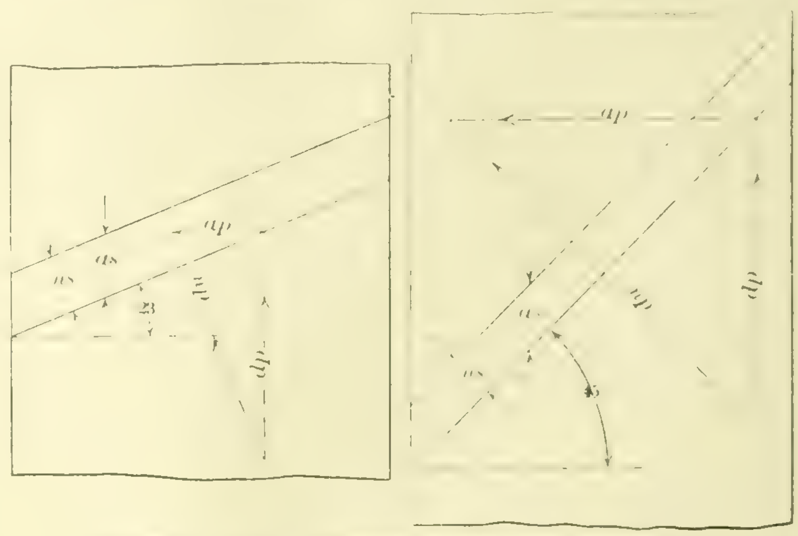
End-milled herringbone gears are usually made in one piece with the teeth joined at the centre. Since the cutter is shaped to the normal pitch, it follows that, in changing over from right to left-hand helix, it leaves a thick wedge in the centre of the face that must be removed by a subsequent operation. The teeth of end milled herringbone gears do not bear over the centre portion.

Generating processes by the shaping and planing types, while successful for straight-cut gears of relatively small size, are not used to any extent for large diameters or heavy pitches. The reason for this may be found in the nature of such processes. The gear blank is required to make a quick angular movement after each stroke of the cutting tool and to come to rest again before the next stroke. Such methods are difficult to apply to large gears on account of the inertia of the gear blank and its support and the consequent difficulties of controlling the short intermittent movements. These difficulties are much increased when such methods are applied to cutting helical teeth, because the blank must make definite and rapid angular movements during each stroke in addition to the motion between strokes. No machine has been devised which will satisfactorily deal with the problem on these lines.

The hobbing process as supplied to straight-cut gears has proved so successful as to arouse a storm of adverse criticism from those who are interested in other methods of gear production. It is not difficult to understand why this process has sprung into prominence in a comparatively short time. It is essentially a rational process. The shape of the teeth is generated from spiral hobs, the threads of which are cut to a plain rack section. There is nothing empirical about a hob, it is a straightforward thread cutting, gashing, and relieving proposition. One hob will cut any gear or pinion of one pitch. This feature alone eliminates a host of errors which are characteristic of gears produced by milling methods. The hob revolves continuously while cutting, as does the gear blank. The feed is also continuous. There are no cutting and return strokes, no intermittent starting and stopping of gear blanks, as in other generating processes. These features do not necessarily ensure the production of accurate gears, but they offer greater facilities to the designer for the achievement of the desired result. The hob is a substantial tool with plenty of wearing and cooling surface, it can be made to stand up to very fast production and to last for a long time. The continuous nature of all motions used in hobbing a gear blank enables this process to be used for the production of the heaviest gears, there are no limitations such as are encountered in other processes. The limit to the size of a hobbing machine is set by the dimensions of the largest gears which are required in sufficient quantities to pay for the investment. There are no technical limits whatever.

Nevertheless there are some slight defects in the hobbing process as applied to the production of straight-cut spur gears. A hob is a worm thread, and as such must have a spiral angle depending on the relationship between the pitch of the thread and the diameter of the hob. A straight-cut gear has no spiral angle, hence the spiral hob must be inclined, more or less, to bring the cutters in line with the tooth spaces to be cut. In order to cut correct teeth, the axis of the hob should be perpendicular to the axis of the gear blank. In such case the hob will generate involute teeth if its threads are cut to the same axial section as the straight-sided parent rack for the required pitch. Since the hob must be inclined to cut a spur gear, the teeth are not generated from the axial or rack section, but from a diagonal section. The axial pitch of a hob for cutting spur gears is not the same as the pitch of the gears which it cuts. The normal pitch of the hob threads must be the same as the gear pitch.

Hobs for cutting straight spur gears are usually made of large diameter to reduce the spiral angle and consequent errors of tooth form to a negligible minimum. As a natural consequence, such hobs have only one thread, while their large diameter requires a slow speed of rotation to keep the cutting speed within proper limits. The effect of this is that the blank revolves very slowly, and a coarse feed must be



as	Axial Section	23 Deg.	45 Deg.
ns	Normal Section	as 0·936 as	0.707 as
dp	Driving Pressure	—	—
ep	End of Wedge Pressure	ep 0.424 dp	1.0 dp
np	Normal Pressure	np 1·09 dp	1.414 dp
	Relative $\frac{ep}{ns}$	= 1.19	2.0

FIG. 5 RELATION OF DRIVING PRESSURE TO ANGLE OF TEETH.

used to keep up the output. It is one of the peculiarities of each hob action that only one tooth of the hob puts the finishing touch to the bottom of a tooth space once in each revolution of the gear blank. If the feed is coarse there will be noticeable feed marks and roughness in the gear teeth produced. A coarse feed used with a hob of large radius throws severe stresses on the hob arbor and its supports.

The necessity of a swivel motion on the hob slide, to enable straight spurs to be cut with hobs of varying spiral angle, compels the use of a hob drive which passes through the pivot. It is almost impossible to design such an arrangement without undesirable restriction in the dimensions of driving gears and shafts combined with excessive overhang of the hob arbor in relation to its supporting slide. The general want of rigidity about most hobbing machines used for the production of spur gears is traceable to the above causes. Rational critics of the hobbing process have based their objections on these features.

The hobbing process properly applied to the production of herringbone gears has none of the disadvantages incidental to its application to spur gear cutting, which have been shown to lie in the necessity of inclining the hob axis. Since a helical gear and a hob must both have a spiral angle, it is only necessary to make the thread angle of the hob the complement to the corresponding angle of the gear teeth to secure the advantages of perpendicular fixed axes. These are of great practical value. Since the hob axis is always perpendicular to the axis of the gear blank, it follows that the teeth are generated from the axial and true rack section of the hob, while the linear pitch of the hob is the same as the circular pitch of the gear which it cuts. The hob axis is fixed and the hob can be supported on a rigid slide with the

minimum of overhang. There is no restriction to the size and strength of the gears and shafts used to drive the hob.

Wuest Herringbone Gears.—It has been explained that the teeth of the Wuest gears are so designed that those on the right and left-hand sides of the gear are stepped half a space apart and do not meet at a common apex at the centre of the face, as in the usual type of herringbone gear. It has often been argued that the ordinary herringbone tooth is stronger than the Wuest tooth, because the latter lacks the support given by the junction of the teeth at the centre. This argument would be sound if gear teeth were ever stressed to anywhere near their breaking point. But it has been found in practice that considerations of wear so far outweigh those of mere breaking strength that a gear which is designed to give reasonable service will carry anywhere from 10 to 20 times the working load without fracture. A point of vastly greater importance is that the stepped form will wear more evenly under extreme loads than the ordinary type. The reason for this is shown in Figs. 2 and 3. The resultant tooth pressure is always normal to the teeth and tends to bend them apart. The stepped form offers a uniform resistance along its whole length, carrying the load from end to end (Fig. 2). The teeth of ordinary herringbone gears tend to separate more at the sides than near the supported centre, causing the load to be concentrated toward the centre (Fig. 3).

Any system of gearing, if it is to be generally applied, must be interchangeable. The variable features of involute spur gear teeth are limited to the pressure angle, addendum and dedendum. In a herringbone-gear system we must have, besides, uniformity of spiral angle and relative position of the right and left-hand teeth. The standards which have been adopted for Wuest gears are the result of experience gained in Europe during the last six years. The spiral angle of the teeth is about 23° with the axis. The choice of this angle is controlled by a number of considerations, the most important from the user's standpoint being that the angle must be sufficient to allow the engagement of successive pinion teeth to overlap within a reasonable face width. Once this condition is satisfied there is no advantage in an increase of spiral angle, while there are disadvantages in the use of steep angles. It was necessary, before choosing a definite spiral angle, to determine what constitutes a reasonable face width for this class of gearing.

Since the nature of the action eliminates shock, it follows that the pitch required for given conditions will be much finer than would be chosen for spur gears. On the other hand, the face width will not be less, because there is as much necessity for wearing surface with one kind of tooth as with the other. Spur gears are usually made with face width equal to three or four times the pitch. Herringbone gears may conveniently have a face width equal to six times the pitch, not because the width of this type need actually be greater, but by reason of the pitch being proportionally less.

Starting with a width equal to six times the pitch, and allowing once the pitch as the non-bearing portion in the centre, there remains two and one-half times the pitch available for the teeth on each side. To ensure continuity of engagement under all ordinary conditions, each tooth is inclined so as to cover an advance of once the pitch within its length. The angle of 23° satisfies this requirement (see Fig. 4). There are a few cases where an angle less than 23° would be sufficient, a steeper angle is only needed if the available face width has to be unduly restricted. Neither of these extreme conditions should influence the choice of angle for an interchangeable system best adapted for general use.

There are other good reasons why a moderate spiral angle is to be preferred. In all spiral gears the pressure acts in a direction normal to the teeth and is the resultant of the tangential (driving) and axial pressures. The normal pressure becomes greater in proportion to the useful driving pressure as the spiral angle is increased, while the available normal tooth section becomes less (Fig. 5). When the spiral angle is sensibly steeper than the angle of repose for the materials in contact, there is a tendency for the teeth to bind with a wedge action. Herringbone gears with abnormally steep spiral angles show loss of efficiency and increased wear from this cause.

The pressure angle which has been adopted for standard gears is 20°. The teeth are shorter than the usual standards, with addendum 0·8 and dedendum 1·0. These standards of tooth height and pressure angle have been adopted after systematic trials and experience extending over several years of regular manufacture. The high ratios used with these gears call for an average pinion diameter which is less than is used with straight spur gears for similar duty. The teeth are generated by hobs, and the short addendum combined with wide angle gives satisfactory tooth shapes, without undercutting of teeth, for small pinions. Pinions with very few teeth are cut on the well-known system of enlarged addendum which is used for small wormwheels and bevel pinions. The teeth are cut to diametral pitch standards measured circumferentially as with ordinary spur gearing.

The dimensions proposed for an interchangeable system for these gears are as follows:—

Tooth shape .... Involute

Pressure angle .... 20°

Spiral angle .... 23°

Pitch diameter (20 teeth and over) $= \dfrac{\text{Number of teeth}}{\text{D.P.}}$

Blank diameter (20 teeth and over) $= \dfrac{\text{Number of teeth} + 1\cdot6}{\text{D.P.}}$

Pitch diameter (under 20 teeth) $= \dfrac{0\cdot95 \times \text{Number of teeth} + 1}{\text{D.P.}}$

Blank diameter (under 20 teeth) $= \dfrac{0\cdot95 \times \text{Number of teeth} + 2\cdot6}{\text{D.P.}}$

Addendum... ... ... $\dfrac{0\cdot8}{\text{D.P.}}$

Dedendum... ... ... $\dfrac{1\cdot0}{\text{D.P.}}$

Full depth... ... ... $\dfrac{1\cdot8}{\text{D.P.}}$

Working depth ... ... $\dfrac{1\cdot6}{\text{D.P.}}$

Standard face width for gears with pinions of not less than 25 teeth — 6 times circular pitch.

Face width for high ratio gears with small pinions ... ... 6 to 12 times circular pitch.

When a pinion of less than 20 teeth is used with a standard gear the centre distance must be slightly increased to suit the enlargement of the pinion. If it is desired to keep the centre distance to the standard dimensions, the gear diameter may be reduced by the amount of the enlargement given to the pinion. For example: If a pinion of 10 teeth, 5 D.P. is to mesh with a gear of 90 teeth at 10in. centres,

$$\text{Pitch diameter of pinion} = \frac{0\cdot95 \times 10 + 1}{5} = 2\cdot1\text{in.}$$

Enlargement over standard pinion $= 0\cdot1$in.

$$\text{Pitch diameter of standard gear} = \frac{90}{5} = 18\cdot0\text{in.}$$

$$\text{Reduced pitch diameter of gear} = 18\cdot0 - 0\cdot1 = 17\cdot9\text{in.}$$

$$\text{Centre distance} = \frac{17\cdot9 + 2\cdot1}{2} = 10\text{in.}$$

Strictly speaking, there can be no enlargement or reduction of the pitch diameter in a pinion or gear of given pitch and number of teeth. It is convenient to assume this enlargement and reduction, while using teeth with long and short addenda but standard depth. In these gears the teeth need not have the same breaking strength as with spur gears, because they have not to combat the heavy and indeterminate stresses which arise from inequalities of angular velocity. On the other hand, it is necessary to provide against rapid wear. By using a finer pitch, each tooth has less individual wearing surface, but this is more than compensated for by the larger number of teeth in simultaneous contact than with gears of equal diameters but coarser pitch. In high ratio gears, using pinions of exceptionally small diameter, the pitch is finer than for ordinary ratios, but the face width is extended to give the proper wearing surface.

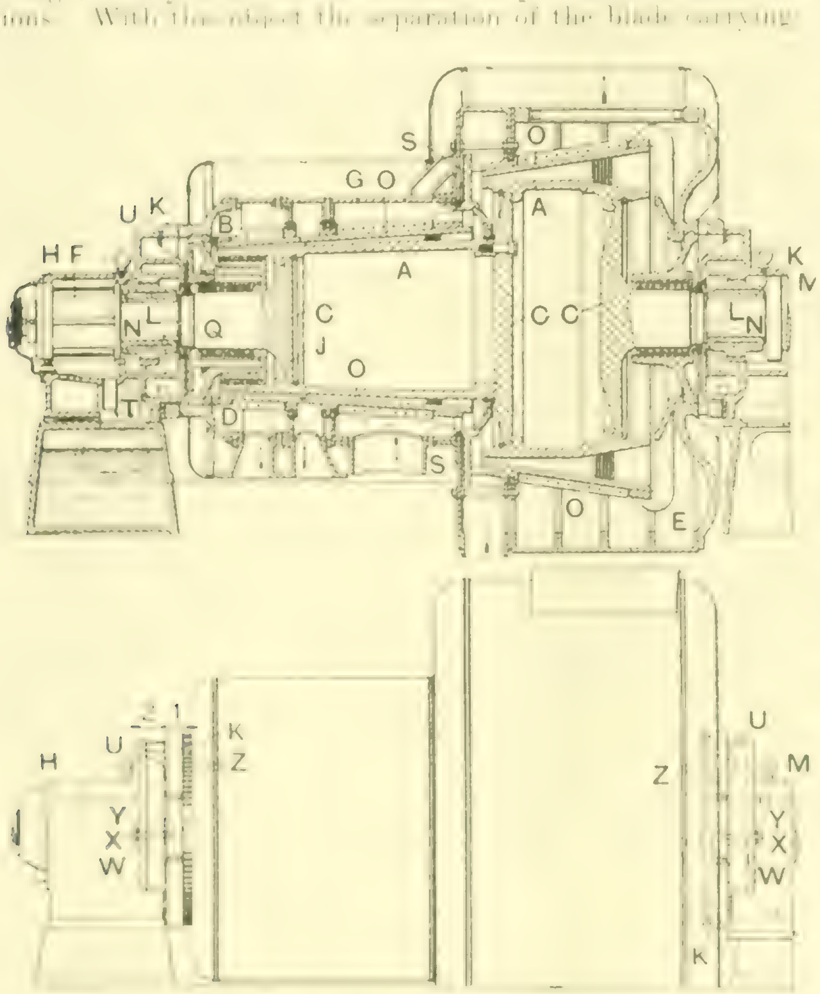
The important factor in determining the proportions of the teeth is the relationship between pitch line velocity and the permissible specific tooth pressure; in other words, the total tooth pressure divided by the area of all the available simultaneous contact along the teeth. Theoretically, this contact has no area since it should consist of lines without breadth. Actually, an area exists, due to the elastic compression of the teeth in contact, in a similar way in which an area of contact exists between a car wheel and a rail. The area of contact is indeterminate, but the specific tooth pressure is proportional to the driving stress on the teeth.

(To be continued.)

FERRANTI'S STEAM TURBINE.

To obtain the highest economy with steam turbines the blade clearances should be reduced to the lowest possible extent. The rotor member, chiefly on account of its complete symmetry of form, now fulfils the necessary conditions with considerable closeness, but the cast-iron casing or stator has often been complicated and unsymmetrical in form, the consequence being that when heated up, the casing expanded irregularly in relation to the more simply constructed rotor and, in addition, generally became permanently distorted in course of time. In order to prevent the running and standing parts coming into contact, therefore, the clearances had to be increased considerably beyond what would, apart from such irregular and differential expansion, be sufficient for safe working.

To overcome these difficulties turbines have been proposed in which a symmetrical blade-carrying stator is enclosed within an outer casing, and the construction illustrated has been designed and patented by S. Z. de Ferranti, Grindleford Bridge, Derbyshire, with a view to improve such constructions. With this object the separation of the blade-carrying



FIGS. 1 TO 4.—FERRANTI'S STEAM TURBINE.

stator from the outer casing is carried a stage further, the stator instead of being as heretofore influenced by irregular expansion of the more or less cylindrical casing, being clear thereof and supported by members which do not share in the inevitable distortions of such casing. The blade-carrying stator in the construction illustrated, it is claimed, expands freely and symmetrically and is entirely uninfluenced by distortions of the outer casing. To sum up, the fundamental principle on which the design is based consists in providing entirely separate organs to fulfil respectively the different functions now performed by the casing or stator alone, so that the blade-carrying stator is relieved of all those influences tending to cause distortion.

Fig. 1 shows a sectional elevation of a horizontal drum turbine in which the steam after initial superheating is partly expanded in the turbine and passed into a reheater before completing its expansion; Fig. 2 shows an elevation; Fig. 3 an end elevation of the bearing at the high-pressure end looking in the direction of the arrow I in Fig. 2; Fig. 4 a sectional elevation of the same end of the turbine casing looking in the direction of the arrow [illegible], and Fig. 5 a cross-section through the low-pressure end of the turbine.

Referring to the figures, the rotor member is built up of drums A carrying the usual blades, the drums being mounted on discs C. The shaft at the high pressure end is carried in bearings, the latter bearing and the thrust block F being mounted in a common housing H slidable longitudinally on its pedestal. The thrust block F is such as to admit of no substantial end movement between the shaft and the slidable housing H. The shaft at the low-pressure end is carried in bearings K enclosed within a housing M, which in this case is fixed to its pedestal, a certain amount of end play being provided between this shaft and its bearings. The stator member consists of two drums O corresponding to the rotor drums and carrying the usual blades; the two drums are connected by a member S provided with symmetrically-disposed apertures through which the steam passes, the member S carrying a diaphragm packed in any suitable manner to prevent passage of steam from one side of the diaphragm to the other.

The stator drums themselves, according to the form shown (see Fig. 5), are built in quadrants so that expansion and contraction may be as symmetrical as possible, each quadrant having fixed to it along each longitudinal edge a flange by means of which it is bolted to the adjacent quadrants. The stator drums O are attached to and carried by the main end castings at the high-pressure and low-pressure ends respectively, the connection at the high-pressure end being made by way of the member B provided with steam passages D symmetrically arranged and at the low-pressure end by way of the spider E. The arms of this spider are angled to agree more or less with the direction of the steam as it issues from the low-pressure blades.

The blade-carrying stator is surrounded by an external built-up casing G of cylindrical shape, also carried by the end castings. This casing carries the pipe connections. The end portions are made stiff enough to be substantially unaffected by distortions of the casing G. The space between the stator and the casing thus forms an annulus through which steam passes. Where necessary special diaphragms are provided in this annulus which allow for differential expansion between casing and stator both in the radial and longitudinal directions.

To prevent leakage of steam or air along the rotor shafts where they pass out of the casing packings formed of carbon segments are provided. The packings for the dummy piston or steam excluder J are arranged not only within the rotor itself but also within a part of it carrying blades, such a disposition of parts leading to a considerable reduction in the length of the turbine. In the case shown, where the turbine is supposed to be driving a dynamo, the dummy J excludes steam from a considerable area of the rotor and so lessens the total thrust, the balance being taken by the thrust block. If the turbine on the other hand drives a screw propeller, the net thrust due to the pressures on the running blades and on the high-pressure end of the rotor shell outside the dummy packing are arranged to balance or nearly balance the propeller thrust. A thrust block should generally be provided in addition to take up any balance of thrust due to different conditions of working and so forth.

The end castings carrying the stator O and the casing G, are supported on the housings H and M in a special manner, designed to allow the heated turbine parts to expand freely in a radial direction in relation to the cooled bearing parts, while ensuring at the same time that stator and rotor remain co-axial. Thus, referring particularly to Figs. 2 to 4, the end castings have each formed on them a ring K on the inside of which at about the level of the axis are two lugs L. These lugs rest on brackets N cast on the outside of the lower half of the housing H and M respectively, and are held down by other lugs P on the upper half of the housing. The brackets N are provided with stops Q arranged transversely with regard to the turbine so as to prevent longitudinal movement of the lugs L supported by them while allowing radial movement. (See also Fig. 3.) Moreover, a key R secured to the housing H at its lower part bears against the bottom of a corresponding recess or keyway T formed on the end castings, the said key and keyway having vertical sides allowing relative radial movement. The lugs, keys and so forth form a system of interlocking guides which act to maintain the proper coaxial position of stator and rotor.

As regards provision for longitudinal expansion and contraction of the turbine parts, the housing H of the main bearing at the high-pressure end is slidably mounted on its pedestal and is pushed to the left on expansion of the turbine stator and casing taking place by the action of the facing strips U on the ring K butting against the turned face V on the housing H. The thrust of the turbine is arranged to act towards the right in Fig. 1 so as always to maintain the butting surfaces in contact during work. To provide for the return of the bearing to the right as the turbine cools down after running, bolts W screwed into the lugs L on the ring K pass through the enlarged part of the housing H to which the brackets N are cast, and are arranged with their heads X in operative relationship to facings Y. Similar bolts W are provided at the low-pressure end. These bolts and the strips Q on the brackets N thus assist one another.

In order to minimise heat transmission from the heated turbine parts to the cooled bearings, the rings K at each end of the turbine are secured to the body of the respective end castings by a number of spaced ribs Z formed by drilling out the intervening metal. The facing strips U also assist in preventing transmission of heat to the bearing.

In order to secure the full benefits of the turbine structure above described, it is very desirable that the symmetrical

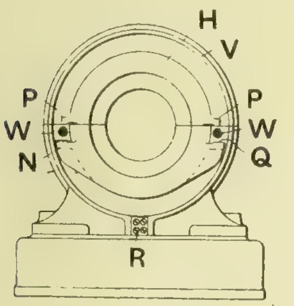


FIG. 3.

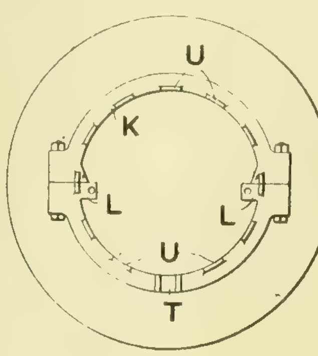


FIG. 4.

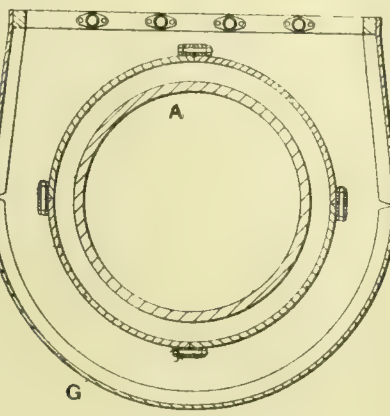


FIG. 5.
FERRANTI'S STEAM TURBINE.

stator should be symmetrically stressed at different temperatures so as the better to maintain its shape. If the blades are caulked in place, this condition is only attained accidentally or under very special circumstances, the stresses due to caulking in nearly every case being irregular and varying with the temperature. For these reasons the blades are welded in place electrically. For the same reasons, the blades are also preferably welded to the rotor.

It will be seen that with a turbine constructed in the manner and with the precautions above described, the blade-carrying stator O of simple symmetrical construction and supported in the manner described is free from the usual distortional stresses to which the stator parts of turbines as at present constructed are subjected and therefore maintains its symmetry on expansion and contraction.

The Society of Engineers.—An ordinary meeting will be held on Monday, February 5th, at the Institution of Electrical Engineers, Victoria Embankment, W.C. The chair will be taken by Mr. F. G. Bloyd (president, 1911), who will present the premiums awarded for papers published in the "Journal" during 1911. The retiring president will introduce to the meeting Mr. John Kennedy, the president for 1912, who will deliver his presidential address.

WATER POWERS OF CANADA.

A REPORT recently issued on the Water Powers of Canada, the result of nearly two years' work of investigation and compilation by the Canadian Commission of Conservation, states that, owing to the paucity of information available respecting water powers in Northern Canada and the northern portions of the various provinces, and also respecting many of the minor powers in the settled area, it has not been considered advisable in this report to make an estimate of the total water power available in Canada. The following estimate is given, however, of the total water power developed in Canada in 1910; the figures of the power developed in 1909 (prepared for the Washington Conference on the Conservation of Resources, held in that year) being added for purposes of comparison:—

	1909.	1910.
	H.P.	H.P.
Ontario	331,157	532,266
Quebec...	50,000	300,153
Nova Scotia	13,300	15,272
New Brunswick	—	9,765
Prince Edward Island...	—	500
Manitoba	18,000	48,300
Saskatchewan	—	45
Alberta	1,330	7,300
British Columbia	73,100	100,920
Yukon	—	2,000
Total	486,887	1,016,521

Of the water power developed in 1910, 742,955 h.p. was used for the generation of electrical energy, and 158,051 h.p. in connection with the paper and pulp industries.

TURBINE PUMPS FOR MINES.

AT the fourth general meeting of the Institution of Mining and Metallurgy, held in London on the 18th inst., Mr. Cyril Brackenbury contributed the result of his recent experience in "Unwatering Tresavean Mine," in Cornwall, which, although worked out as a copper mine about 50 years ago, was now being opened for tin, which had been discovered in quantity in the lower workings. The unwatering had now been successfully carried out by means of electrically-driven high-lift turbine pumps, in spite of serious obstacles, down to beneath the 248-fathom level below adit, and most useful practical data were recorded as to the method of cutting through chokes, &c., in a way not hitherto accomplished in this country. Six of the pumps, which were used in pairs, were designed to deliver 600 galls. per minute through a lift of 600ft. The sinking pumps were of the vertical type and actuated by 3-phase alternating-current motors designed to give an output of 190 b.h.p. In addition to several bad chokages of the shaft and the exceptionally bad condition of the shaft walls, progress was hindered by the large inflow of water due to exceptionally heavy rains in December, 1910, but in spite of this an average speed of 5ft. per day was maintained, and only three periods of four weeks showed losses when the pumps were driven back. Their successful operation demonstrated several strong advantages for the high-lift turbine pumps over the Cornish pumping system, viz., much less space was taken up in the shaft, and the turbine, with its rising main, could be lowered more quickly to follow the water. Although the first cost was undoubtedly greater, the surplus power after the unwatering was completed was used for installing permanent electrically-driven ram pumps and performing other work in the mine and at the surface. To prevent excessive erosion of the bronze impeller blades it was found advisable to fix at the bottom of the suction pipe a copper strainer of ample area provided with small openings.

RECENT DEVELOPMENTS IN STEAM TURBINE PRACTICE.*

BY K. BAUMANN.

(*Continued from page 71.*)

2. **Development of the Curtis Turbine.**—The first Curtis patents, dated 1896, refer to turbines of the impulse type consisting of a number of single Laval wheels arranged in series. Curtis did not consider this arrangement to be the best means of reducing the speed of a steam turbine, and he therefore introduced with success the velocity stages which were already described in English Patent No. 144, dated 1858, by John and Ezra Harthan.† The pressure stages were reduced and the correspondingly high steam velocity utilised in wheels with several rows of blades on the velocity stage principle. These wheels are known as Curtis wheels or velocity wheels.

The first turbines built by the General Electric Company of Schenectady, who secured the license for the Curtis patents, consisted of only two pressure stages and two wheels each with four rows of blades; afterwards these were changed, on account

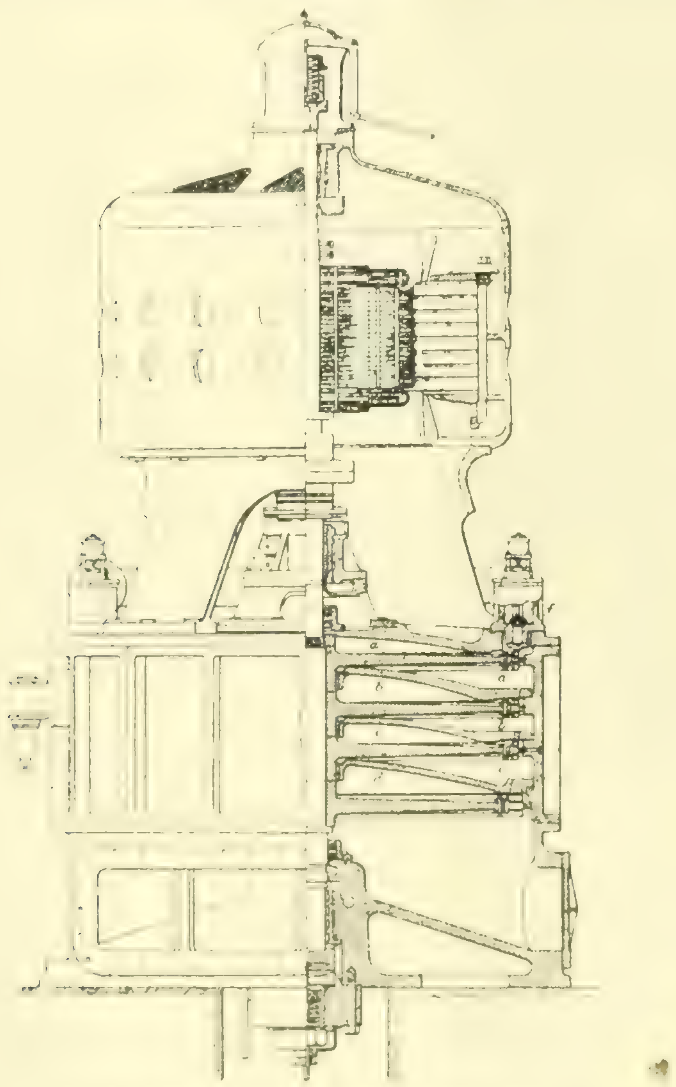


FIG. 9.—VERTICAL CURTIS TURBINE (about 1902).

of poor efficiency, to four pressure stages and four wheels, each with only two rows of blades (Fig. 9). The General Electric Company always built their turbines with vertical shaft, in order to reduce the floor space required. The steam entered the turbine at the top end through nozzles to which the steam was admitted by separately controlled valves opened one after the other according to the load. The General Electric Company were the originators of the nozzle-controlled turbines.

In order to understand clearly the further development it is necessary to compare the efficiencies which can be obtained with the Curtis wheels, having two or three rows of blades, with those obtainable with single wheels of the de Laval type.

Let

u = mean peripheral velocity of blades.

c = steam velocity corresponding to pressure drop.

η = blading efficiency.

If steam is admitted to a wheel with one row of blades at a certain velocity c and the wheel is revolving at different speeds u, calculation shows that the efficiency is at a maximum for a certain peripheral velocity, which is given by the ratio:—

$$\frac{u}{c} = \frac{\text{peripheral velocity}}{\text{steam velocity}} = \tfrac{1}{2}.$$

For any other ratios $\frac{u}{c}$ the efficiency will be smaller and changes according to curve A, Fig. 10, which is of a parabolic nature. It will be zero when $u = o$, as in this case no work can

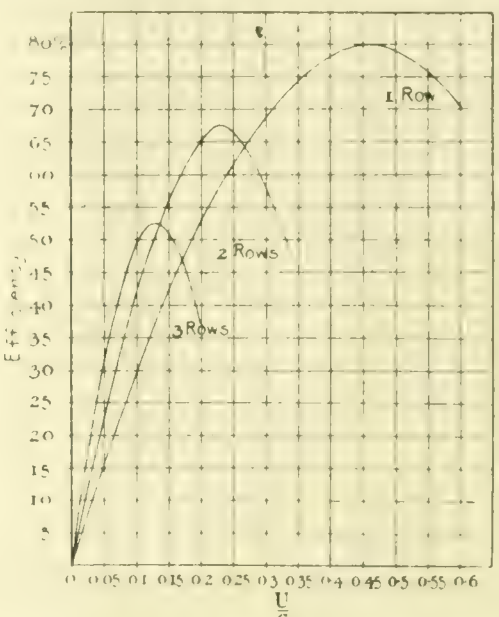


FIG. 10.—EFFICIENCIES OF RATEAU AND CURTIS WHEELS.

be done, and also when $u = c$, as in this case the torque will be very small.

The actual maximum efficiency and the ratio $\frac{u}{c}$ at which it is obtained depends mainly on the inlet angle and the ventilation losses of the wheel. Curve A in Fig. 10 represents a fair average of test results actually being obtained in the low-pressure part of modern Rateau turbines. The maximum efficiency according to this curve is:—

$$80 \text{ per cent. for } \frac{u}{c} = 0{\cdot}46.$$

The average efficiency of high-pressure and low-pressure wheels of a Rateau turbine, designed for maximum efficiency, will be

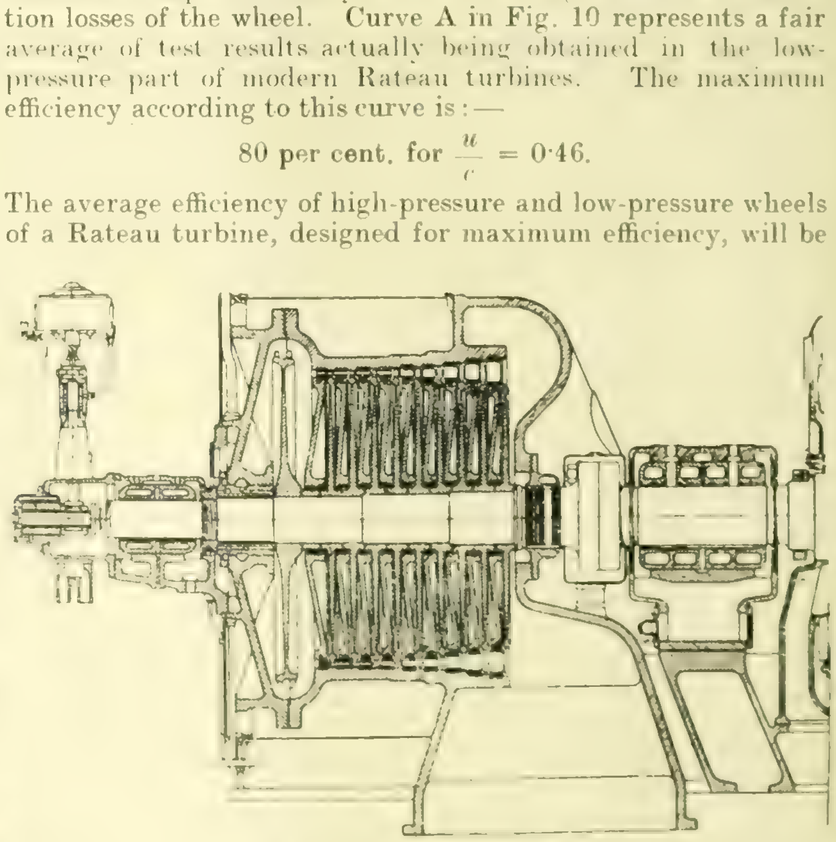


FIG. 11.—A.E.G. TURBINE, 1903.

about 77 per cent., allowing for increased friction and leakage losses in the high pressure part of the turbine.

For velocity wheels with two rows of moving blades the efficiency changes in quite a similar manner, the only difference being that the maximum efficiency is reached for $\frac{u}{c} = \frac{1}{4}$ approximately. The efficiencies which can be obtained are given by curve B in Fig. 10, which shows a maximum efficiency of 67·5 per cent. at $\frac{u}{c} = 0{\cdot}23$.

For velocity wheels with three, four, or five rows of blades the maximum efficiency is obtained for $\frac{u}{c}$ less than $\frac{1}{6}$, $\frac{1}{8}$, $\frac{1}{10}$, re-

* Paper read before the Manchester Section of the Institution of Electrical Engineers, [illegible].

† Stodola, "Steam Turbines," [illegible]

spectively. Of these however only the velocity wheels with three rows of blades are of practical importance. The actual efficiencies obtainable are given by curve C, Fig. 10, which shows a maximum efficiency of only 52·5 per cent. for $\frac{u}{c} = 0{\cdot}133$. The efficiencies of velocity wheels with more than three rows

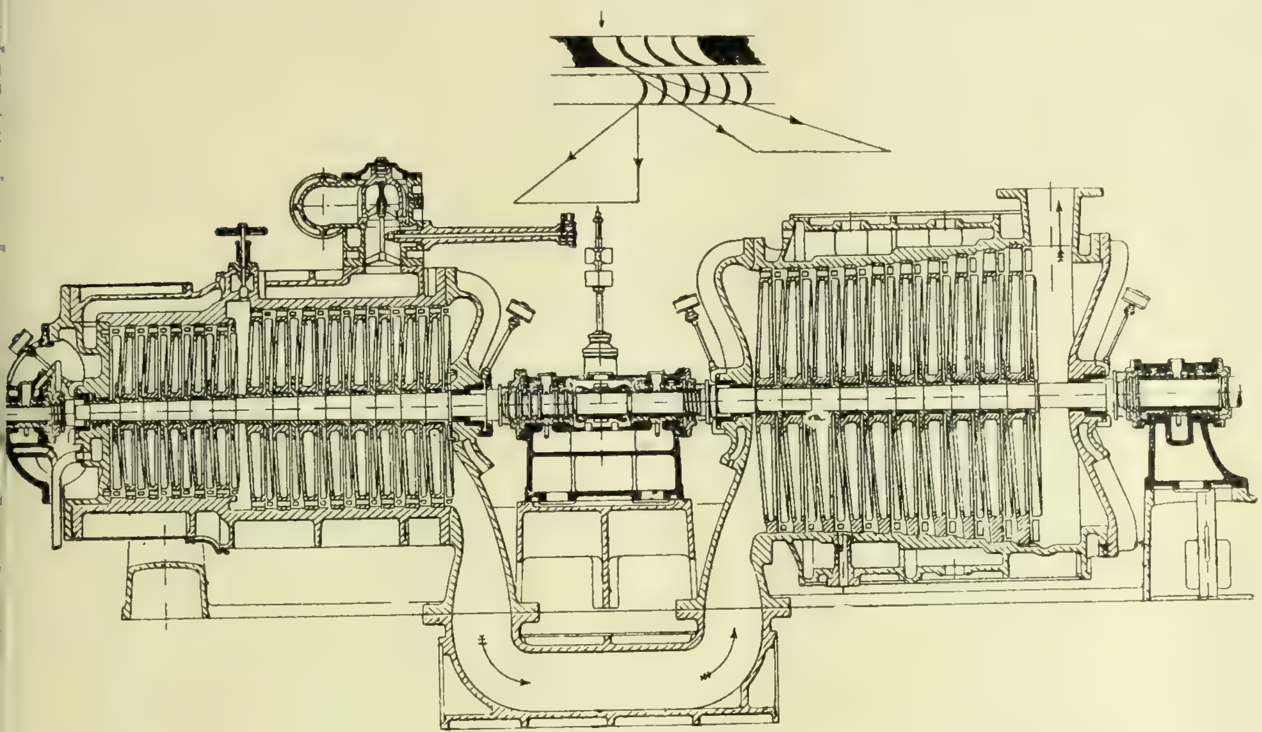


FIG. 12.—RATEAU TURBINE, BUILT BY SAUTTER HARLE, 1902.

are still worse, and are therefore not used except in cases of marine turbines.

According to diagram Fig. 10, it is obvious that with different wheels of the same diameter, running at the same peripheral velocity, the wheel which has two rows of blades will be able to utilise, at its best efficiency, a steam velocity twice as high as that for a wheel with one row of blades; a wheel with three rows of blades will utilise a velocity about 3·46 times as high as that for which the efficiency of a wheel with a single row is a maximum. As the heat energy increases with the square of the steam velocity, this means that turbines designed to utilise the same heat drop with the best efficiency obtainable with the different kind of wheels must have—

1 wheel with 3 rows of blades, maximum efficiency being 52·5 per cent.; or

3 wheels with 2 rows of blades, maximum efficiency being 67·5 per cent.; or

12 wheels with 1 row of blades, maximum efficiency being 77 per cent.

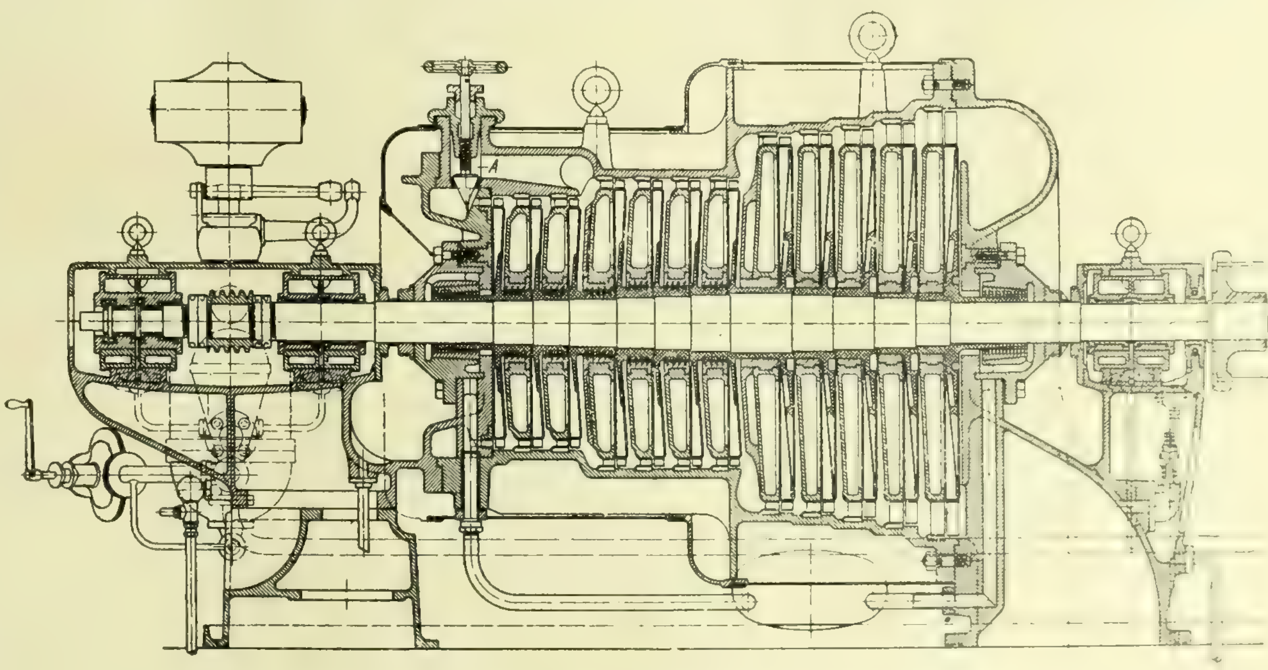


FIG. 13.—RATEAU TURBINE, BUILT BY ENGINE WORKS, OERLIKON, [illegible]

When the A.E.G. Company took up the building of Curtis turbines they had to consider these facts, as it was of the greatest importance to them to have a turbine able to compete in economy with the Parsons turbines, which latter turbines up to the year 1905 undoubtedly held the field. The higher cost of coal in Germany, as compared with America, necessitated the use of more economical turbines than the pure Curtis machines built in America by the General Electric Company.

The pure Curtis turbine has the great advantage of small pressures and low temperatures in the turbine casing, due to the relatively great expansion through the first nozzles, an advantage which the designer of a Continental Curtis turbine could not dispense with. The Curtis wheels in the low-pressure end, which, according to the table given above, cannot give as good efficiencies as single wheels, were replaced by the more expensive Rateau wheels, in order to obtain a turbine with a competitive efficiency. The result was the turbine shown in Fig. 11, of which the first reports were given by O. Lasche in a paper read before the annual meeting of the Verein Deutscher Ingenieure in 1906.

The turbine is, in addition, built with a horizontal shaft which very recently has also been adopted by the General Electric Company in America. Though at first sight it is differently built from the pure Curtis turbine, there is still quite a noticeable resemblance to the original machine in some of the parts which are peculiar to the A.E.G. turbines. The predominating part is still the velocity wheel, which is made of a larger diameter than the Rateau wheel in order to reduce the pressure in the turbine casing as much as possible. The cylinder is divided at the high-pressure end of the turbine by a vertical joint. The high-pressure end cover is generally made of cast steel and in one piece, in the same manner as the original Curtis turbine. This is obviously necessary because the high-pressure pedestals are fixed on this cover; if this cover were made in halves unsymmetrical deflections of the cover would occur, and this would throw the bearing out of line. The design of the diaphragms is also similar to that of the original Curtis turbine. They are made in one piece, and must be assembled on the shaft at the same time as the wheels. This arrangement makes erection rather difficult and reduces the accessibility of the shaft to a great extent.

Another feature of the A.E.G. turbine is the arrangement of the turbine and generator shafts and the bearings, known as the three-bearing design, which is also identical with the design of the Curtis turbine. One of the first turbines of this design, of 3,000 kw. normal output, running at 1,500 revs. per minute, installed at Moabit in Berlin, was reported in March, 1907, to use only 12·8lbs. of steam per kilowatt-hour, and a similar turbine of 4,000 kw. normal output at 1,500 revs. per minute, installed at Rummelsburg, near Berlin, was reported in April, 1909, to have a steam consumption of only 11·7 to 11·95lbs. per hour. Both figures were the lowest figures recorded at the respective times.

3. Development of Rateau and Zoelly Turbines.—The principle of the Rateau or Zoelly turbine is very old. In 1827 Real and Pichon took out French patents for a similar turbine with 31 wheels. Another patent for a similar turbine was taken out

in England in 1876 by Edwards as a communication from Jas. Mourhouse, of Petersburg (Patent No. 2,068/1876). This turbine was also of the impulse type, and was provided with 25 wheels. The drawing showed already increasing area through the nozzles, in order to allow for the increased volume due to the expansion of the steam.

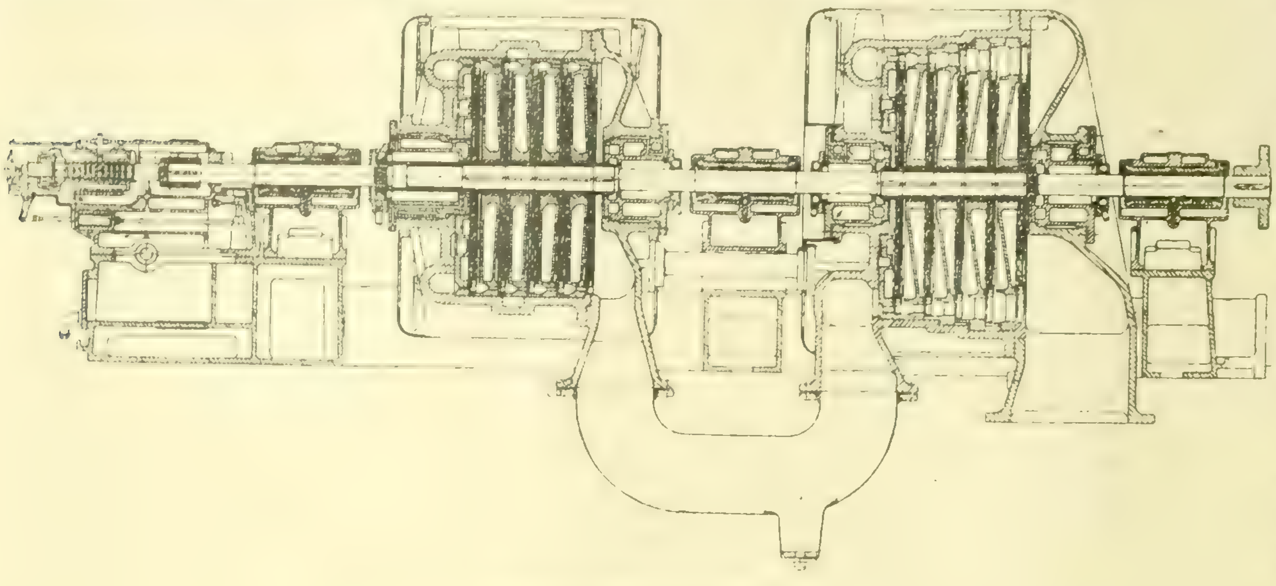


Fig. 14.—Zoelly Turbine, 1903.

The credit for the further development of this type must, however, be given to Prof. Rateau. The first turbine, which was built by Prof. Rateau, in 1898, together with the engineering firm of Sautter Harle & Co., of Paris, consisted of only one wheel running at a very high peripheral velocity. This design however was found to be too expensive, and the next turbine was made as a multi-stage turbine, which consisted of a series of discs rotating between diaphragms, in accordance with Prof. Rateau's patents (English Patent 21,204/1898). One of the first turbines of this type actually built consisted of 25 wheels in two casings shown in Fig. 12. The peripheral velocity was kept rather low, in order that built-up wheels, consisting of boiler plates riveted to a boss on the shaft could be used, which at that time were cheaper than forged wheels. Soon afterwards this type of turbine was made with a smaller number of wheels in one casing by the Engineering Works, Oerlikon (Fig. 13).

The Zoelly turbine, of which the first machine was made in 1903, was similar to the Rateau turbine, the only exception being that the number of wheels was considerably reduced. The wheels were made out of forged steel, and this enabled the designers of the Zoelly turbines to increase the peripheral speed considerably, and at the same time to decrease the number of wheels. The first Zoelly turbine (Fig. 14) consisted of 12 wheels in two casings, in a similar manner to the Rateau turbine shown in Fig. 12. The patents of Zoelly refer to a particular method of fixing the blades on a rotating disc. Another peculiarity of the first Zoelly turbines was the open blade without shrouding. The reduction in the number of wheels was proved to be a great advantage, and this, together with the care exercised in the design of the detail parts which were partly taken from the water turbines—*e.g.*, the governor with oil relay — caused a very rapid commercial development of the Zoelly turbine. The design in which two casings were used was soon abandoned for one with a single casing. A turbine of this type, made in 1907 for the Elektrizitatswerk, in Kubel, near St. Gall, is shown in Fig. 15.

Both Zoelly and Rateau used smaller diameters for the high-pressure wheels and large diameters for the low-pressure wheels, in order to keep the disc friction and ventilation losses of the high pressure wheels as small as possible. On the other hand, this increased the number of stages, and consequently lengthened the turbine—it further involved the introduction of high pressures and high temperatures in the turbine casing, the danger of which was not fully realised at that time. Also it was usual on these turbines to have the shaft running above the critical speed, so that when starting up, the turbine had to pass through the first critical speed. The experience gained in the running of this design of turbine emphasized these disadvantages, and forced the builders of the Rateau and Zoelly turbines to change their designs by adopting the same diameter of wheel all through the turbine in order to reduce their number and to shorten the machine. In addition, the pressure drop through the first nozzles was increased in order to decrease the pressure and temperature in the turbine casing. The sacrifice in the efficiency of the high-pressure wheels was balanced as far as possible by the improved efficiency obtained on the low pressure wheels. These alterations were made at the same time by Zoelly and Rateau in 1908, and proved to be a great advance.

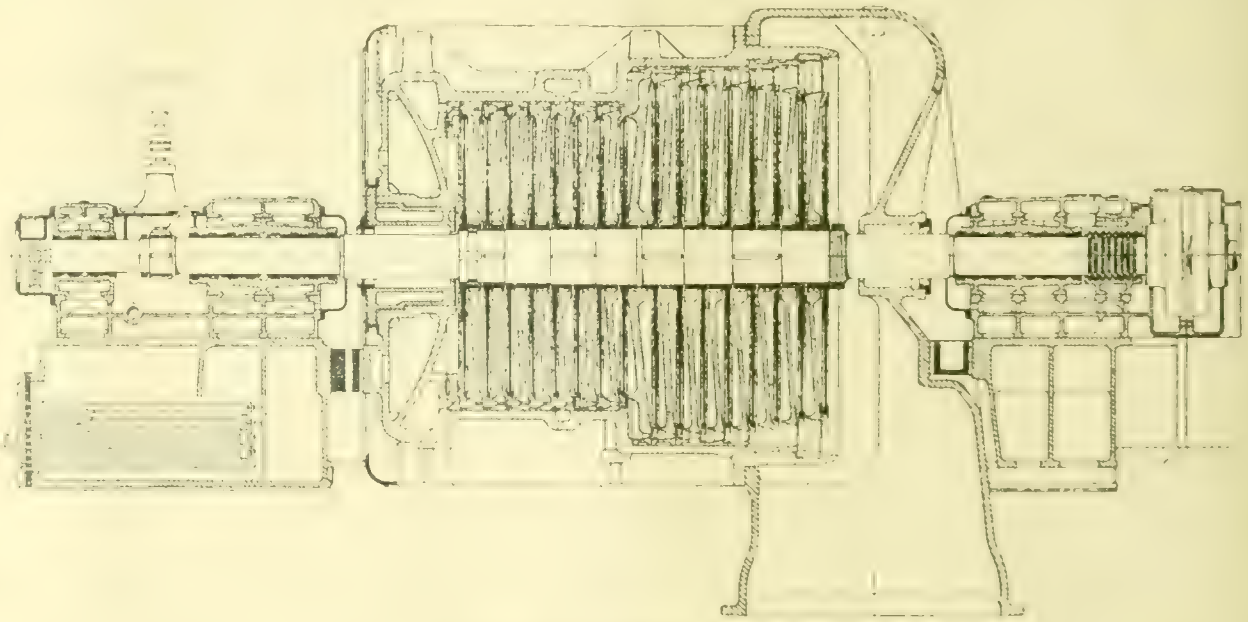
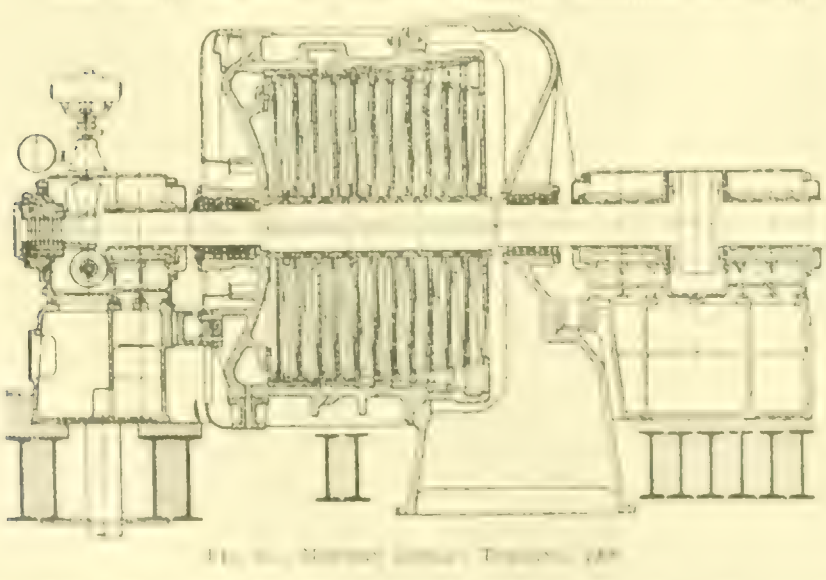


Fig. 15.—Zoelly Turbine, 1907.



[illegible]

The new Zoelly turbine is shown in Fig. 16, and a Rateau turbine in Fig. 17. It will be noted that in principle there is no great difference between the Zoelly turbine and the Rateau turbine. In the meantime, owing to the rapid development of the disc turbines, the steel manufacturers had obtained great experience in the making of discs, and this enabled them to reduce the cost considerably. This caused Prof. Rateau

to revert to the forged discs originally used, and this enabled him to increase the peripheral velocity of the blades. Open blades as used on the first Zoelly turbines were abandoned for the newer design with shrouding, which increased the efficiency considerably.

It was obvious that by replacing the first single wheels by a velocity wheel, the pressures and temperatures could still further be decreased. The Maschinenfabrik Augsburg-Nürnberg was the first of the Zoelly turbine builders to replace the high-pressure wheels by a velocity wheel (1909), as a result of extensive tests on velocity wheels and also on combined turbines. These tests showed that the efficiency of a correctly-designed velocity wheel compared very favourably with the efficiency obtainable with the first Rateau high-pressure wheels of the new design.

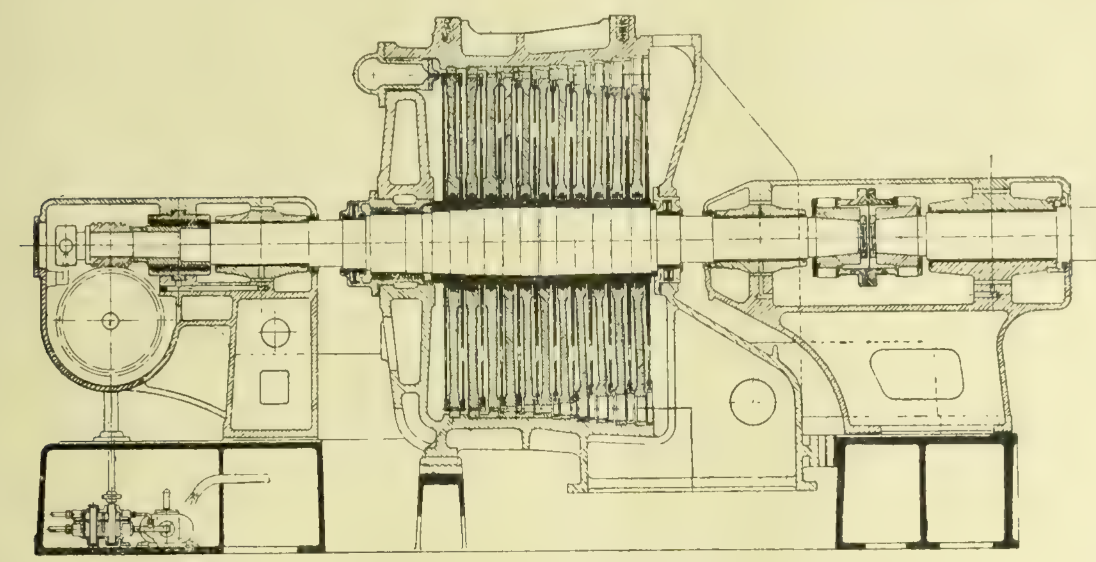


FIG. 17.—MODERN RATEAU TURBINE. 1908.

When the British Westinghouse Company commenced the building of Rateau turbines in 1908, it had the benefit of experience gained in the building of Parsons turbines, which already had resulted in 1903 in the use of velocity stages in the high-pressure end. One of the first Rateau turbines built by the Westinghouse Company is shown in Fig. 18, which represents a section of a 5,000 kw. turbine running at only 750 revs. per minute, supplied to the London County Council power station, Greenwich. This turbine, on account of the very low speed, had to be provided with 24 wheels. The type of Rateau turbines built since 1909 is shown in Fig. 19. The steam is admitted to the velocity wheel through nozzles fixed to nozzle boxes of cast steel, and which, with the steam chest, are the only parts of the turbine subject to high pressures and high temperatures. The design of the casing and the diphragms, in halves with only horizontal joints, allows of a very easy inspection and accessibility to the rotor, and to the interior of the turbine by lifting the top half. Due to the use of a velocity wheel the gland question which, during the whole development of the steam turbine was a very important one, becomes much simpler.

In the case of a pure Rateau or Zoelly turbine, the glands have to be made reasonably tight against high pressures. In the beginning they were made of loose metal packing rings, and according to the latest practice with loose carbon rings. When using a velocity wheel an ordinary labyrinth gland has proved to be quite satisfactory with regard to the leakage of steam, and has the advantage of greatest simplicity and reliability. The high-pressure gland is connected to the exhaust of the turbine and is sealed against air by the well-known water gland used on the Westinghouse-Parsons turbines, which is also adopted as a low-pressure gland.

Comparison of the Modern Turbines.—The recent development of the various steam turbines outlined above shows very clearly the tendency towards the use of the two types known as the disc and drum type or the Curtis-Parsons type and the Curtis-Rateau type.

This must be considered the most important type at present in use, as is best shown by the fact that practically all turbine builders in this country are adopting one or the other, and it will therefore be interesting to examine closely the points of difference between them. To do this it is necessary to consider the two types with regard to reliability, economy, and first cost. This examination will show that it is not possible to give a definite statement that in general one is better than the other, but this depends on the particular conditions under which the turbine is required to work in any particular case.

The reliability of the turbine will depend much more on the design of the details than on the principle on which it is constructed. It is quite certain that the design of the fixing of the blades, for instance, which does not depend on the type of the turbine, is of great importance. But it is also evident that a turbine with very small clearances between fixed parts and parts running at a relatively high velocity will not be so reliable as a turbine with large clearances between these parts.

With regard to the other points—*i.e.*, economy and first cost—we will limit our comparison to the high-pressure turbine, which is mainly used in power stations.

Dividing the turbines into three categories:—

1. Turbines with small outputs less than 750 kw. at 3,000 revs. per minute, or less than 2,250 kw. at 1,500 revs. per minute;
2. Turbines with moderate outputs, 750-1,500 kw. at 3,000 revs. per minute, or 2,250-4,500 kw. at 1,800 revs. per minute;
3. Turbines with large outputs, above 1,500 kw. at 3,000 revs. per minute, or above 4,500 kw. at 1,500 revs. per minute;

we can state the relative position to be as follows:—

For turbines with small outputs the disc and drum type is certainly cheaper—*i.e.*, the disc and drum type can be made at a lower price for the same steam consumption, or allowing the same price for both types, the disc and drum turbine can be made with the better efficiency.

For moderate outputs the two systems are about equal with regard to economy and first cost.

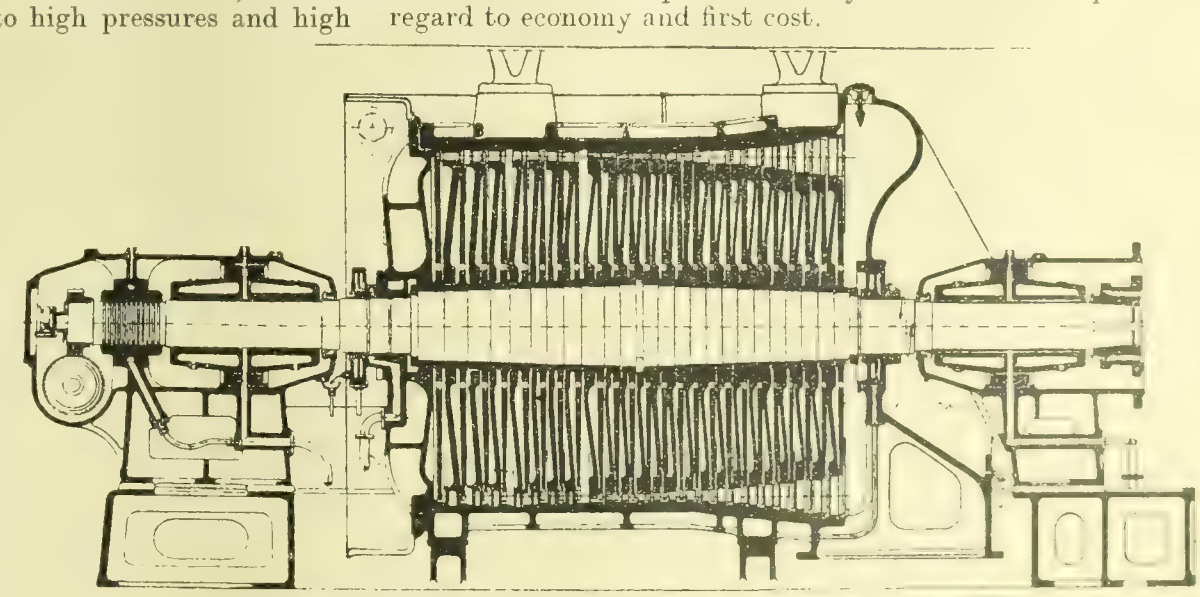


FIG. 18.—RATEAU TURBINE, BUILT BY THE BRITISH WESTINGHOUSE COMPANY, [illegible]

For large outputs, the Curtis-Rateau turbine is the better because the disc and drum type would have to be made as a double-flow turbine, in the low-pressure part, which would increase the cost of the turbine considerably without a corresponding increase in efficiency.

In short—

The drum turbine is the design for small outputs

The disc turbine is the design for large outputs.

The following investigation proves that the maximum out-

put which can be obtained with a disc turbine, under the same conditions with regard to working stresses, leaving losses and vacuum, is about twice as large as the maximum output which can be obtained with a drum turbine.

(To be continued.)

BLOWHOLES IN STEEL.

An interesting lecture on "Blowholes in Steel" was delivered by Mr. J. E. Stead, F.R.S., to the members of the Sheffield Society of Engineers and Metallurgists on the 15th inst.

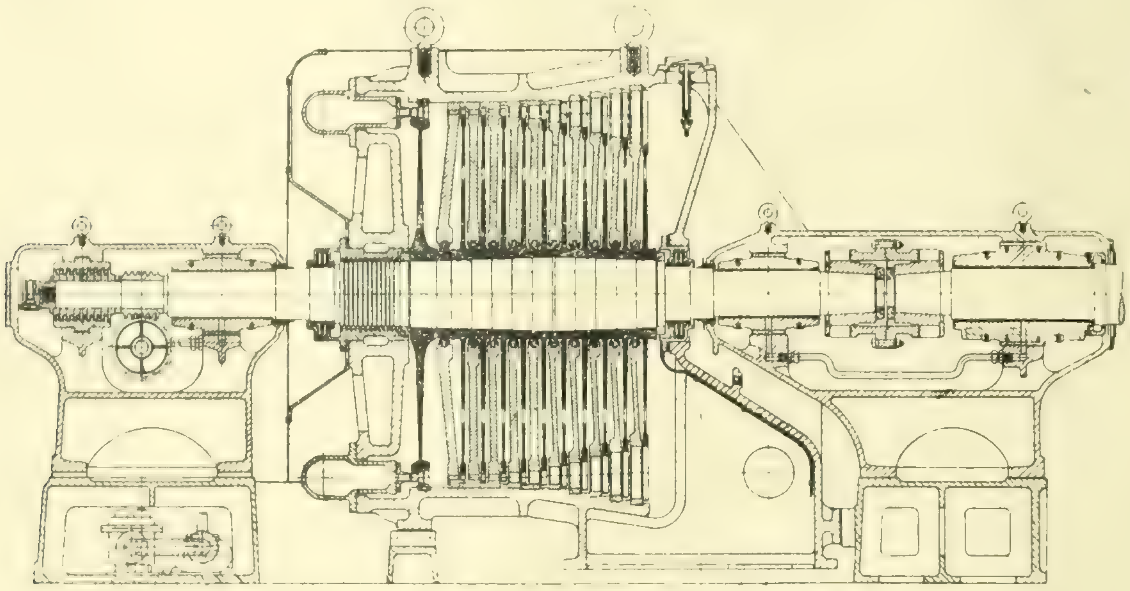


Fig. 19. Modern Westinghouse Rateau Steam Turbine, 1910.

The lecturer stated that the presence of steel crystallites in blowholes was evidence that the blowholes became larger after they had been completely closed round by solid and plastic steel owing to the evolution of gases from the surrounding steel forcing the residual liquid—rich in carbon, sulphur, and phosphorus—through the plastic wall of steel in front into the still liquid column of steel beyond. The gases forming and rising from the freezing wall would then ascend and sweep the impure portions upwards, where they finally collected and solidified in the upper part of the central axis of the ingot. Dr. Stead explained that this was the reason why the formation of honeycombs in steel caused segregation of impurities. When the upper surface was closed by the steel becoming solid, the evolution of gases from the remaining liquid steel below would be checked, but before this could happen great internal pressure would be produced, and this would squeeze a portion of the carbon, sulphur, and phosphorus-rich liquid (mechanically trapped in the plastic steel located in front of the previously formed blowholes) back into those bubbles, partially filling them. The sulphur, as sulphide of manganese, partially covered the cell walls, and, as it was the exact equivalent of slag, it prevented the metallic faces of portions of the blowhole walls from coming into metallic contact when ingots were forged. The lecturer then showed that but for this objectionable sulphide the welding up of blowholes would, under ordinary conditions of heating and forging, be absolutely perfect, but so long as there was sulphur in steel a portion of it would find its way into the bubble cavities, and he concluded, therefore, honeycombed ingots could not give such sound finished forgings as ingots which were initially free from blowholes or porosities. There had been great improvement in the manufacture of crucible steel in Sheffield during the last 20 years, and he believed that in no works were honeycombed ingots produced except by accident. This could not be said as regards ingots for structural material, such as rails, plates, &c., but freedom from initial porosity was not so important in these classes as in high-class crucible steel; indeed, it was claimed that soft steel ingots rolled better, and were not so liable to break in the rolls, as those which were absolutely sound.

Dr. Stead spoke of the splendid change that had gradually taken place in the steel trade, in its attitude towards research, as compared with what it was some time ago. The encouragement and generosity shown by Sheffield manufacturers in fostering metallurgical science, so ably taught by Dr. Arnold and his assistants, was only a single proof. In Middlesbrough, steelmakers had always been ready to make experiments at his instigation and under his direction for purposes of elucidating scientific problems, and he had found the same spirit prevailing in Sheffield. He had occasion to ask several Sheffield steelmakers to assist him in a special scientific research he had been conducting, and all had responded without exception. Sheffield was said to be a most terribly conservative place, and they could understand how delighted he was to find that there was not a single refusal of his request. Much of the practical work given in the lecture was done by steel manufacturers in Sheffield.

THE HARDENING OF BRONZE.

Many writers in their descriptions of ancient bronze implements make a point of stating that in ancient times workers of bronze possessed the art of tempering the cutting edges of bronze implements in a way unknown at the present day. Like many other popular traditions, however, the statement is not true, as Prof. Gowland pointed out in the course of his presidential address to the Institute of Metals. Such hardness as the implements possessed was secured by simply hammering the cutting edge. He observes: "It is to this hammering, and to it only, that the hardness of the cutting edges of both copper and bronze weapons is due, and not to any method of tempering. Much has been written about the so-called art of tempering bronze, supposed to have been practised by the men of the Bronze Age in the manufacture of their weapons; the hardness is also said to be greater than can be given to bronze at the present day. I should like to correct this error, as it can only have arisen owing to its authors never having made any comparative practical tests of the hardness of bronze. Had they done so, they would have found that the ordinary bronze of to-day can be made as hard as any, in fact, harder than most, of prehistoric times, by simple hammering alone."

Ventilation Standards in Coal Mines.—In the course of a recent lecture, Mr. G. H. Winstanley, M.Sc., president of the Colliery Managers' Association, referred to the standards of ventilation introduced by the new Coal Mines Regulation Act. It was provided, he said, that return airways must not be used as haulage roads if ordinarily they contained more than a half per cent. of inflammable gas. He was afraid that in some of the coalfields in South Wales and probably in Lancashire, that point would give rise to very considerable difficulties, and he wondered if the authorities responsible had quite appreciated the fact. In a seam of coal of a gaseous character every freshly-exposed surface of coal would give off gas into the surrounding atmosphere, and they would be compelled to carry on haulage in the intake airway. That, he suggested, would make it very difficult, indeed, to prevent the intake from being fouled to the limit permitted by the new Act. One way out of the difficulty might be the making of a third roadway—neither an intake nor a return—for haulage, where legally as much as $2\frac{1}{2}$ per cent. of inflammable gas would be permitted. He did not suppose colliery managers would be anxious to adopt that plan. The impression amongst miners that firedamp would always find its way to the roof and stay there was a dangerous delusion. As a fact, it would mix freely with the surrounding air until it reached the explosive point unless the ventilation diluted it sufficiently to make the gas harmless.

PROGRESS OF GAS POWER IN 1911.*

BY ROBERT H. FERNALD.

Large Gas Engine Units.—The development of large gas engine units has gone steadily forward for the past decade. The first engine of this class was that exhibited by the John Cockerel Company at the Paris Exposition in 1900. This was an engine of 600 h.p. rating. At the present time 1,500 h.p. in each cylinder of the 4-stroke cycle type and 2,000 h.p. in each cylinder of the 2-stroke cycle engine are reported as one of the exhibits at the recent Exposition at Brussels. This means units of 8,000 h.p. of the twin-tandem double-acting type. It is understood that at least one company is prepared to install gas engine plants of large power capacity at a cost not exceeding, and in some instances less than, that of the corresponding steam turbine installations.

Development and Application of the Diesel Engine.—Although the steam turbine has superseded the reciprocating steam engine for electrical development in central station work, and will probably hold the field for some time to come, it is interesting to note that the Diesel engine, owing to its great success in small station work, is looked upon seriously as a possible rival to the steam turbine within a short time. In a paper recently presented before the Municipal Electrical Association at Brighton, England, the relative cost of a 10,000 kw. installation for steam turbines, gas producers, and engines, and Diesel engines, was discussed at length. The author's proposition was to use seven sets each of 1,450 kw. capacity. His figures of operating expense, &c., are decidedly in favour of the Diesel engine installation. Attention was also called to the very economical use of these engines as a substitute for sub-station converting machinery. Such stations are already putting in their appearance in London.

In this connection it is interesting to note the development in point of size of the Diesel engine. Engines of a few hundred horse-power have become European practice. In Swiss electric stations Diesel engine units of 2,000 h.p. are now in use, and one writer on the subject states that the development of the large-sized Diesel engine has been so successful that it will not be long before 1,000 h.p. developed in one cylinder will be thought nothing extraordinary. One company of world-wide reputation is at present considering more than 2,000 h.p. in the single cylinder of Diesel engines. It is stated that engines of this type with four cylinders, developing 1,000 h.p. each, can be made as light as the corresponding triple-expansion steam engine. The weight of such engines compares favourably with that of the corresponding turbines and boilers. It is understood that a 1,000 h.p. installation of this type weighed only 187lbs. per horse-power, as compared with 180lbs. for a steam turbine and boiler installation.

The crude oil engine is now definitely under consideration for all types of marine craft. For small vessels the advantage lies in the safety afforded by the use of crude oil as compared with lighter oils. The crude-oil engine is being used by many of the principal navies of the world for submarine boats, and designs are already under way for comparatively large engines for torpedo boats and similar craft.

A few months since, the "Vulcanus," a vessel of 1,900 tons displacement, 196ft. long, equipped with 6-cylinder 4-cycle single-acting reversible Diesel engines, was put in regular service between Holland and Borneo. This engine is about 500 b.h.p. capacity at 180 revs. per minute. The fuel is a crude oil from Borneo, and the quoted guarantees are 0·42lb. per brake horse-power hour at full speed; 0·44lb. at three-quarter speed; and 0·5lb. at half-speed. In a recent trip the "Vulcanus" covered 3,312 miles in 19 days and 3 hours. The average speeds varied from 6·86 knots to 7·80. It is understood that the average consumption for this ship amounts to 1 ton of fuel oil per 100 knots.

The technical journals of recent date record many such installations. Among these, Russia is credited with at least four freight vessels of 1,000 h.p. and two 14-knot gunboats of the same horse-power rating. This month two vessels nearly 400ft. long, of 7,000 tons capacity, each fitted with Diesel engines of 2,500 h.p. rating, and with two auxiliary Diesel engines aggregating 500 h.p., will be tried out in European waters. A recent announcement is to the effect that the Hamburg-American Company propose to build an ocean liner using oil engines for motive power.

In this connection attention is especially directed to the most recent development in the oil-engine field—the Junkers marine oil engine. These engines, for the freight vessels of the Hamburg-American Line, are of the twin-tandem type of 1,600 total shaft horse-power each. The engines operate on the 2-cycle principle, and through the introduction of two pistons into each cylinder double action is secured.

An interesting comparison will shortly be placed before the public by the British Admiralty, as it is proposed to try out side by side in a twin-screw cruiser a steam engine and a Diesel engine of 6,000 h.p. rating.

Another destroyer recently ordered by the British Admiralty, according to current reports, will have on each shaft a steam turbine and a Diesel engine. The plan is to operate the turbines when high speeds are required, but under cruising conditions, when the speeds are low, owing to the poor economy of the steam turbines, the Diesel engines will be used. The combined economy due to this arrangement will be exceedingly interesting. One of the interesting features of these engines is the fact that there seems to be a marked tendency towards the 2-stroke cycle for marine work.

With the introduction of these engines the discomforts of the stokehold will be greatly reduced, and the amount of labour required will be less than under present marine conditions, and the character of labour much improved. Although it is not probable that steam installations are to be rapidly displaced in the larger ocean-going craft, yet the crude-oil engine seems to be especially adapted for such service as that previously indicated. The fuel needed approximates a third of that required for the steam engine, thus greatly increasing the radius of action if the same weight of fuel be carried. Boilers can be done away with and their space utilised for carrying cargo.

Tar as a Fuel for Diesel Engines.—Tar oil has become more or less common as a fuel in Diesel engines of 600 h.p. to 800 h.p. rating, and it is understood that it is used in at least one engine of 4,000 h.p. rating. Recent experiments indicate that both thin gas-retort tar and thick coke-oven tar can be used in a similar manner by injecting into the cylinder a small percentage of light oil to assist in igniting the tar. It is claimed that a wide range of tars can be used in this manner without producing smoke or appreciable residue. In tests at the Körting works, about 2 per cent. of the ignition oil was used at full load and about 13 per cent. at half-load. Reports indicate that an order has been placed for a 600 h.p. Diesel engine to operate on raw tar.

Internal-combustion Engine Locomotives.—Locomotives using internal-combustion engines and operating on the standard gauge track have recently been put into service. The range of fuel for these engines covers gasolene, benzol, alcohol, and petroleum. The Prussian State railways are reported to be operating a 1,000 h.p. locomotive using a Diesel engine as motive power.

The Gas Turbine.—Results are soon to be expected from the more recent investigations and tests relating to gas turbines. It is believed that some of the types are based on correct principles, and that after a rotary air compressor of satisfactory design has been secured rapid progress in the development of this prime mover may be expected.

Reliability of Internal-combustion Engines.—Not only do the renewed and increased orders for internal-combustion engines by the great manufacturing corporations indicate a feeling of assured reliability, but the subsidising by European war departments of petrol motor lorries indicates a feeling of reliability in the internal-combustion principle that is beyond dispute. These vehicles will be held subject to purchase in case of need by the war department. An important stipulation is: "The engines must be of the internal-combustion type using petrol, and by preference having four cylinders."

The Humphrey Pump.—This internal combustion pump has been before the gas power public for two or three years past. Many similar internal-combustion pumps are clamouring for admission to the field. The comptroller, in discussing the validity of the Humphrey patents, states: "The Humphrey pumps show an important advance in the art. Although

* Abstract of address of the Chairman delivered at the annual meeting of the American Society of Mechanical Engineers.

many applications have been filed for patents since 1858, none has embodied the principles of the Humphrey pump." The 1,000 h.p. pump occupies about the same space as the tandem double-acting gas engine of the same power. Mr. Humphrey says: "With the compression pressure of 11 atmospheres absolute, the theoretical thermal efficiency of the cycle is 52·5 per cent., whereas that of the Otto cycle is only 40 per cent. when all corrections for varying specific heats are allowed for. With very moderate compression, under 50lbs., an actual thermal efficiency of 23 per cent. has been obtained on a 4-cycle Humphrey pump. This corresponds to 0·95lb. of anthracite per hydraulic horse-power hour, and was obtained on a lift of only 35ft."

Illuminating Gas from Sewerage.—A report is current to the effect that the municipality of Bruss, Austria, is to convert the solid residue from the town sewerage into illuminating gas. The figures reported indicate that 1lb. of solid residue is secured from 60 galls. of sewerage, and that 380 cub. ft. of gas are obtained from each 100lbs. of solid residue. The calorific value of the gas is reported as at least equal to, and the light better than, that of coal gas.

Utilisation of the Waste Heat of the Gas Engine.—Various methods of utilising the waste heat of the gas-engine exhaust have been attempted from time to time, and the demand for such devices for heating buildings has been considerable. Several schemes for accomplishing this result are now commercially in use, but according to recent opinions the most efficient method of utilising the exhaust is through a combination of gas and steam engines. Present practice indicates that about 3lbs. of steam are generated per brake horse-power hour by means of exhaust boilers.

According to Mr. Chorlton, the use of exhaust boilers with efficient steam engines and specially designed gas engines of the 2-cycle type will effect marked thermal economies and reduce initial cost of the installation per horse-power. One of the technical journals states that Mr. Chorlton shows by numerical examples the possibilities of such an engine, first examining the case of the addition of a steam end to a normal economical gas engine. He assumes a standard engine to use 9,500 B.T.U. per brake horse-power hour. As the engine is ordinarily arranged with jacket feed to the boilers, we may take 40 per cent. of this amount to be recoverable. From this at 80 per cent. efficiency of conversion at 100lbs. pressure we would recover about 2½lbs. of steam per brake horse-power hour. This amount in an ordinary simple steam engine would not give more than 10 to 12 per cent. of the main engine power, a return which hardly justifies the first cost of the steam cylinder. Consequently, no development has taken place in this direction.

When, however, we are dealing with a special combined compound engine, each part of which is made in the most suitable way for the purpose required, we get a very different result. In order to reduce the cost of the gas engine part the compression would be lowered, and with the ignition retarded a much lower maximum pressure and temperature would result; the total heat units used would go up to, say, 12,000 B.T.U., but more would be rejected to the exhaust, and with a special arrangement of boiler, economiser pipes, superheaters in exhaust, &c., 50 per cent. waste heat should be recoverable. There should be obtained from this 4lbs. of steam per brake horse-power hour.

The steam cylinder used would be similar in type to that of the 2-cycle engine, that is, with no exhaust valves. The unidirectional flow engine of this type has been largely re-introduced in Germany with very economical results. The jacketing of the ends could be done by exhaust gas. For small engines of this type it is safe to assume a steam consumption of 12lbs. per brake horse-power hour; a consumption of 10lbs. has been obtained in actual practice. Hence the power obtained from the steam cylinder would be one-third of that of the gas cylinder, and the consumption for total effective power would be reduced to 9,000 B.T.U. per brake horse-power hour, less than that for the economical gas engine alone.

Surface Combustion.—By what he terms "surface combustion," Prof. Bone reports for gas-fired boilers evaporations of 21·6lbs. per square foot of heating surface, and an efficiency of heat transmission of 94 per cent. The heat balance of a test reported by him shows:—

Gas burned per hour (at 32° Fah. and 14·7lbs.), cub. ft.	997
Net calorific value of gas, B.T.U.	562
Total heat supply to boiler per hour, B.T.U.	559,800
Temperature of feed water, degrees Fah.	42
Pressure of steam, lbs.	100
Water evaporated per hour, lbs.	450·3
Water evaporated from and at 212° Fah., lbs	550
Heat transmitted to water, B.T.U. ... 450·3 × 1,172 =	527,800
Heat ratio 527,800 ÷ 559,800	0·943

In the reports of the surprising results of these investigations, attention is called to the fact that the combustion was perfect, as was shown by analysis. An efficiency of 94 per cent. was obtained. Deducting 4 per cent. for the power required for supplying air pressure still leaves 90 per cent.

Prof. Bone says: "The new boilers could be set up in brickwork and require no elaborate flues or chimneys. They are liable to no strains, as they are short. With some sacrifice of efficiency the evaporation could be raised to 30lbs. per square foot. The steam was raised quickly (steam at 100lbs. pressure obtained in 20 minutes from cold start), and tubes could be grouped and cut out separately so as to vary the fuel consumption to suit the fluctuations of load." In the first foot of the tubes 65 per cent. of the steam was generated, 25 per cent. in the second foot, and 10 per cent. in the third.

Producer Gas from Low-grade Fuels.—Progress is steadily being made in the utilisation of lignite, peat, and high-ash coals in producer-gas work. The investigations of the Canadian Government show that peat can be prepared for fuel purposes at a cost averaging from 30 to 40 per cent. of that of an equivalent B.T.U. value in anthracite in Canada.

As the foundation of a method that may result in extensive use of high-ash fuels without prohibitive cost of operation, attention is directed to the present producer-gas investigations of the United States Bureau of Mines, resulting in the successful fusing of the ash and the use of water-cooled producer linings. In line with this specific conservation of fuel resources, it is interesting to note that one estimate states that the United States Steel Corporation alone, through its installations of blastfurnace gas engines, displaces or saves a consumption of approximately 1,000,000 tons of coal per annum as against the old-fashioned methods.

Small Producers for Bituminous Coal.—Reports are persistently before us indicating the successful development of gas producers of small power to operate on bituminous coal, coke breeze, anthracite screenings, "front end cinders," &c. Such plants are in great demand, but it is doubtful whether the development and application have been as great as the advertising these plants receive. It is interesting to record, however, that a company manufacturing anthracite gas producers and gas engines which expressed its firm conviction in 1904 that the United States Government tests with bituminous coal in producers would fail utterly, recently put itself on record as recommending the use of its own engines with small bituminous producers manufactured by another company.

Crude-oil Gas Producers.—The development of the crude-oil gas producer, for which there is great demand in oil regions remote from the coalfield, has been exceedingly slow, but it is believed that very definite progress has recently been made along this line. The most recent notes on this subject relate to the Grine oil producer. In this type steam spray is used for atomising the oil which is introduced into the upper part of the generator, where partial combustion takes place. The down draught principle is then applied, and the hydrocarbon broken up and the tar fixed by passing through a bed of incandescent coke. Mr. Grine reports that a power plant using one of these producers has been in operation a year in California. With crude oil as fuel, costing 95 cents per barrel, or 2·3 cents per gallon, the plant is reported to develop the same amount of power per gallon of crude oil as is ordinarily developed by the standard internal-combustion engine operating on distillate at 7 cents per gallon. Including the cost of fuel, labour, supplies, interest, depreciation, and taxes, Mr. Grine states the cost per brake horse-power hour to be 0·76 cents for a plant of 100 h.p. rating.

It is gratifying to note that each year removes many of the absurd prophecies regarding the elimination of practically all prime movers save the internal combustion engine, and that the past year may be regarded as one of steady, conservative progress and development.

SURFACE COMBUSTION STEAM GENERATOR AND FEED WATER HEATER.

In our issue of June 16th last (see page 749, Vol. 27) we described and illustrated a novel design of steam boiler, the invention of Messrs. Bone, Wilson, and McCourt. A somewhat modified arrangement for steam generating and feed water heating has recently been patented by the same inventors, and is shown in the accompanying cuts, Fig. 1 being an elevation partly in section, and Figs. 2 and 3 enlarged details. B is the shell of any suitable diameter and 3ft. to 4ft. long traversed by a number of boiler tubes T which are closed at their entrance ends with fireclay plugs P, each of which is provided with a central aperture S for the admission of the combustible mixture of gas and air. The tubes T are packed with granular or fragmentary refractory material G made by crushing firebrick to pass a 1in. mesh, the finer material such as will pass a $\frac{1}{2}$in. mesh being rejected; the granular material is kept in position at the exit ends of the tubes by grids. The chamber W is connected by means of the duct H with the feed water heater A which latter is itself similarly connected by means of the duct Q with the fan F which maintains the suction necessary to draw the gases through the system and also discharges the cooled products of combustion to the chimney. The damper D serves to regulate the gaseous flow through the system. The chamber W is provided with doors for the purpose of charging the tubes T with granular material. The feed water heater comprises a shell A to which the cold feed enters by the inlet E, the heated water leaving the heater by the outlet J. The shell A is traversed by the tubes shown which are packed with granular material similarly to the tubes T. The heater is so formed that the duct Q and the end plate may be disconnected for the purpose of charging the tubes with granular material.

Owing to the low temperature to which the products of combustion are cooled in passing through the packed tubes of the feed water heater condensation of water vapour may take place. The resulting water requires to be drained away, and for this purpose a drain pipe is provided dipping into a water seal K and of such length that air will not be drawn up the drain pipe by the suction in the duct Q. The feed water heater fulfils a double purpose. It not only serves to increase the efficiency of the plant, but also to cool down the products of combustion to a temperature at which the fan will conveniently deal with them.

C is a gas chamber attached to the front of the boiler to which the combustible gas is admitted under suitable pressure (for example, 2in. water gauge in the case of coal gas) from the main O, the supply being regulated by means of a valve. Openings are provided in the gas chamber through which pass pipes M leading into the fireclay plugs P. Centrally opposite each pipe M is a jet N controlled by the valve R, Fig. 3. When it is required to fire less than the total number of boiler tubes present iron caps are screwed over the open ends of the mixing tubes connected with those boiler tubes which it is desired not to fire, with the object of preventing cold air from being drawn through those tubes.

The admission to each boiler tube under given working conditions, of the desired amount of combustible gas together with its proper proportion of atmospheric air, as well as the complete admixture of the gas and air before reaching the zone of combustion is effected under the suction of the fan with the aid of the devices shown in detail in Figs. 2 and 3. M is a tube of such length and cross-section as to cause the combustible gas and air drawn there through under the action of the fan to mix completely prior to entering the granular bed. R is a tube connected with the larger tube M and of such cross-section as to cause a homogeneous and explosive mixture of combustible gas and air to be drawn through at a speed considerably in excess of the speed of back-ignition of the mixture, to the intent that no combustion of the explosive mixture shall take place prior to entering the bed of granular material situated in the boiler tube. With the arrangements described and when employing coal gas the inventors have found that the tube R may be conveniently of $\frac{5}{8}$in. bore and about $3\frac{1}{2}$in. long, and the tube M of 1in. bore and about 8in. long, and that a suction at the fan amounting to 15in. water gauge is suitable. An important function of the plug P is to protect the joint of the boiler tube in the tube plate L from the action of the heat. Owing to the fact that the whole of the heat is generated inside the boiler tubes in a zone well removed from the tube plates, steam is generated at so great a rate as corresponds to an evaporation of 20lbs. of water per square foot of heating surface per hour without any liability of overheating the tube plates or the joints of the tubes therein.

In starting up the boiler the fan is first set going and the combustible gas turned on and ignited at each jet N so that the resulting flames extend into the mixing tubes M and proceed to heat the granular material at the entrance ends of the boiler tubes; as soon as the granular material near the fireclay plugs P becomes sufficiently incandescent each gas jet N is momentarily turned off and immediately turned on again with the object of extinguishing the flame and of causing a mixture of gas with air sufficient for its complete combustion to be drawn through the mixing tube M and the aperture S of the plug P on to the incandescent granular material in the tubes T where the combustion now takes place.

If the tubes T are of too great diameter, the heat developed at the hottest point may not pass away with sufficient rapidity, with the result that the granular material may be softened. When using coal gas it has been found that with an internal diameter of 3in. a packing of crushed fire-

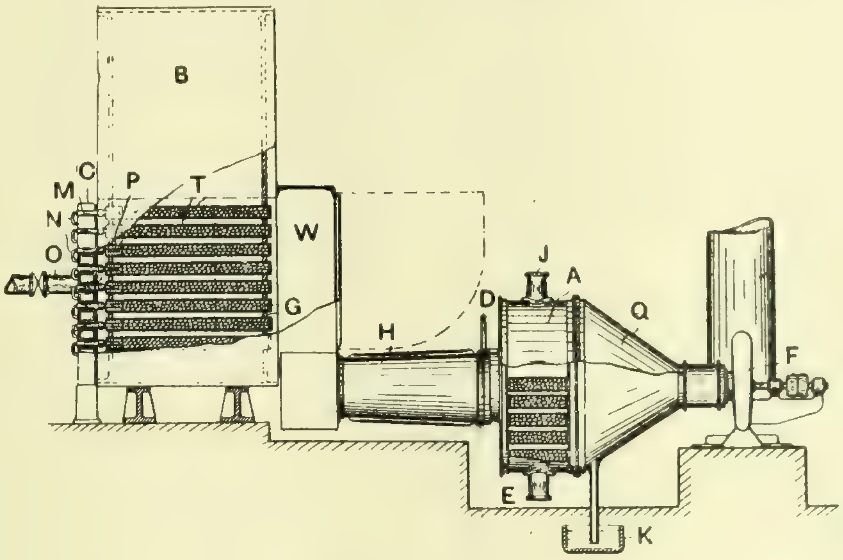


FIG. 1.

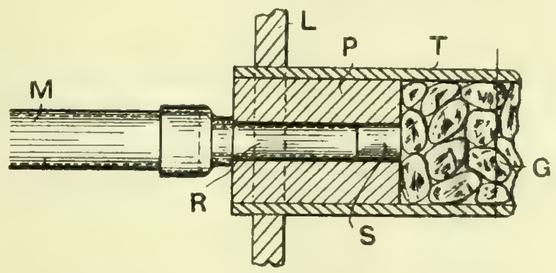


FIG. 2.

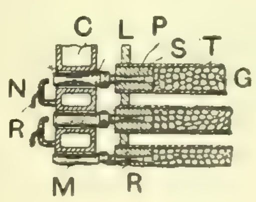


FIG. 3.

SURFACE COMBUSTION STEAM GENERATOR AND FEED WATER HEATER.

brick may be employed without material softening, whilst with an internal diameter of 4in. granules of fireclay situated in the hottest zone are liable to become softened. In this case the core of granular material at the hottest region should consist of magnesite or other very highly refractory material. Where, however, the combustible gas is of low calorific intensity, as, for example, producer gas, this precaution is not necessary. In order to distribute the flow of heat more evenly along the tube, it is desirable in some cases to line the tube with refractory material for a portion of its length near the hottest point to secure the desired distribution.

The most suitable length of tubes T to employ will depend on the diameter thereof, on the calorific intensity of the gas employed, on the rate of consumption of the gas, and on the temperature at which it is desired that the products of combustion should leave the generator. When burning coal gas or coke-oven gas at the rate of 100 cub. ft. per hour per tube, the tube or tubes need not be more than 3ft. to 4ft. long and 3in. internal diameter.

The following are the results of a test upon a horizontal boiler with tubes 3ft. long and fired with a mixture of coal gas (of net calorific value 560 B.Th.U's. per cubic foot at N.T.P.) and air in such proportions that the products of combustion contained only 1 or 2 per cent. of oxygen, but no trace of unburnt gas. When supplying to each tube of the boiler 100 cub. ft. of coal gas per hour plus air sufficient

for its complete combustion and generating steam at 120lbs. per square inch above atmospheric pressure, the products of combustion left the ends of the boiler tubes at a temperature not exceeding 240° C. (464° Fah.) or only 69° C. (123° Fah.) above the temperature of the water in the boiler, and although the products contained no more than 2 per cent. of oxygen the combustion of the gas was perfect. After the products had traversed the "feed water heater" their temperature was reduced to about 95° C. (203° Fah.). The thermal efficiency of the boiler plus feed water heater exceeded 92 per cent., reckoned on the net calorific value of the gas, and the rate of evaporation in the boiler exceeded 21lbs. per square foot of heating surface per hour.

ON THE BEHAVIOUR OF CERTAIN ALLOYS WHEN HEATED IN VACUO.*

BY PROF. THOMAS TURNER.

I.—Experiments on Brass.—In some experiments conducted in my laboratory last session, on the gases in brass, by Mr. J. Cartland, M.Sc., it was observed that when brass is melted *in vacuo* the zinc is entirely volatilised and the copper remains behind. This separation is quantitative providing that the materials employed are pure, and that the heating is not at too high a temperature or too prolonged. Otherwise the copper itself may begin to volatilise, though at 1,200° C. the loss of copper occurs very slowly. The following are examples of the results obtained:—

Sample.		By Analysis.	By Loss *in Vacuo.*
		Per Cent.	Per Cent.
1	Percentage in Zinc.	36·90	36·80
2	,, ,,	28·63	28·85

The experiments were performed as follows: A weighed quantity of the brass was placed in a porcelain boat, and introduced into a porcelain tube, the ends of which were then suitably closed, and the tube exhausted till the pressure was less than 5 millimetres of mercury. The tube was heated in an electric tube furnace of the well-known platinum resistance type until it was seen, through the glass cover at the end of the tube, that the metal was melted. By the aid of a thermo-couple placed within the tube of the furnace, but outside the exhausted tube, care was taken that the temperature did not rise more than a few degrees above the melting point of copper. If the alloy is maintained for about half-an-hour at this temperature, all volatile metals will have been removed from the copper, which, on cooling, is obtained in beautiful prills of a clear red colour, and usually with plainly developed crystal surface markings. The zinc condenses in the cooler parts of the tube in crystals which have a perfect metallic lustre.

In view of these results the question naturally arose as to what would be the effect of heating *in vacuo* an alloy which contained considerable proportions of other metals in addition to copper and zinc. A sample of impure brass was obviously a suitable material for preliminary investigations.

II.—**Poisoned Brass.**—Occasionally, during the past 25 years, when visiting brass foundries in the Birmingham district, I have heard the workmen speak of "poisoned" brass. It is described as being a variety of brass which is no good for casting purposes if used alone, and the evil influences of which are manifest in any alloy of which the poisoned material may form a part. The language employed might at first sight suggest some occult or living power in the brass, and recalls the ideas of an Indian writer who, a few years ago, suggested that metals might be living or dead, ill or well, like animals or plants. No such thought is present in the mind of the workman, however, for he uses the word "poisoned" rather to express a property of the material than to suggest any hidden or deeper meaning. The language of the uneducated metal worker is often that of the science of an earlier age. Thus when a puddler calls the blue flame of carbon monoxide "sulphur" he does not suppose that what he would call "brimstone" is really present, but that some volatile and combustible principle is being evolved or produced. In this way he exactly imitates the philosophers who preceded Priestley and Lavoisier, and who constantly employed the term "sulphur" in a similar manner.

A few years ago a sample of "poisoned" brass was received from Mr. R. H. Best, who regarded it as somewhat of a curiosity, and it was placed in the Metallurgical Museum. It was part of an ingot, nearly semicircular in shape; it was rather light yellow in colour, had the sharp fracture of a brittle material, and was full of blowholes, some of which were not much less than a quarter of an inch in diameter. Enquiries as to the source of origin of this sample showed that it was made by melting up the general scrap of a foundry. The makers apparently did not consider it sufficiently good for their own purposes, so sold it at a cheap rate. The blowholes were stated to be due to the use of a damp mould, and this may probably be correct at least in part.

An analysis of the alloy, conducted in my laboratory by Mr. P. T. Brühl, M.Sc., gave the following results:—

	Per Cent.
Copper	72·53
Zinc	11·65
Lead	7·11
Tin	5·52
Iron	2·00
Aluminium	0·75
Arsenic	0·09
Manganese	0·06
Phosphorus	Nil.
	99·71

An examination of these figures will fully explain the inferior results which would be obtained on using such an alloy, and would justify the use of the word "poisoned" in the sense in which it is employed by the workmen.

A weighed quantity of this alloy was placed in a porcelain boat and heated *in vacuo* in a porcelain tube to a temperature of about 1,200° as before described.

The residue left in the boat from the poisoned brass was weighed and analysed by Mr. C. R. Groves, B.Sc., and the results obtained are as follows:—

Residue in the boat (by Analysis).

	Per Cent.
Copper	72·36
Tin	5·01
Iron	1·96
Lead	Nil
Zinc	Nil
Arsenic	Nil

Loss by Volatilisation.

	Per Cent.
Zinc	11·65
Lead	7·11
Tin	0·51
Arsenic	0·09

These results account for about 98·69 per cent. of the whole. The aluminium and manganese were not estimated, on account of the small quantity of the material which was available.

It will thus be seen that when zinc and lead are present together in the alloy in certain proportions, the whole of the zinc and lead may be removed by heating to the melting-point of copper *in vacuo*, and the two metals are recovered in the metallic state. The loss of arsenic is also significant.

III.—**Crucible Experiments.**—An experiment was now conducted on a somewhat larger scale, in order to test the rate of volatilisation *in vacuo*. For this purpose 180 grammes of 70/30 brass, of good quality, were melted in a clay crucible in a coke fire. About 30 grammes were poured into a small mould to obtain a check sample. The residue, weighing about 150 grammes, was quickly placed in a covered glass desiccator, and a vacuum at once obtained by means of a Fleuss pump. To prevent fracture of the glass, the inside of the desiccator was properly lagged by means of two layers of asbestos cloth, and an intermediate layer of crushed firebrick. The crucible was also covered with a firebrick to prevent radiation. By surrounding the crucible in this way, a red-hot crucible, containing over a quarter of a pound of molten brass, can be kept in a glass vessel for a considerable period without the containing vessel becoming appreciably warm.

* Paper read before the Institute of Metals, January, 1912.

The original metal contained as nearly as possible 30 per cent. of zinc. When remelted, the sample cast in the mould contained 70·80 per cent. of copper. The loss of zinc in remelting in an open crucible was therefore about 0·8 per cent. The molten metal was placed in the desiccator, and, after being allowed to remain *in vacuo* for seven minutes, was removed and analysed, and found to contain 73·94 per cent. of copper, showing a loss of 3·14 per cent. of zinc. As the metal was quite solid and only dark-hot at the end of seven minutes, it was probably fluid not more than three minutes, in which case the loss of zinc would be at the rate of 1 per cent. per minute. In other words, if by internal heating or other suitable means a charge were kept fluid during the whole period, complete volatilisation of zinc might be expected to take place in less than an hour. Metallic zinc, weighing 4·9 grammes, was actually scraped off the under side of the firebrick cover. A repetition of the experiments with different weights of metal gave almost identical results.

These experiments show that considerable refining of impure copper could be accomplished by melting the metal *in vacuo*, as zinc, lead, arsenic, some tin, and probably other metals, could be volatilised and recovered. There does not appear to be any good reason why such a process should not be experimentally tried on a fairly considerable scale. In these days of electric melting furnaces, and efficient air-pumping machinery, it should not be difficult to design a form of apparatus which would be suitable for treating impure residues and crude coppers. There might perhaps be introduced a process in two stages, in the first of which crude molten metal would be purified by being maintained for a time in an exhausted vessel, while in the second stage the partially purified copper could be refined in an oxidising atmosphere to remove the remaining iron, tin, and other non-volatile metals.

IV.—**The Refining of Hard Zinc** *in vacuo*.—Zinc distils readily *in vacuo;* the temperature required is much lower than in air, and the losses are so much diminished, that it is probable means will be devised in future for considerable applications of vacuum distillation in connection with the zinc industry.

The material known as "hard zinc" is produced in the ordinary process of producing galvanised iron. The bath of molten zinc which is employed, and in which iron is being constantly dipped, gradually takes up iron until it contains about 5 per cent. of the latter metal. The iron-zinc alloy is then unsuitable for further use in galvanising, and is sold to the metal refiner or zinc works to be redistilled. This alloy appears to be specially suitable for refining under reduced pressure.

A sample of hard zinc analysed in my laboratory by Mr. Groves contained:—

	Per Cent.
Zinc (by difference)	94·48
Iron	4·71
Lead	0·81
	100·0

There was also present a trace of arsenic; but tin, copper, cadmium, antimony, and bismuth, though tested for, were not in sufficient quantity to be detected.

This hard zinc was tested by heating 1 gramme *in vacuo* for varying times at different temperatures. In all cases the pressure in the evacuated porcelain tube was less than 1 mm. of mercury. The results of the tests are given in the following table:—

Heating of Hard Zinc in Vacuo. Analyses by Mr. Groves.

Temperature, Degrees Centigrade.	Time, Minutes.	Iron in Residue, per Cent.	Iron Volatilised, per Cent.	Zinc in Residue, per Cent.	Lead in Residue, per Cent.
1000	15	2·08	2·63	Nil	Nil
600	30	2·32	2·39	Nil	Nil
550	30	3·42	1·29	Nil	Nil
500	45	4·70	Nil	0·40	Nil
500	45	4·80	Nil	1·52	0·30

In the second experiment at 500° C., the furnace was heated more quickly up to the required temperature, and the metal was therefore exposed to the heat for a rather shorter period than in the first case. Doubtless this accounts for the higher residue of lead and zinc noted in the second test.

These experiments show that at high temperatures the greater part of the iron is carried over with the zinc when hard zinc is distilled *in vacuo*. At a temperature of 500° C., however, the whole of the iron is left in the form of a non-volatile residue, while zinc is obtained in the metallic state. If this process of refining were adopted on the large scale, there is no doubt that the consumption of fuel would be much diminished, while there should be no loss of zinc, as there is no possibility of oxidation. The necessary temperature is only just sufficient to render the metal visible in the dark, or in other words, it is a scarcely visible dull red heat, so that in all probability unlined iron vessels might be employed for the distillation. The labour costs should be small, and when the apparatus was once in working order the great reduction in fuel consumption and in loss of zinc should render its working remunerative.

V.—**The Equilibrium of the Copper-Zinc Series.**—Hitherto experiments in the equilibrium of the copper-zinc series have been conducted at constant pressure, and the published diagrams are of this character. The experiments already described indicate that the conditions of equilibrium must vary greatly with changes of pressure, and open up a wide field of enquiry as to the effect of differences in the composition of the alloys and the variations in the pressure of zinc vapour. Particulars of a few preliminary observations in this direction may not be without interest.

In order to ascertain the approximate temperature at which zinc vapour begins to be evolved *in vacuo* a hard glass tube was taken, and into this was introduced some of the metal or alloy to be tested. The tube was then evacuated, until the pressure was less than that of 1 mm. of mercury, and the tube was afterwards sealed. It was then placed vertically in an air bath so arranged that the lower part of the tube, which contained the metal, could be heated to the desired temperature, while the upper part of the tube was out of the air bath and kept well below the melting-point of zinc. The air bath was then gradually heated until a deposit of zinc could be seen on the cool part of the tube. Proceeding in this way, it was observed that a deposit of zinc was produced in a few moments when zinc itself was heated to 375° C. With 60:40 brass, or "yellow metal," the deposit did not form with any rapidity until a temperature of 520° was reached, while with 70:30 brass a still higher temperature, of about 550°, was necessary. By a modification of the experiment a piece of pure (Mond) zinc and clean pure (electrolytic) copper were introduced end to end in a horizontally placed evacuated tube, and then gradually heated in an air bath provided with a glass lid through which the progress of the experiment could be watched. The pieces of metal were arranged so as not to touch each other, and the whole of the tube was uniformly heated. It was observed that at a temperature of 380° C. the copper rapidly assumed a yellow colour. When thin sheet copper is acted upon, the brass coating is found to be quite firmly adherent and to stand polishing, or scratching with a knife, without change of colour. The resulting sheet brass is very soft and ductile. By prolonging the heating for about two hours sufficient zinc is absorbed to cause the copper to become first yellow, then redder in colour, and afterwards brilliantly white. It is therefore possible to prepare brass while the constituent metals are both in the solid state, through the absorption by the copper of the vapour emitted by the solid zinc. The action recalls to mind the ancient method of making brass, and the process of "sherardising" iron, the great difference being that the temperatures necessary *in vacuo* are so much lower, and there is no loss of zinc.

It will be seen, therefore, that at 375—380° C. copper readily absorbs zinc vapour; at its melting-point no zinc is retained; at 520° zinc vapour is given off by 60:40 brass, while 70:30 brass gives off vapour of zinc at about 550°. With more careful experiment probably these temperatures will be lowered, for it is stated that at about 184° C. faint indications can be obtained of the volatility of zinc *in vacuo* if the observation be extended over about fifty hours.

Zinc vapour is quite colourless and transparent when in the hot evacuated glass tubes. Zinc can readily be distilled in glass vessels, and its close resemblance in appearance to the distillation of mercury makes the experiment very pleasing and interesting.

AIR COMPRESSOR EFFICIENCY.*

BY B. M. WOODHOUSE.

AIR compressors belong to that class of machinery which, to a very large extent, is dependent for its mechanical success upon the source of power from which it derives its motion. This being the case, it is natural that the development of compressors, prior to the electrical era, should have proceeded hand in hand with that of the steam engine, and that its development has been marked by a gradual increase of rotary speed in order to keep pace, firstly with the steam engine, and more recently with the electric motor. The latest development—that of the turbo-compressor—is one in which steam and electrical prime-movers are equally interested, and very keen rivals.

Rapid as the development of air compressing machinery has been, it has always been hindered by difficulties common to reciprocating pressure-raising machinery in general. Some of these difficulties, however, attain their maximum of importance when experienced in connection with com-

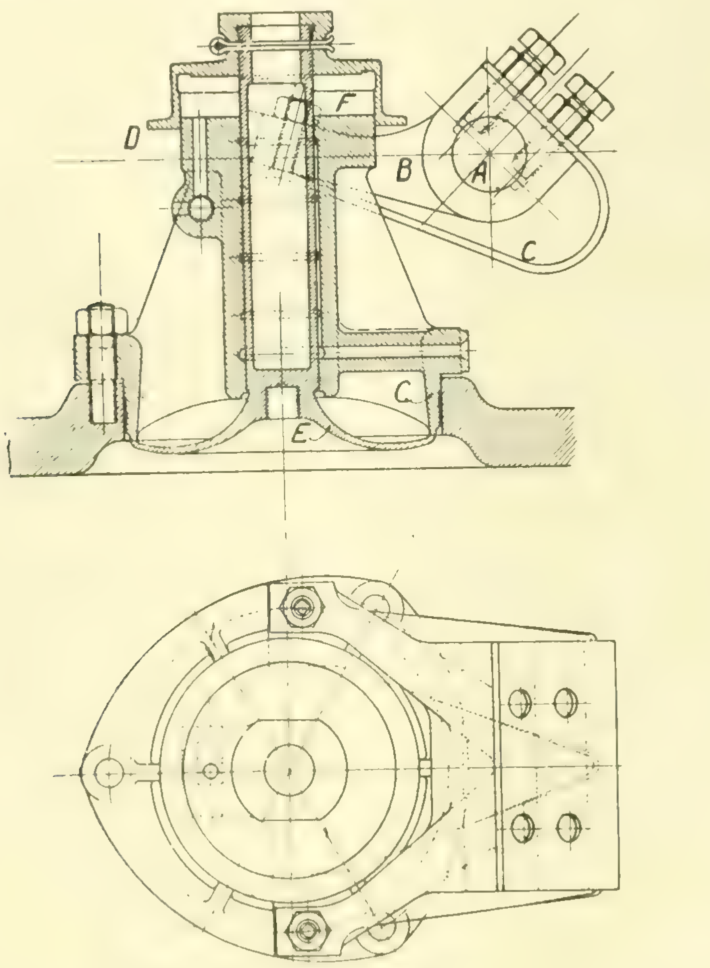


FIG. 1. RIEDLER SUCTION VALVE.

pressors of gaseous fluids. Low pressure compressors—commonly called blowers—never offered any very serious difficulties, for, being as a rule required to deliver very large air volumes, their dimensions are so large that they are not suitable for high speeds. Even to-day they are seldom run at more than about 90 revs per minute, to which speed the blastfurnace gas engine forced them.

In 1882 a large blower of the beam-engine type was built by Messrs. Breitfeld, Daňek & Co., of Prague, and tested by Professor Doerfel, of the same city. The air cylinders of this engine were 2,854 mm. (about 112·5in.) in diameter, and had a stroke of 2,846 mm. The speed was 12·3 revs. per minute. The tests demonstrated that the compound steam engine, which indicated 332 h.p., required 9·67 kilos of steam per hour for each indicated air horse-power; that the mechanical efficiency of the engine (ratio of the indicated air to the indicated steam horse-power) was 88 per cent., and that the final air pressure within the cylinder was only 1·096 times the pressure in the delivery main. With such results as these there was no need to be discontented as far as the blower was concerned, so it is safe to assert that such engines have been speeded up chiefly that their dimensions might be more moderate and that the steam end might be more economical.

When, however, high air pressures are required the temperature rise becomes a source of danger and a cause of serious ineconomy unless adequate means for moderating it are employed. Water jackets being of very little use for this purpose, attempts were made to compress air in the presence of water in so-called wet-compressors. Even quite recently much attention was paid to this type of compressor, and in 1891 designers were to be found in France patenting special constructions whereby the thermal efficiency of compressors should be improved. For instance, the compression chamber was formed in such a manner that the surface of the water in contact with the air should vary during the engine stroke at the same rate as that at which the heat generated during compression changes; further, too, chains and similar devices were hung within the compression chamber so as to be alternately wetted by the water and exposed to the air during compression, in order that the film of water on their surfaces might more readily be evaporated, and thus cause compression to take place as nearly as possible isothermally.

Continual increase of the rotary speed of the steam engine, and the economy of steam attainable with higher steam piston velocities made wet compressors and their adjuncts undesirable. The half-wet type of compressor was consequently introduced. In it the air was drawn in, compressed, and delivered as in a modern dry compressor. During the compression stroke, however, water was sprayed into the cylinder for the purpose of reducing the temperature of the air. Although this method of cooling has not yet been totally abandoned, it is nowadays seldom met with because its two chief disadvantages are fully appreciated. They are: Increased wear and tear due to the presence of water in the cylinder making proper lubrication difficult, and unsuitability of wet air for use in air-driven machines and tools, especially if they work expansively, on account of the formation of ice in the exhaust ports and mains.

The present-day methods of overcoming difficulties due to heating of the air during compression, and of increasing the thermal efficiency of compressors are: (1) To water-jacket the air cylinder and ports as thoroughly as their mechanical construction will allow of. (2) To compress in stages if the final pressure required is so high as to make efficient lubrication difficult, the danger of spontaneous ignition of the lubricant (and frequently of entrained coal dust) imminent, or the power required for compression in one cylinder excessive.

A brief review of the changes that have been made in the design of air valves, in order that compressors might safely run at the high speeds now common, will possibly be of interest. In the days of slow-running machines the valves were very simple. With blowers weighted leather flap-valves were usual, for higher pressures ordinary spring-loaded valves of the mitre or similar type were employed. As rotary speeds advanced, such crude valves were found to be unsatisfactory. Their weight alone was sufficient to cause the final pressure within the cylinder to rise considerably above that in the delivery main, whilst the springs required for returning them promptly to their seats not only added to this source of economy, but, aided by the difference of air pressure above and below the valves, returned them to their seats with such energy that the life of valves and seats was anything but satisfactory.

Experience, therefore, demonstrated that for higher speeds valves of a different kind from those hitherto used were required. Present-day valves have resulted through development along the following lines: (1) Reduction of weight. (2) Reduction of lift. (3) Introduction of air buffers. (4) Use of auxiliary valve gear. (5) Use of mechanically controlled valves. (6) Use of positively worked valves. (7) Introduction of unloaded valves. (8) Use of so-called weightless valves.

With moderate rotary speeds, much success was achieved with a combination of positively worked and automatic valves. The Harrass valve-gear was probably one of the

* Paper read before the Rugby Engineering Society, January 23rd, 1912.

first of this type, and, as it is still quite frequently built into good-class blowing engines, a few words of description follow. It consists essentially of two elements: a Corliss valve (frequently double ported but in most up-to-date forms of the gear a separate Corliss valve for suction and for delivery) for controlling the end of the delivery period and the beginning and end of the suction period, and (usually a number of) automatic valves, free to open when delivery is to commence. For low pressures the gear is most satisfactory, but at high pressure ratios the resulting high temperatures make lubrication difficult.

The idea here involved is the use of automatic valves for the introduction of delivery only. The Corliss valve terminates the delivery period and allows the automatic valves to return to their seats at their leisure, and with the same air pressure below and above their seats. They need, therefore, no heavy spring to close them promptly, nor does a difference of air pressure hammer them on to their seats. As competition increased and sellers sought talking points, it was discovered that, besides other disadvantages, the Harrass gear had the peculiarity of enclosing a space between the Corliss and the automatic valves which added to the clearance volume. Strnad, to a great extent, got rid of this defect by mounting the automatic valves within the Corliss one.

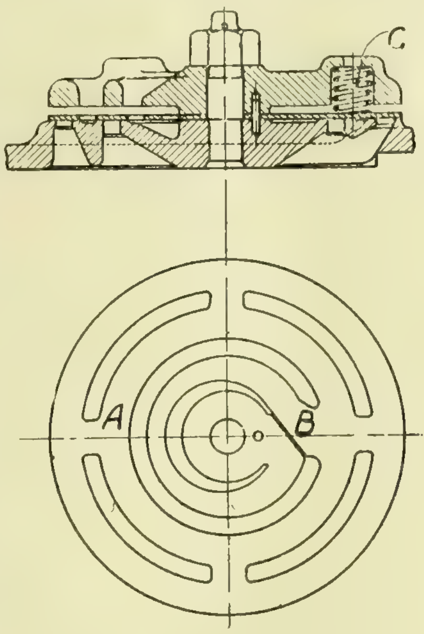


FIG. 2.—HOERBIGER VALVE

Further reduction of the clearance volume was, however, as time went on, thought to be a matter of importance. This gave Prof. Riedler an opening for the introduction of his mechanically controlled automatic valves. These were mounted upon the cylinder covers themselves, and thus reduced the clearance volumes to a minimum. The valve is, for moderate rotary speeds, an ideal one, and it is largely made use of even to-day on compressors of large size. Messrs. Fraser & Chalmers took over the patent rights for Britain and her Colonies at an early date, and they have fitted a large number of compressors with the gear.

Fig. 1 illustrates a suction valve of the type in question as manufactured by Messrs. Breifeld, Daňek & Co., of Prague. The following description of the action of the valve will also render its construction clear. At the time when the suction stroke begins, the spindle A has already turned through such an angle as to have moved the lever B and the attached spring-lever C well out of the way of the collar D of the valve E. When, therefore, the pressure within the cylinder has become low enough the valve automatically opens unrestrictedly, until the air buffer F limits its stroke. Towards the end of the suction stroke the lever B approaches the ring D of the valve, presses upon it by means of the spring-lever C, and forces the valve back upon its seat G just as the piston arrives at its end position. The lever B still continues its motion in the closing direction for some little while, the spring-lever C taking care that the valve is not damaged. At H a lubricant is introduced to minimise wear, and does so very satisfactorily, for the life of such valves leaves little to be wished for.

With the Riedler valve, the speed of compressors advanced sufficiently to induce electrical engineers to advocate their direct driving by means of electric motors. For large units the flywheel type of motor was usual, and its expense led to a further speeding up of the compressor. Thus speeds were soon reached which made the elimination of exterior valve gear necessary; automatic valves again became fashionable, and extensive use was made of air buffers. It was, however, soon discovered that the air buffer not only acted so as to check the opening motion of the valve as wished, but that it also hindered it in closing and thus led to its hammering on the valve seat. Buffers, therefore, gave way to the so-called weightless type of valve; of this type we now have innumerable varieties.

An early form of the weightless valve was patented by Hoerbiger, of Vienna. Originally it was only a sheet-steel ring, to which one end of each of the three steel spring carriers was riveted. The three remaining ends were attached to the valve casing on a pitch circle of about the size of that on which the previously-mentioned rivets were placed. By this construction the valve, although definitely located, was forced to make a slight rotary motion during every stroke. This was said to keep the valve well bedded upon its seat. The construction of the valve has gradually been changed to that in which we at present find it. Such alteration was due to trouble experienced with the riveted connections between the valve-ring and its carriers. Fig. 2 shows the latest type of Hoerbiger valve, as made and used with much success by Messrs. Willans & Robinson, in connection with their air pumps. The illustration requires but little comment. It will be noticed that the suspenson springs have given place to suspension by the valve plate A itself; that this is slit in such a manner at B as to form a kind of coiled spring, and that auxiliary loading springs C are used. This valve has an excellent reputation.

Some other constructions of this type of valve ought, perhaps, to be referred to. Messrs. A. Borsig, of Tegel, use, for instance, a plate valve (patent Lindemann), the plan of which is shown in Fig. 3. One spiral spring with a diameter roughly equal to D in the figure is employed for loading the valve. Rudolf Meyer makes use of a multiple-part valve. Each valve-element consists of a simple strip of steel, like a toothless hack-saw blade. It is guided at each end by a pin, around which the loading springs are coiled. The elementary valves are mounted upon grid seats of circular form, and of such a size that for each cylinder end only one group of suction and one group of delivery valves are required. They are built into the lower and upper sides of the cylinder ends respectively, much in the manner in which the drop-valves of steam cylinders are accommodated. Prof. Gutermuth has patented a valve construction which is very compact, and peculiar on account of the way in which the open valve permits the current of air to pass with a minimum of deflection. Each valve element consists of a steel spring wound spirally round a spindle to which it is attached, and by means of which the spring tension is adjustable. The free end of the spring is thickened up to form the valve. The suction and delivery valves are mounted upon the same grid, which is usually fitted to the cylinder end in a way similar to that adopted in the case of Corliss valves. The grids, however, have no motion imparted to them by the compressor.

FIG. 3.—PLAN OF LINDEMANN'S VALVE.

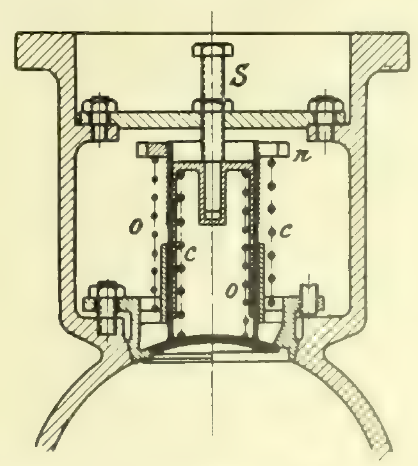


FIG. 4.—KLEFAL VALVE.

One other type of valve should be noted before leaving the subject of valve development, not because it has as yet been very extensively used, but because it complies with the theoretical requirements enunciated by Prof. Koerner, of the Prager Technische Hochschule. After careful experi-

ments he arrived at the conclusion that the automatic valves of compressors and pumps need a force for accelerating their opening as well as one for returning them to their seats promptly.

O. Klepal has devised and made use of a valve embodying this idea. It is illustrated in Fig. 4. The right-hand half of the figure shows a suction valve, the left-hand half a delivery valve, as already frequently built into compressors and pumps of various kinds. It will be noticed that the valves are free to open as far as they are required to do in order to accommodate the fluid passing, when simultaneously acted upon by the fluid pressure and springs. The usual

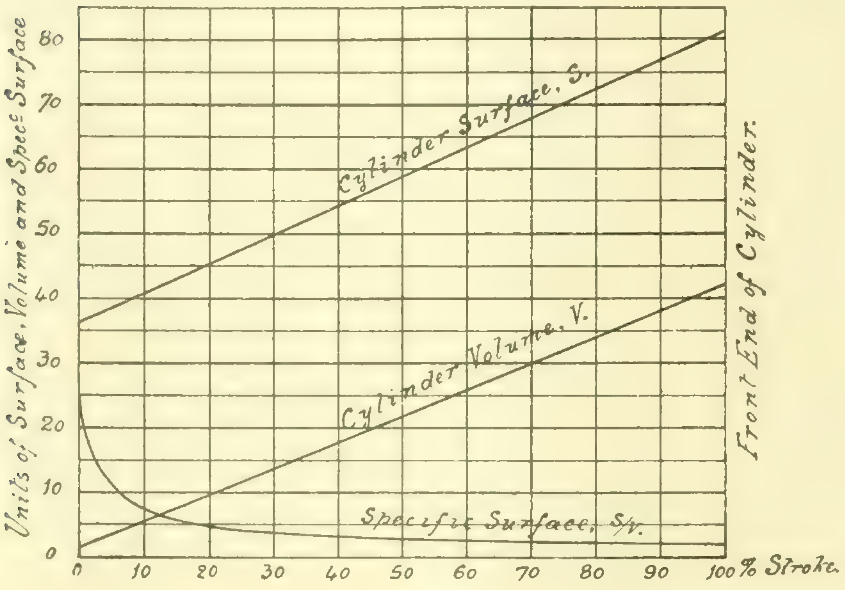


FIG. 5.

closing springs are marked C; the opening springs, the new feature of the design, are lettered O. It will also be observed that both springs of each valve are separately adjustable by means of the nut n and the set-screw S. When properly adjusted these valves are said to work without any noise at all, and with little wear even at from 250 to 300 revs per minute, and with valve lifts of 6 mm. to 8·6 mm.

Through the elimination of exterior gearing it is now possible, with properly designed valves, to couple compressors directly to motors running continuously at from 450 to 600 revs. per minute, whilst for intermittent use they are sometimes run at as much as 800 and even 1,200 revs. per minute with success. If still higher speeds are required, turbo-compressors must be employed. The absence of valves is, of course, a great point in favour of this new type of compressor. With them, however, other troubles are experienced—as, for instance, the heating of the air during compression—which render it difficult to obtain, with turbo-compressors, efficiencies materially better than those attainable with reciprocating machines of modern construction.

Turbo-compressors certainly expose greater surfaces suitable for water jacketing than reciprocating compressors offer, and whilst being compressed in turbo machines the air is distributed along passages and channels of smaller mean depth than those met with in the older type of machine. It appears, therefore, at first sight, that thorough cooling during compression should be an easy matter. Results scarcely confirm such expectation, chiefly, no doubt, in consequence of two peculiarities of turbo-compressors. There are:—

1st. The amount of heat to be dissipated is considerably more than that due to adiabatic compression, as the mechanical energy lost through internal air leakage, unavoidable eddy currents, air impact, and air friction, reappears as heat energy stored mostly in the air itself. Heat is also generated through the resistance opposed by the air to the rotation of the flyer.

2nd. The temperature rise of the air is gradual, consequently the temperature of the air in the early stages of the compression is too little different from that of the atmosphere to enable rapid dissipation through the necessarily somewhat thick cast-iron walls of the housing.

Recapitulating, we can say that since 1882 the rotary speed of compressors has gradually increased from 12 to 1,200 revs. per minute in the case of reciprocating machines, and to 4,000 revs. per minute, and even more, in the case of turbo-compressors. This change has been accompanied, in the case of reciprocating compressors, by continual variation of valve design, so that it is scarcely surprising to find that both manufacturers and users of air-compressing machinery are ready, and even anxious, to give the turbo and other valveless types of compressors a fair chance of demonstrating whether or not they are able to establish themselves as reliable and commercially efficient substitutes for the reciprocating antecedents.

As already stated, heating of the air during compression is a source of waste of energy. A minimum of work is required to accomplish compression when the rise of pressure takes place isothermally, and although, with reciprocating dry compressors, this ideal is unattainable, it is still one after which the designer must necessarily aspire. If we consider each stage of a compound reciprocating air compressor as a distinct unit, it is safe to say that, in practice, compression takes place almost adiabatically. This is on account of the extreme difficulty of extracting from the air the heat generated during compression whilst the air is within the cylinder.

The appended diagram (due to L. Richter), Fig. 5, gives some explanation as to why this is so, especially if it be remembered that air is a very bad conductor of heat, and that cylinder walls are always of considerable thickness (say, at least ½in. thick), and of cast iron. The diagram, which refers to a cylinder 360 mm. in diam. by 400 mm. stroke, shows how the cylinder volume, the internal area of the cylinder, and the ratio of area to volume vary during the stroke.

In consequence of the low mean ratio of area to volume (even without reference to the cycle of thermal conditions) it is difficult to reduce air temperatures within the cylinder below a certain minimum, no matter what quantity of cooling water is passed through the jacket. This statement, as Fig. 6 shows, is supported by test results. The information in question is due to Lebrecht, and the figure records the variation of volumetric efficiency and of final water temperature, when the quantity of water circulated through a cylinder jacket was varied and the other working condi-

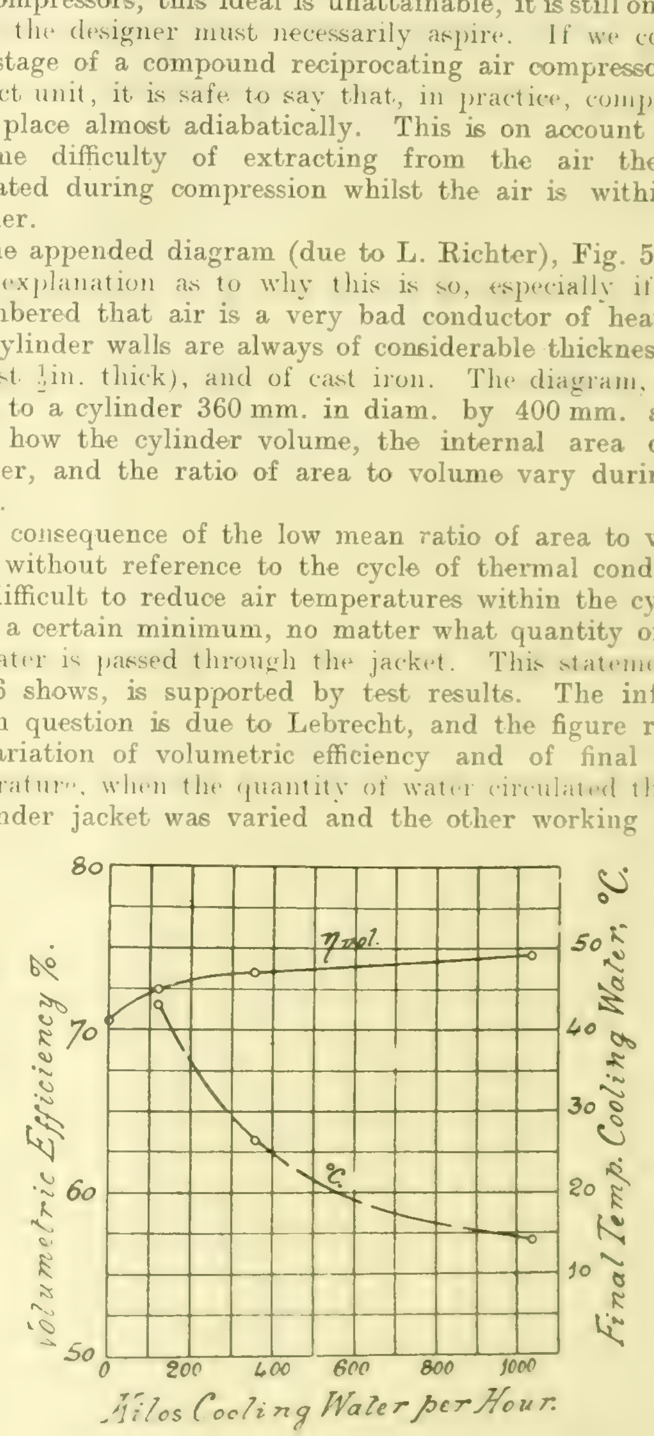


FIG. 6.

tions were maintained constant. It clearly shows how little use it is to increase the amount of circulating water indefinitely. In the case in question the final air pressure was five atmospheres.

H. Wunderlich made a striking experiment which further supports the contention that water jackets are of little value on compressor cylinders. He ran a 1,000 cubic metre per hour compressor firstly with and then without water circulating in the jacket, and recorded only 5°C. higher temperature in the second than in the first case. It is a pity that Mr. Wunderlich did not seem to think the

matter of sufficient interest to warrant his giving further details concerning the tests or the machine used. He does not even state the normal working pressure of the unit.

The volumetric efficiency of compressors was, until quite recently, almost without exception, determined by means of the indicator diagram. Many persons were in the habit of contending that volumetric efficiency was of small or even of no importance. Such, however is far from correct. Messrs. Alley & Maclellan, Ltd., of Glasgow, were, I understand, the first builders of compressors who took the volumetric efficiency of their machines into consideration when rating them. Before the time of this innovation,

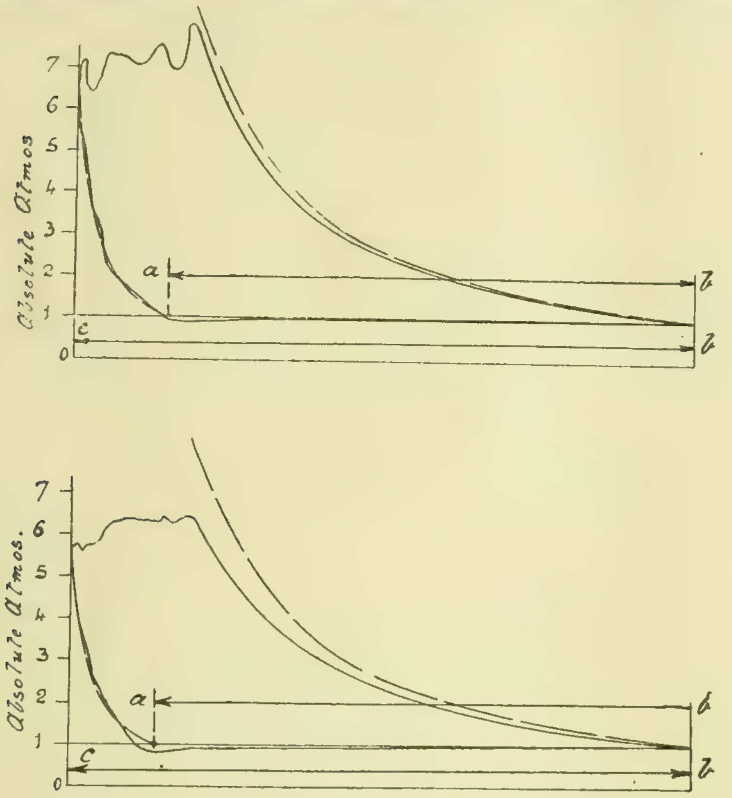


FIG. 7.

compressors were mostly rated by the volume swept by the piston; a method still very prevalent in America. Later it became fashionable to rate compressors by their indicated volumetric efficiency. This method is exceedingly common even now—after the fallacy of the proceeding has been thoroughly recognised. It is highly probably that most builders of compressors mean, when speaking of volumetric efficiency, indicated volumetric efficiency, and that they themselves have but a very rough idea of the true volumetric efficiency of their machines.

How very important careful discrimination is becomes perfectly clear in the light of the indicator diagrams such as the pair reproduced in Fig. 7. Both cards were, according to Lebrecht, taken on the same compressor; the first at a time when it was known to be in good air-tight condition, the second two years later, after the suction valve was known to be leaking. That the working pressure was not in both cases the same, is of no importance, as the adiabatic compression curves and the isothermal expansion curves are in both cases shown by means of broken lines. When the compressor was in good condition the actual compression line ran, as the first diagram indicates, very little below the adiabatic line, and re-expansion took place practically isothermally. The indicated volumetric efficiency was $ab \div cb = 84{\cdot}5$ per cent.; determined by measuring the volume of air delivered, it proved to be but 76·5 per cent. The general run of the card confirms the statement respecting the air-tightness of the machine. The second card indicates that the suction valve was leaking; for not only does the re-expansion line drop too quickly, but the compression line is also too far below the adiabatic. In this case, moreover, the indicated volumetric efficiency was 88 per cent., *i.e.*, considerably better than originally, although actually, as measurements showed, it had decreased to 72 per cent.

Now the common way of expressing the commercial efficiency of an air compressor is to say that for each horse-power absorbed by the compressor, x cubic feet of free air are delivered against a receiver pressure of y pounds per square inch. This expression would leave little to be wished for if the volume of air dealt with were actually measured. When, however, the delivery is determined with the help of the indicator diagram it is, as we see, a very loose expression, because the condition of the machine in respect to air-tightness is entirely neglected.

Volumetric efficiency—both as indicated and as measured—is materially affected by the magnitude of the final air pressure and by the volume of the clearance spaces. Fig. 8 has been plotted to illustrate the action of these factors upon volumetric efficiency as determined by measuring the volume of air delivered. Referring to the figure, it will be seen that the abscissæ represent pressure ratios, *i.e.*, the ratio of the final to the initial pressure, and that the ordinates are percentual volumetric efficiencies. The upper line refers to a compressor with only 0·5 per cent. volumetric clearance. It was a single-acting compressor with a cylinder 220 mm. in diam. by 300 mm. stroke. The tests from which the chart was plotted were made at 106 revs. per minute. The lower line was determined by tests made upon a high speed, single-acting, twin-cylinder compressor. Cylinders 160 mm. in diam. by 65 mm. stroke. Speed: 800 revs. per minute. Clearance volume: 3·5 per cent. of the piston displacement.

It will probably be contended that the curves are not comparable. The following facts, however, adequately deal with any such contention. The single-cylinder compressor was tested by W. Heilemann at three different speeds (50, 80, and 160 revs. per minute), and showed at the highest speed the best volumetric efficiency. This somewhat surprising fact is doubtless due to a reduction of leakage losses by increase of speed. The twin-cylinder compressor experimented upon by Lebrecht was also run at slower speeds, but, as the experimentalist himself observes, "without any improvement of the volumetric efficiency."

In connection with Fig. 7, it was intimated that there is a marked difference between indicated and actual volumetric efficiency. Fig. 9 brings this point into greater prominence. The line Id records the variation of the indicated volumetric efficiency of a double-acting compressor, with changes of pressure ratio. The line Im is a similar record of the actual volumetric efficiency as determined by measuring the volume of air delivered. The compressor in question had a cylinder 260 mm. in diam. and 300 mm. stroke. The valve gear was of a type already referred to, viz., Corliss suction valve and automatic delivery valves. The diagram will doubtless gain in interest by the addition of lines IId and IIm, which record similar information to that embodied in the lines Id and Im, when the same cylinder was fitted with a special Corliss valve having an equalising

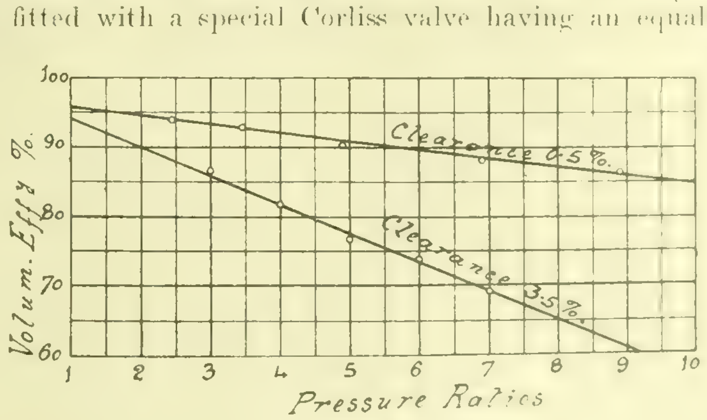


FIG. 8.

port. It will be noticed that not only the volumetric but also the commercial efficiency was materially reduced by this alteration. Curves I and II indicate the extent to which the commercial efficiency was effected; they record the number of cubic metres of free air compressed and delivered per hour for each horse-power indicated in the air cylinder. This last chart demonstrates strikingly that there is no advantage to be gained by using equalising ports, as originally introduced by Weiss for vacuum pumps, in connection with air compressing machinery.

It is impossible, in such a paper as this, to deal fully

with the subjects of compressor design and efficiency. It is hoped, however, that sufficient has been said to awaken interest (1) in air valve design, as upon this detail the mechanical success of the air end of the unit is, to a large extent dependent; (2) in the cooling of air during compression, because high thermal efficiency is certainly unattainable when water-jackets only are used; (3) in the importance of volumetric efficiency, on account of the great effect it has upon the commercial efficiency of air-compressing machinery.

It is the writer's opinion that compressors can be run successfully and with good commercial efficiency at any speed suitable for reciprocating machinery of similar construction, provided always that the valves are of appropriate design, and that the air ports are constructed in such a way as to avoid excessive wire-drawing or too voluminous clearance spaces.

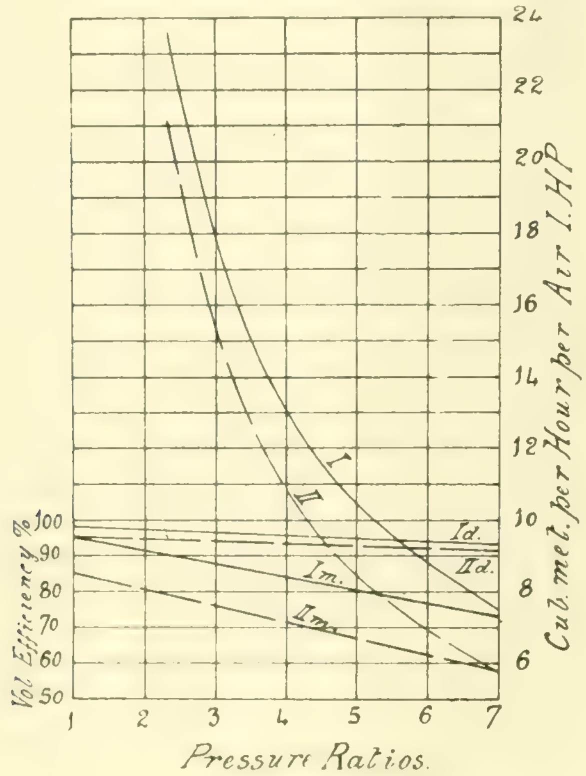


FIG. 9.

TESTING OF MATERIALS OF CONSTRUCTION.

THE Watt anniversary lecture of the Greenock Philosophical Society was delivered on the 18th inst., by Mr. James T. Milton, M.Inst.C.E., chief engineer surveyor to Lloyd's Register. The lecture was devoted to the subject of "The Testing of Materials of Construction," with special reference to mechanical engineering. The importance of systematic testing of materials, he observed, was now more than ever realised. An international association had been established in the hope of attaining international agreement in regard to methods of testing, and an engineering standards committee in this country had successfully standardised specifications and tests of many structural materials. Systematic testing resolved itself directly into two branches; the first might be called scientific, and consisted in the determination of the various properties of different kinds of material; the other was devoted to what might be called commercial or acceptance tests. It was to this latter system that the labours of the Engineering Standards Committee had been directed with such excellent results, their specifications for the acceptance tests of nearly all structural material having been universally accepted in this country.

After reviewing the historical data regarding testing, Mr. Milton went on to define some of the qualities which materials possessed, and referred to the methods of ascertaining them. All the straining actions which came upon constructive material could, he said, be resolved into two kinds, acting either singly or in combination. These were direct stress, whether of tension or compression, and stress of shear or distortion. When either of these stresses was applied to any material deformation took place. If the stress was very low this deformation, called strain, was small, and it was found by experiment to be directly proportionate to the stress. With increasing stress, however, in ductile materials a point was reached at which the strain increased at a greater ratio than the stress, and in very ductile materials a further increase of stress produced an altogether disproportionate increase of deformation. The points at which the strain commenced to increase at a greater ratio than the stress was called the limit of proportionality. Below the limit of proportionality the application of a stress produced the proportionate strain. If the stress was altogether relieved the strain disappeared, and the material returned to its original form and dimensions. If the stress was reduced but not entirely taken off, the strain reduced itself also to the amount which would have been produced by the same stress initially applied. In other words, the material was perfectly elastic. When a stress higher than the limit of elasticity was applied part of the deformation produced was permanent. It was certain that the limit of proportionality and the limit of elasticity, as above defined, did actually fall near together; many considered these points to be coincident. It was argued by many engineers that as the material stressed below the limit of elasticity returned to its original dimensions all its qualities must also be unaltered, and therefore, as one application of a stress within the limit did not affect any of its properties, it must be able to withstand an unlimited number of applications of such stress without injury. It was this view which led to the importance which was attached by some engineers to the inclusion of the determination of the elastic limit in the acceptance tests of materials.

Each kind of material possessed its own peculiar properties of strength, ductility, hardness, &c. All of these, Mr. Milton went on to say, could be measured quantitatively, and when the material was of good quality the various measurements would be found to fall within comparatively narrow maximum and minimum limits. It must be noted that the properties actually determined in acceptance tests of ductile materials not only might be different from those required in the structure, but might be qualities which served no useful purpose. Notable examples could be taken in the case of mild steel. This, when of good quality, subjected to a gradually increasing stress, would yield very considerably before finally giving way. A tensile test would give an extension of from 20 to 30 per cent., and a bend test would deform enormously without breaking. These properties of excessive deformation were, he considered, of no use whatever in actual structures, yet if mild steel did not possess them it was rejected. That structural material could be reliable without excessive ductility was evident when we considered the satisfactory use of cast iron for cylinders and other parts of steam engines. The reason why such excessive ductility was required in the acceptance tests of mild steel was not because it was useful *per se*, but because we knew that good mild steel, while possessing properties which made it a useful constructive material, also possessed this ductility, and that if from any cause its ductility fell below its usual amount then doubts would immediately be raised as to its possessing, in due proportion, all the properties which made it useful and which were actually required. In conclusion, Mr. Milton confidently stated that not only had the systematic testing of the properties of constructional materials largely assisted in the developments of their manufacture, but without it such structures as the Forth Bridge, the Olympia, and Titanic would not have been possible.

Trials of the Destroyer "Archer."—This vessel, one of the five special destroyers under construction for the British Admiralty at the works of Messrs. Yarrow & Co., of Glasgow, had a successful official full-speed trial on the 17th inst. on the Skelmorlie measured mile. Although the weather was exceptionally bad, a speed of 30·3 knots was attained during a continuous run of eight hours. This exceeded the contract speed of 28 knots by 2·3 knots. Throughout the trial the machinery worked perfectly. The special feature of interest is the boiler installation, the boilers being fitted with Yarrow's patent system of superheating. The average superheat during the trial was 94° Fah., from which a very appreciable gain in economy was obtained.

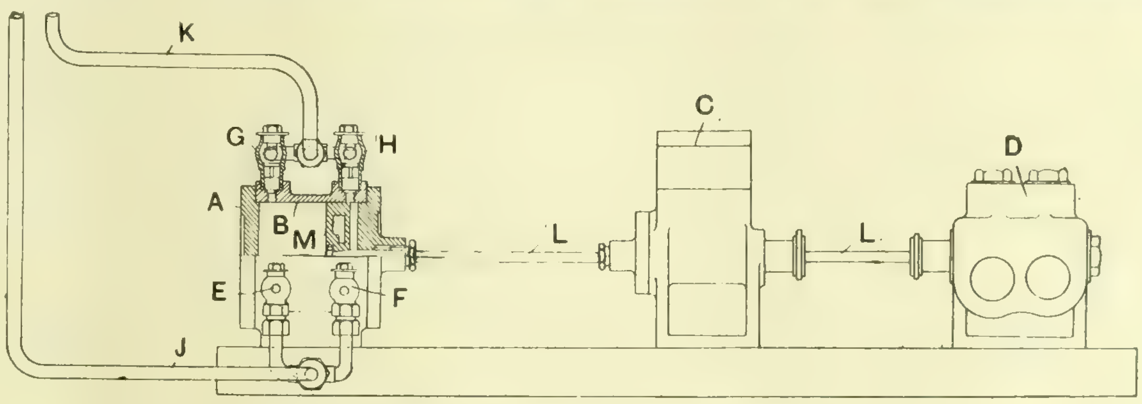
WATER-LEVEL REGULATOR FOR STEAM BOILERS.

For the purpose of controlling the supply of feed water to boilers a number of arrangements have from time to time been proposed. In one arrangement the lower end of the cylinder of a plunger donkey pump is placed below the highest water level and is supplied from the boiler through a pipe connected to it at the highest permissible water level, so that when the water in the boiler rises to or above this level, water enters the annular space of the cylinder and drives the plunger upwards instead of steam, the water being forced back into the boiler through a restricted passage, whereby the speed of the pump is reduced. In another arrangement a separate special cylinder is placed below the highest water level, the piston of which is actuated by the feed pump, and connected at both ends to the boiler at the highest water level, so that when water flows into the cylinder the speed is reduced. These arrangements have the disadvantage that the cylinder is not emptied of the water when the level in the boiler falls again. To obviate this disadvantage other devices for controlling the water level have been proposed, in which a horizontal cylinder provided with a piston actuated by the boiler feed pump and placed at the highest water level is connected at the top to the steam space and at the bottom to the water space of the boiler at or about the middle of the length of the cylinder, so that when the water in the boiler rises above this level, water rises also into the cylinder, and being trapped by the piston at one or both ends of the cylinder, is either forced from one end to the other through a restricted passage, whereby the speed of the feed pump is retarded, or forced into an accumulator, the rise of whose piston controls the water supply to the feed pump. Or the piston is entirely arrested by the trapped water and the feed-water supply to the pump shut off, a spring being arranged in the mechanism transmitting motion to the piston to allow its stoppage without arresting the donkey pump. The regulator cylinder empties itself of water by gravity when the water level in the boiler sinks. Now the arrangement of the regulating cylinder at the highest water level is in most cases inconvenient, and particularly so when it is to be actuated directly by the piston rod of a steam pump without a crank shaft, and the use of such regulators has therefore been greatly restricted.

This objection is, it is claimed, overcome by the arrangement illustrated, the joint invention of John G. A. Kitchen, 7, Rose Bank, Scotforth, Lancaster, and Isaac H. Storey, which consists in so placing the regulating cylinder that when the water in the boiler rises above the highest level it is sucked into the cylinder through a free-lifting or self-closing valve or valves and forced back into the boiler through a non-return valve and restricted passage, whereby the speed of the feed pump is retarded if it is of the crankless type, or its stroke is reduced if actuated from a rotary steam engine, the motion being transmitted to the regulator piston through springs in that case. With this arrangement of the regulator it may be placed as desired below, or at some distance above, the highest water level in the boiler, and the cylinder is emptied of water when the level in the boiler falls again.

Referring to the illustration, the regulator consists of a double-acting piston pump when the boiler feed pump is a double-acting steam pump, and a plunger pump when the feed pump is single acting, so as to equalise the work of the feed pump to some extent by arranging the regulating plunger pump so that it makes its outward stroke during the forcing stroke of the feed pump and its inward stroke during the suction stroke of the feed pump. This arrangement is also used where the water is very dirty and has a lot of scum. The regulator pump A is a double-acting piston pump consisting of a cylinder B with inlet clack valves E and F and outlet valves G and H. The inlet valves are connected to the pipe J which is in open communication with the steam boiler at the water level, and the outlet valves are connected to the pipe K which is in open connection with the boiler either on the same level as the pipe J or slightly above it. C is the steam cylinder of a Worthington or similar pump and D the feed pump actuated by it. The piston rod L of the steam pump is prolonged through the cover of the same and the piston M of the regulator pump is fixed to it. The pipes J and K and the valves are of a small diameter, and means may be provided for limiting the lift of the outlet valves G and H, or a cock or valve for restricting the bore of the pipe K may be arranged.

As long as the water level in the boiler is below the pipe J the regulator pump will draw in and expel steam only, which will offer no resistance or only a very slight one to the movement of the piston, and the steam pump C D will work at its normal speed and deliver the maximum quantity of water required to the boiler. If the consumption of steam from the boiler is reduced or stopped, the water will gradually rise, and as soon as it reaches the pipe J a little water will be drawn into the regulator cylinder along with steam, and as this water is expelled at the end of the stroke, the small openings of the delivery valves will offer additional resistance to its discharge, so that the speed of the feed pump piston will be reduced towards the ends of the strokes. As the water level rises a little higher, more water will be drawn into the regulator pump and the retarding effect will be extended for the greater part of the stroke, till, with a further small rise in the water level of the boiler, water only will be drawn in, and the retarding effect extended over the entire stroke. By limiting the openings of the delivery valves G and H the resistance of the outlets to the flow of water can be made so great that it and the resistance of the feed pump piston almost equal the steam pressure on the piston of the cylinder C, so that the pump almost comes to a standstill and the feed-water supply to the boiler is virtually stopped. If the steam consumption is increased again, or steam blown off through the safety valve, the water level in the boiler will fall again and the pipe J will become uncovered, so that some steam and less water will be drawn into the regulator pump A and finally steam only, so that the water will be cleared out again and only steam pass into the regulator, and the feed pump will resume its normal speed. When the regulator pump is placed above the water level the pipe J will be connected to the boiler a little below the highest water level so as to be entirely covered when the water rises to this level, as the regulator pump will draw water only after the pipe has been entirely covered.



WATER-LEVEL REGULATOR FOR STEAM BOILERS.

With the arrangement described, the stroke of the feed pump remains unaltered, but the number of strokes per minute is reduced. Where the feed pump is actuated from a continuously-rotating engine, the number of strokes made by it per minute will remain constant. In such cases a modified form of regulator is used, by means of which the length of the stroke of the feed pump is reduced.

Grimethorpe Colliery Boiler Explosion.—The formal investigation ordered by the Board of Trade to be held in this matter is fixed for hearing in the Council Room, Town Hall, Barnsley, on Tuesday, the 6th proximo, at 11 a.m.

The Institution of Mining and Metallurgy.—The council have accepted, on behalf of the Institution, an invitation from the Canadian Mining Institute to hold a joint meeting in Canada early in 1912. The meeting, for the reading and discussion of papers, &c., will occupy three days—Wednesday, Thursday, and Friday, March 6th, 7th, and 8th, 1912.

THE CORROSION OF CONDENSER TUBES BY CONTACT WITH ELECTRO-NEGATIVE SUBSTANCES.*

BY ARNOLD PHILIP, B.SC., A.M.I.E.E., ASSOC.R.S.M.

ALL condenser tubes through or round which sea water flows are corroded, but the nature of this corrosion varies very greatly. By far the greater number of such tubes are merely uniformly corroded over as much of their surface as is exposed to salt water. It is not, however, with cases of corrosion of this uniform character that it is proposed to deal here. A certain small number of tubes, besides the uniform corrosion of their surface on the sea-water side, also undergo a local corrosion or pitting. The general uniform surface corrosion, although doubtless undesirable, is comparatively harmless. It is the local corrosion or pitting which is the cause of trouble to the engineer. The following remarks must be understood as applying specially to the relatively small number of cases in which localised corrosion occurs in condenser tubes made of Admiralty composition, namely, copper 70, tin 1, and zinc 29 parts per cent.

Within the last eighteen months, owing to the fact that the Corrosion Committee of this Institute decided to examine as a first step in their investigations the question of the corrosion of condenser tubes by sea water, a good deal more attention has been given to this particular form of corrosion by the general technical public than had previously been the case. Nevertheless, it must not be forgotten that a very considerable amount of knowledge had already been accumulated by those whose duty it had been to deal practically with machinery involving the use of sea-water condensers, and it is the author's opinion that the cause for fully 90 per cent. of the cases of corrosion observed in the establishments of the Royal Navy has long been known, and the methods of overcoming or neutralising such corrosive action have also been experimented with, and that very effective protective devices have been employed for a long time back. It is, however, conceivable that more satisfactory preventive methods may be devised in the future, and it is to this end that the investigations of the Corrosion Committee will no doubt be largely directed.

In the author's opinion, then, the main problems which remain to be solved concerning localised condenser-tube corrosion are, firstly, the explanation of the cause of rather less than 10 per cent. of the small number of cases which are now observed; and, secondly, the device of a general means of preventing these and all other cases of corrosion superior to the method of protector bars, &c., of zinc, aluminium, steel, or iron, as at present employed.

The 10 per cent. of the total cases of observed corrosion referred to above is considered to be rather an excessive estimate of the number which are found to be obscure in origin, and whose occurrence cannot be readily assigned to one of the more usual causes of corrosion. There are several reasons for this opinion, and among them is the difficulty of obtaining full and reliable information concerning the natural history of the occurrence. The necessarily high pressure under which engineering duties are normally carried out renders it always difficult and sometimes impossible to fully state all the observable conditions under which a particular case of corrosion has occurred, and the omission of such details, it is considered, frequently cause such a case of corrosion to be classed as one of the 10 per cent. of obscure cases, whereas it should actually be classed amongst those whose origin is known.

It is the engineers, who are actually responsible for the efficiency and maintenance of condensers, who are able to provide the necessary information upon which an opinion can be formed as to the causes of observed cases of corrosion. In order to secure that such information is not overlooked at the time, it is very desirable that a suitable schedule of queries should be filled in. This course was proposed by the author in the discussion on Admiral Corner's paper† at the annual general meeting of the Institute held in January, 1911, and he is glad to understand that this proposal is now to be actually taken up. A copy of such a schedule of queries as used in the past by the author, and as revised in February, 1910, may be of some interest at the present moment, and is therefore given *in extenso*:—

FORM OF SCHEDULE OF PARTICULARS TO BE FURNISHED WHEN THE STATE OF ANY CONDENSER IN WHICH CORROSION IS SUSPECTED IS REPORTED UPON.

As far as possible the following particulars should be given:—

1. Name of ship or establishment.
2. Date of examination.
3. Nature of cooling water (fresh, salt, or brackish).
4. Does cooling water flow inside or outside tubes?
5. Date at which tubes were first installed.
6. Has condenser been continuously in use?
7. If not continually in use, state, if possible, the approximate total periods of use and disuse.
8. When condenser is not in use, has it been the custom to leave the cooling water in the condenser or to drain it off?
9. If water is drained off, are tubes dried by steaming?
10. Are condenser tubes horizontal or vertical?
11. Nature of metal casing (iron, steel, gun-metal, &c.).
12. Nature of ends of casing or doors if of different material from body.
13. Nature of metal of tube plates.
14. Method of securing tubes in tube plates; are they in metallic contact?
15. Total number of tubes in condenser.
16. Total number of leaky tubes.
17. Length of tubes.
18. Thickness of walls of tubes.
19. If protector bars or plates are used, of what metal are they?
20. How are protector bars fitted, if used?
21. Transverse and longitudinal sketch diagrams of the paths of the condenser water through the condenser should be given, and the points of entry and exit of the water in the tubes should be clearly marked, as also the points of corrosion.

Note.—When it is desired to remove faulty condenser tubes from a condenser for examination, it is desirable that before the tubes are loosened the ends shall be so marked as to show clearly which is the lower side, and also to indicate the end at which the cooling water or (steam) enters.

After marking and withdrawing the tubes they should, if possible, be forwarded for examination, without further cutting or other mechanical damage. If it becomes necessary for the purpose of inspection or packing to cut a tube, the cutting should be carried out without the use of any lubricant.

It may be found desirable to enlarge the above schedule after further experience has been gained in its use, and suggestions in this direction, especially such as have been arrived at as the result of practical experience, are invited.

Notwithstanding the attention which has been concentrated by the Admiralty upon the question of the corrosion of the condenser tube, it must be remarked that the actual percentage of tubes in which this localised corrosion or pitting has been observed is extremely small. In short, one of the chief difficulties in studying the behaviour of condenser tubes under corrosion is due to the fact that the corrosion so seldom appears. In spite of the fact that some millions of tubes are in use in the Royal Navy at any given moment, the number of cases as coming under the notice of the author, in which localised corrosion has been observed, do not at present amount at the most to more than about two per annum. This freedom from corrosion must, it is considered, be attributed to three causes: Firstly, to the particular chemical composition of the metal which has been selected for the manufacture of tubes. Secondly, to the very satisfactory manner in which tube manufacturers are able to produce tubes of the exact chemical composition specified. (In this connection it may be stated that during the past ten years only one case is known to the author in which the chemical composition of a corroded tube could in any way be considered as not satisfying the specified limits, and in that particular case the 1 per cent. of tin had been omitted from the mixture.) The third cause to which the freedom of corrosion of the condenser tubes used in H.M. service is to be attributed is undoubtedly the consistent manner in which the use of steel, iron, or zinc protector slabs and bars, &c., has always been insisted upon.

* [illegible], January [illegible], 1912.

† [illegible] Vol. XXXVII.

The protective action of iron and zinc in condensers in H.M. service has been made use of in several forms. It was originally used in condensers in which the body was of cast or wrought iron, and the sea water passed outside the tubes, and was therefore at the same time in direct contact with the outside of the metal condenser tubes and the inside of the iron case. Under these circumstances the protection was very complete, and whilst corrosion of the steel or iron casing took place, the corrosion of the tubes was practically unknown. A particular and remarkable case in which this protective action of a cast-iron casing has been very clearly demonstrated is that described by Admiral J. T. Corner.* Steel or zinc protector slabs and bars have been used attached inside the condenser doors, or on the tube plates themselves, or some of the tubes of the condenser have been replaced by iron or steel or even zinc rods, whilst in some condensers, built about four years ago, the bodies have been of metal of a composition closely approximating to that of the tubes, and the doors have been made of iron or steel. More recently condensers have been made with steel bodies.

The presence of a so-called electro-positive protective metal such as aluminium, zinc, or iron, is not, however, alone sufficient to prevent the corrosion of the condenser tubes immersed in the same bath of sea water. It is essential that there shall be a direct electrically conducting connection between the tubes and the protecting metal or metals, and that the protector metal and the condenser tubes shall be both immersed in the same electrolyte. It has been shown again and again that any want of a good electrical connection renders the protective action of the iron, steel, or zinc upon the condenser tubes quite nugatory. Where, however, the contacts of the protective metal with the tubes are satisfactory, corrosion does not occur.

Some facts concerning the usual length of life of main condenser tubes in H.M. service may be of interest. The ordinary normal length of life for the main condenser tubes of a battleship should be from 10 to 12 years, and many such cases can be cited. Taking four first-class battle-ships, A, B, C, and D. These ships were attached to one port from 1897 to 1906, and during that period none of the main condensers was retubed except in D. In this particular case of the ship D, the main condensers were retubed in 1903, and again in 1909, but this was a special case; the necessity for retubing was not due to corrosion, but, the tubes being slack in the diaphragm plates, the vibration gradually caused the tubes to be cut through. In the case of the ship B, some trouble was experienced in 1899, but on fitting additional protectors this was remedied, and as far as is known the condensers have not been entirely retubed to the present date—that is, 13 years.

The first-class twin screw armoured cruiser of over 14,000 tons denoted by E recently had her condenser tubes examined, and they were found in good condition after having been in use for eight years. They were all replaced in the condenser after examination, and it is expected that they will last at least another three to four years. A first-class battle-ship F, built and put into commission four years ago, recently had her main condenser tubes drawn and examined, and these were all found in excellent preservation, with no trace of local corrosion; all the tubes were replaced.

There are, however, cases when condenser tubes have often been found to require renewal, and in certain ships it has been necessary to renew the whole or part of the tubes after two years' service, or even less. In all such cases—and they are very rare—which have come under the author's notice, the trouble which had occurred was clearly shown to be due to the unsatisfactory character of the metal connection between the tubes and the protector bars.

A further peculiarity of the small number of these cases in which corroded condenser tubes have been observed is the fact that in almost all the tubes the corrosion has occurred along the bottom of the inside of the tubes, and it is considered that this indicates that the trouble has been set up by the contact of particles of coke, carbon, or ferric oxide, or other conducting electro-negative solid materials deposited from the cooling water upon the inside bottom surfaces of the tubes setting up local galvanic action. Such action is, of course, increased when a condenser is not in use and the tubes remain full of sea water, for the particles then have time to settle out along the bottom line and give rise to the localised corrosion.

* "Journal of the Institute of Metals," No. 1, 1911, Vol. V., p. 119.

If, on the other hand, the condenser is emptied of sea water when out of use, there would again appear to be a possible source of danger of corrosion along the bottom inside surface of the tubes, owing to the fact that this portion would be longest exposed to the joint action of salt water and air.

In either method of treatment, however, it is considered that these causes of corrosion could be minimised or altogether removed if it were found to be at all feasible to employ condensers with vertical or strongly inclined tubes, and if every precaution were observed, to take up the cooling water from such positions as will give the least chance of ashes from the ash ejector, &c., being carried into the tubes.

The following five cases of corrosion of condenser tubes are all that have come under the author's own observation during the past three years, and in only one of these—Case I.—it is not possible to ascribe the corrosion to the contact of particles of electro-negative solid conducting material. It must be remembered that the following particulars do not apply to the whole of the Navy, but only to such cases as happened to come directly under the author's own observation; but in this respect, as most cases in which corrosion occurs, the precise causes of which are not at once apparent, are referred to him for investigation, it is probable that his experience errs on the side of having been too largely drawn from the class of less satisfactory tubes.

CASE I.—ELECTRO-GENERATING STATION CONDENSERS.

Result of analyses of five corroded condenser tubes:

	Per Cent.
Copper	70·95 to 71·8
Tin	0·96 to 0·98
Lead	0·32 to 0·44
Zinc	By difference.

Circulating Water.—Sea water which analysis showed to be of normal composition.

Casing.—Gun-metal.

Protectors.—Zinc bars used. It was remarked that these protectors only corroded very slowly.

Remarks.—The tubes had been drawn without any note being kept as to their position, and it could not be definitely ascertained as to whether the corrosion had occurred along the bottom inside surfaces or not.

It was considered evident that the corrosion had been due to the faulty connection between the tubes and the zinc protectors which had been very little acted upon.

CASE II.—BATTLE-SHIP'S CONDENSERS.

Result of the analyses of ten corroded tubes:—

	Per Cent.
Copper	69·8 to 71·2
Tin	0·92 to 1·30
Lead	0·25 to 1·30
Zinc	By difference.

Circulating Water.—Sea water.

Casing.—Gun-metal.

Protectors.—Steel plates.

Remarks.— Out of 32 tubes drawn at one examination, 10 were partially corroded, and in nine of these the corrosion had taken place on the lower inside surface of the tubes, whilst in the remaining one it had occurred at the top. Twenty-two of the tubes examined were quite uncorroded.

CASE III.—ELECTRO-GENERATING STATION CONDENSERS.

Composition of Tubes. — Eight corroded tubes were analysed with the following results:—

	Per Cent.
Copper	70·90 to 71·05
Tin	0·95 to 1·09
Lead	0·20 to 0·33
Iron	0·05 to 0·08
Zinc	By difference.

Circulating Water.—Sea water which analysis showed to be of normal composition.

Casing.— Gun-metal.

Protectors.— Steel plates.

Remarks.—In every corroded tube the corrosion occurred along the bottom inside surface on the sea water side. The tubes were horizontal, and the axes of the corrosion pits were in every case greatest along the length of the tubes.

The corrosion was more marked at the ends of the tubes where the cooling water entered, and was almost all within the first two-thirds of the length of the tube. Corroded tubes

appeared in three out of six condensers, and the three which were free from corrosion were those that had been most constantly in use. In one of the condensers in which corroded tubes were observed, all the corroded tubes were situated in the lower half of the condenser, *i.e.*, near where the cooling water entered, and most were in the very lowest tubes. In the second condenser in which corroded tubes were observed three-quarters of the corroded tubes were found in the bottom half of the condenser, and most of these were in the lowest seven rows. The cooling water used, although sea water of normal composition, was liable to contain particles of coal-dust, and it is to the action of this material that the corrosion is attributed.

Case IV.—Electro-generating Station Condensers.

Composition of Tubes.—Satisfactory Admiralty composition.

Circulating Water.—Sea water which analysis showed to be of normal composition.

Casing.—Wrought iron.

Protectors.—Zinc plates.

Remarks.—The corroded tubes are distributed fairly equally over the whole of the condenser, but the corrosion in each case occurs mainly along the bottom of each tube and throughout the length of the tube.

Case V.—Torpedo-boat Condenser.

Composition of Tubes.—Satisfactory Admiralty composition.

Circulating Water.—Sea water.

Casing.—Cast brass.

Protectors.—Steel slabs.

Remarks.—The corrosion is most marked along the bottom inside surfaces of the tubes.

PECULIARITIES OF ALUMINIUM CASTINGS.

By J. B. Thurman.

While the average designer is usually more or less familiar with the practical work of the machine shops, it is rare that he is also a foundry expert and acquainted with the problems met there. Obviously, then, his first duty is to get in touch with the patternmaker and foundry, where it is possible, and learn for himself the conditions under which the results of his work are to be produced. A little time devoted to this one thing will often prevent unnecessary delay, extra labour and cost, together with the worry so caused. An authority has said that fully 50 per cent. of the failures in aluminium castings made from the number of moulds set up may be traced directly to the designer, and another 25 per cent. to the patternmaker. This is probably due to the fact that aluminium possesses certain physical properties, such as its exceptionally high contraction and weakness just after solidification, that are not always allowed for in the design.

All castings are liable to defects due to blowholes, shrinkage, or contraction. Many designers seem unable to grasp the idea that the last two expressions refer to two distinct changes of a metal in its heated state, but the same is true nevertheless. For instance, as soon as aluminium is poured into a mould the metal begins to set, and as a result shrinks. There is, however, a certain point at which it ceases to shrink, and settles into a solid state. During the cooling process that follows, the metal gradually contracts, and it is while this physical change is taking place that ruptures occur between different sections imperfectly proportioned in regard to each other. Were it always practicable to have the heaviest portion of the casting uppermost, it is quite possible that because of its accessibility for feeding, unsound castings would be as rare as they are now frequent.

Now, it is by no means possible to attain soundness in all kinds of castings by the means just quoted. There are many moulds in which such a procedure would not be practicable. The prospective designer can find no better school for studying defects in castings than the scrap pile. There one may find shrinkage and blowholes in all forms, and fillets that were intended to add strength that have instead weakened the castings. Nearly all castings are more or less filleted, and it is a mistaken idea that the larger the fillet the stronger the casting. In those cases where the fillet is fed by metal contained in other bodies than its own, the above may be true with regard to strength, but they are many times so situated that they cannot be fed by any other metal than that contained in their own bodies, and as a result castings are weakened at the intersection of two parts. The strains which the different parts of a casting will have to stand should not always be the basis upon which to rest the proportions, for it is better to increase the thickness of respective parts in excess of what strength is actually required than subject the metal to the possibility of "draw-holes," due to an unequal thickness of parts. All these are points for the designer and patternmaker to bear in mind.

In foundry practice there is scarcely any other factor that will affect the condition of a casting more than the temperature at which the metal is poured. The speed of crystallisation is governed by this consideration alone. The cooler a metal can be poured into a mould the more quickly it solidifies, and the crystals have less time to arrange themselves. The result will be a strong, fine-grained casting. The lowest temperature at which aluminium, or for that matter any metal, can be poured, is that at which the metal will run perfectly into the finest part of the mould. If the thinner parts are so designed that the metal must be poured at extreme temperatures, the longer it will take for the thicker portions to solidify, and the weaker the parts will be, owing to a coarser crystallisation.

By increasing the size of the lighter parts so that the metal can be poured 100° cooler, at least 10 per cent. may be added to the strength of the whole casting. Here again it is for the designer to decide if this may be done without doing more harm than good. This is a vital point. Incidentally the weight of aluminium may be taken at 162lbs. to the cubic foot. To obtain, however, the most reliable data for any special class of work, it is necessary to pour a number of test pieces under various conditions, and adopt that system which the result proves to be most adaptable to the requirement desired.

Great care and considerable skill are required to set cores properly in a mould. Lack of proper bearing surfaces causes them to float and shift frequently, and is often the result of defective castings, especially if the cores are small and under a heavy head of metal. Large cores should be made hard enough to allow them to be handled freely, and should be made solid and reinforced with iron rods and wires. This makes them hard to crush, but incidentally the compressive force exerted by a large core upon a thin metal surface is liable to produce cracks in that surface, and the addition of one more piece to the scrap-heap. It is almost impossible to use any large core in connection with a thin section of casting in a complex mould without avoiding the great compressive stress thus developed.

It is therefore essential that coreprints be made large and deep, giving a strong anchorage, to hold the cores in the required position without the use of chaplets. It is impossible, without pouring the metal at an excessively high temperature, to fuse the chaplets into the body of the casting. Where a dry-sand core will frequently cause a casting to crack a green-sand core will crush and give way during the cooling process, which is just as bad; but the use of green-sand cores promotes cheapness of output, as well as convenience and ease in working. Where many small castings of a given kind are to be made, it is cheaper and better to have both the pattern and core made of metal, since they neither warp nor crack, as is so often the case with wooden patterns.

For the various purposes to which the aluminium castings are put there is the choice of using practically three alloys. Common alloys are made with from 2 to 12 per cent. copper. But from these the trade at large has designated three for standard use. No. 1 is made with 8 per cent. copper, No. 2 with 3 per cent. copper and 15 per cent. zinc, and No. 3 with 35 per cent. zinc. These alloys are remarkable for their strength, malleability, and ductility. Test bars made from the foregoing alloys show a tensile strength per square inch as follows: No. 1, 18,000lbs.; No. 2, 22,000lbs.; and No. 3, 35,000lbs. respectively. Nine-tenths of the automobile castings that are made from aluminium are composed of alloy No. 1. The reason for this is that where

aluminium is used, lightness is the factor usually sought for, and while No. 1 is considerably weaker than the other two, it is also much lighter. No. 2 is about 7 per cent. heavier than No. 1, while No. 3 is 18 per cent. heavier than the zinc alloy. Zinc-contained alloys are more subject to shrinkage strains than those alloys containing copper, and deteriorate more rapidly with increased temperature. The absence of these strains, lessening the possibility of cracks due to vibratory stress, together with its lighter weight, renders No. 1 particularly applicable to use in automobiles, aeroplanes, and similar machines.

Other aluminium alloys, such as aluminium bronze, aluminium brass, silicon and iron, antimony, tin, and tungsten, are used for various purposes. Aluminium bronze is an alloy composed of 10 per cent. of aluminium and 90 per cent. copper, and comprises many characteristics that distinguish it from all other alloys. The tensile strength of casting made from this alloy runs from 75,000lbs. to 90,000lbs. to the square inch, and from 4 to 14 per cent. elongation. Brittle alloys are produced by increasing the proportion of aluminium beyond 11 per cent., and therefore no alloys are made for standard use containing more than this quantity. Other standard grades contain, $1\frac{1}{4}$, $2\frac{1}{2}$, 5, and $7\frac{1}{2}$ per cent. respectively, their tenacity varying from 25,000lbs. in the first to 65,000lbs. in the last named, the torsional strength, elastic limit, and resistance to compression decreasing proportionately. The following table shows the result of tests of aluminium bronzes:—

Tensile Strength.

Aluminium per Cent.	Tons per Sq. In.	Lb. per Sq. In.	Elongation per Cent.	Specific Gravity.
11	40 to 45	89,600 to 100,800	8	7·23
10	33 „ 40	73,920 „ 89,600	14	7·69
$7\frac{1}{2}$	25 „ 30	56,000 „ 67,200	40	8·00
$5-5\frac{1}{2}$	15 „ 18	33,600 „ 40,320	40	8·37
$2\frac{1}{2}$	13 „ 15	29,120 „ 33,600	50	8·69
$1\frac{1}{4}$	11 „ 13	24,640 „ 29,120	55	—

Recent tests have shown that the use of too high a percentage of zinc in aluminium is likely to produce brittleness to such an extent as to seriously affect the alloy. With the increase of zinc the susceptibility to shocks and violent vibration becomes greater, and as a result the automobile trade have gradually been replacing castings containing this metal with those made from alloy No. 1. But no matter what changes are made, much depends on the designer, and he must decide which of the three alloys is best adapted to the castings he has in mind. If he will constantly keep before him the oddities of the metal he proposes to use he will avoid, as far as possible, complicated cores and sections of unusual thinness. If, in other words, he will use plain common-sense in the design of his machines, there is absolutely no reason why he should not get from aluminium suitable castings. Without these requirements all the art of the patternmaker and founder will prove useless, and no matter how perfect the conditions under which the castings are made, the result will prove abortive and the time be wasted.—" Southern Machinery."

Petrol - propelled Tramcars.—The first petrol-propelled tramcar used in England on a track was inaugurated at Morecambe on the 15th inst. The car, which has been built by Leyland Motors, Ltd., has a total length, over the collision fenders, of 31ft., a width over all of 7ft. 7in., and a total height of 10ft. $1\frac{1}{2}$in. The gauge is 4ft. $8\frac{1}{2}$in., and the wheel base 8ft. The total weight of the complete car is 7 tons 5 cwts. The engines are capable of developing 55 h.p. Transmission is from a 4-speed gear box through universal joints to a gear case on one of the axles. The two axles are connected together by a roller chain. The axle gear case contains heavy spur and bevel gears, and reverse gear, the whole running in oil on ball bearings. The car is completely controlled by the driver from either end at will. The car is lighted by electricity. Approximately, the cost of the new car, which is a single decker, has been £1,050. It is estimated that the cost of fuel will run out at one penny per car mile.

THE MODERN APPLICATIONS OF ELECTRICITY.

At a meeting of the Royal Scottish Society of Arts held at Edinburgh on the 15th inst., Mr. C. N. Kemp, B.Sc., delivered a lecture on " The Modern Applications of Electricity." The dawn of the electric age, he said, might be assigned to the last quarter of the 19th century. In 1881 in Paris, and in 1882 in the Crystal Palace, London, great electrical exhibitions were held, at both of which there were brilliant displays of arc and incandescent electric lighting. The hitherto supreme position held by gas as an illuminant was seriously menaced, but received a new impetus through the invention of the Welsbach incandescent mantle, which enabled from 10 to 20 times the former amount of light to be obtained for the same consumption of gas, and soon the further important improvements in high and low-pressure gas lighting in turn threatened the carbon filament electric lamp with extinction. Early in the 20th century, however, the invention of the metal filament electric lamp enabled more efficient lighting to be obtained at about one-third of its former cost, and now the position of incandescent electric lighting appeared unassailable, as economy was combined with its many other unique advantages. The improvements in electric generators and in arc lighting were soon followed by the discovery of the possibilities of the electric furnace and of electrolytic methods of manufacture. To the electric furnace they owed, among other substances, calcium carbide, now indispensable to the motorist; silica ware, which was taking the place of the costly platinum vessels formerly used; and carborundum, the valuable abrasive, exceeded in hardness only by the diamond. During the last decade of the 19th century, in which the electrolytic manufacture of aluminium was fully established, the world's production increased from approximately 200 tons to over 7,000 tons, and aluminium had become a formidable rival to copper in its applications to the electrical industry, for overhead and other power transmission lines, and in electric power stations. The enormous value of that marvellous invention, wireless telegraphy, would be appreciated when it was stated on the authority of " The Marconigraph " that a recent estimate proved that at least 3,000 persons owed their lives directly to wireless telegraphy. Wireless signals had been received by Mr. Marconi up to 6,000 miles, and communication had been effected with both aeroplanes and submarines. A further important recent application was the distribution of wireless time signals, enabling ships at sea to ascertain their longitude with a hitherto undreamt of accuracy. Similar signals were used to mitigate the dangers of fogs. They owed so much to the inventive genius of Edison that it was no surprise to learn that he had recently perfected an entirely new form of storage battery, as the result of nine years of patient labour and research. In the Edison cell lead plates and sulphuric acid gave place to nickel and iron plates with an electrolyte of caustic potash solution, and it was claimed among other points that for cells of equal capacity the nickel type weighed about half as much as a lead cell and was of superior durability. In addition, the Edison cell might be completely discharged or short-circuited without damage. That form of battery would seem to open out a new future for electric carriages.

Personal.—The executive committee of the governing body of the Imperial College of Science and Technology have appointed Prof. W. A. Bone, D.Sc., Ph.D., F.R.S., of Leeds University, Professor of Fuel and Refractory Materials in connection with a new department of Applied Chemistry, or Chemical Technology, now being established in the Imperial College at South Kensington. Mr. Edward C. Ibbotson has been elected secretary of the Sheffield Society of Engineers and Metallurgists, in succession to Mr. F. K. Knowles, who, after holding the office for some 20 years, has retired in consequence of his new duties in the metallurgical department of the University. Prof. Arnold, D.Met., of the Applied Science Department of the Sheffield University, has, we understand, been appointed by the Board of Education to the post of Government Examiner in Metallurgy. This will not interfere with his work in Sheffield.

MISCELLANEA.

Automatic Reversible Battery Boosters.—At a recent meeting of the Scottish local section of the Institution of Electrical Engineers held at Glasgow, Mr. Robert Rankin read a paper on "Automatic Reversible Battery Boosters." He classified boosters under three leading divisions, describing the different types in each division, and comparing their merits, and spoke of the methods of using the various systems and their applications to load equalisation under various circumstances. He also described the method of using externally regulated boosters on alternating-current systems and some of the auxiliary pieces of apparatus used to effect control. Practical results from installations of different kinds were given. The paper was illustrated with charts exhibiting the results obtained by the best types.

Estimation of Free Sulphur. — At a meeting of the London section of the Society of Chemical Industry Mr. C. Davis and Mr. J. L. Foucar described a rapid volumetric method for the estimation of free sulphur in spent oxide, more especially that containing small quantities of organic matter soluble in the usual organic solvents. In the estimation of sulphur in the latter material too high results are obviously given by the extraction test and an oxidation test is somewhat tedious. The method proposed was to treat the finely powdered and dried material with a solution of sodium cyanide in absolute alcohol, the resulting sulphocyanide being titrated in the usual way. The results obtained are said to be quite sufficiently accurate for commercial purposes.

Formula for Browning Steel Articles.—The standard formula of the United States Government for use in browning gun-barrels and similar steel articles is given in a recent issue of the "Brass World." The formula is as follows: Alcohol 1½ozs., tincture of iron 1½ozs., corrosive sublimate 1½ozs., sweet spirits of nitre 1½ozs., blue vitriol 1oz., nitric acid ¾oz., warm water 1qt. Dissolve the ingredients in the water and keep in glass bottle. The gun-barrel or other article to be treated is cleaned with potash or soda to remove the grease and all stains are then scoured off with fine emery paper, so that an even, bright surface is produced. The bore and vent, in the case of a gun-barrel are closed by plugs of wood. The solution is then applied to the surface of the steel with a sponge and allowed to dry in the air for 24 hours, after which the loose rust should be rubbed off with a steel scratch brush. Now apply another coating and allow to dry in the same manner, and then rub off with the scratch brush again. Finally wash off with boiling water, dry rapidly, and wipe with boiled linseed oil or give a coat of lacquer.

Birmingham Association of Mechanical Engineers.—At a recent meeting of the Birmingham Association of Mechanical Engineers, the president (Mr. C. H. Wall) in his inaugural address proceeded to trace the history of iron and mechanical engineering from the earliest ages, and afterwards referred to the training of engineers. By testing the iron the mechanical engineer knew his raw material had certain strength and elasticities, and the knowledge prevented labour being wasted. Might not the same principle of ascertaining the quality of the raw material be applied to the case of his apprentices before work was put upon them? Might this not lead to similar economic results in producing a larger percentage of efficient mechanical engineers? Might they not regard their technical schools and universities as the proving houses of the raw material for the engineering apprentice? Might they not look for some exact knowledge of their mental and moral strength and elasticity before they assigned a position for them in the structure of a mechanical engineer's business? The question of preparing and testing human capabilities was infinitely more complicated than that of testing iron, but it was quite as important for their welfare. In recent years courses of instruction in the scientific principles of engineering had multiplied at the universities and institutions of kindred types from a purely engineering point of view. There could be little doubt that the mechanical engineer of to-day needed more education than had sufficed to make him successful in the past.

CORRESPONDENCE.

New Patents, Designs, and Trade-marks Act, New Zealand.

To the Editor of the "Mechanical Engineer."

Sir,—We have received information that an Act relating to patents, designs, and trade-marks has recently passed the Legislature in New Zealand, and is to come into force on July 1st next. The Act has been based principally upon the British Patents Act, 1907, and contains most of the provisions of such Act, with the exception of that relating to the liability to revocation of a patent, should the invention of which it is the subject be manufactured mainly abroad. Instead of this provision, the provision of the Australian Act, 1909, has been embodied in the new law. The position of patents, therefore, will be that at any time not less than four years from the date of the patent and not less than two years after the commencement of the Act, any person may petition for an order declaring that the patented article or process is not manufactured or carried on in New Zealand to an adequate extent. An order may then be issued to take effect at once, or at a future date, and during the currency of the order the patent will not be infringed by the manufacture or carrying out of the process in New Zealand by others. Provision is made for the revocation of the order should its benefits not be availed of. Thus in any event the patentee will retain full patent rights so far as the right to import the patented article into New Zealand is concerned. Consequently, therefore, the patentees of inventions that cannot be manufactured in New Zealand, or manufactured at a price to compete with the imported article, need not take any steps to manufacture within the Dominion in the period referred to. The Act provides for an investigation of the novelty of an invention before the grant of the patent, and for the refusal of the application, or for its grant, on condition that a reference to the anticipations be inserted in the specification. An appeal from the Registrar's decision may be made to the Supreme Court. Hitherto it has been possible to oppose the grant of a patent on any grounds, but the new Act limits the grounds of opposition to certain specified objections corresponding with those allowed under the present British Act of 1907. The Act also follows the British provisions so far as it relates to patents, in respect to a single patent for cognate inventions covered by separate provisional specifications; patent of addition; restoration of lapsed patents; compulsory licenses; revocation of patents on grounds of invalidity; exemption of innocent infringer from damages; the individual rights of co-patentees; restriction on conditions of sale of patented articles; the granting of costs and giving of security for costs in opposition and other proceedings; the exemption of a patent from the effect of unauthorised or unknown prior publication of the invention; and the exemption of the patent from invalidity because of disconformity between the complete and provisional specifications. For design registrations the only important departures made by the new Act are those by which the term of registration (five years) may be extended for two further periods of five years each, and for the same working provisions that apply to patents being applied to designs, with the exception that manufacture must commence within one year of the date of registration. The trade-mark provisions of the new Act follow closely those of the British Act of 1905 with respect to registerable trade-marks, and we consider that the practice under this Act will follow that built up under the British Act. They provide as well for the lodging of security of costs by an opponent in opposition proceedings, or an appellant from a decision of the Registrar, where such opponent or appellant is outside New Zealand. They also provide for the registration of associated marks.—Yours truly,

J. OWDEN O'BRIEN, M.I.M.E.,
Chartered Patent Agent.

6, Bank Street, Manchester,
January 18th, 1912.

Blast Furnace Disaster.—A blast furnace fatality occurred recently at Duisburg (Prussia), as the result of which eight men were killed. The accident is supposed to be due to "hanging," the falling material causing pressure sufficient to burst the walls of the furnace.

INDUSTRIAL AND TRADE NOTES.

Proposed Ship-repairing Yard on the Mersey.—It is understood that Lord Pirrie is in active negotiation with the Mersey Docks and Harbour Board for obtaining an extensive site on the northern extremity of Liverpool dock system for the purpose of establishing a ship-repairing yard on a large scale.

Central London Railway Extension.—The extension of the Central London Railway from the Bank to the Liverpool Street Station of the Great Eastern Railway is nearing completion, the whole length of the tunnel having now been bored. It is anticipated that the new section will be ready for public use next June.

Colliery Enginemen's Demand. — The National Federation of Colliery Enginemen and Stokers have decided to support the demand made by the union's members in South Wales and North Staffordshire for an eight-hour day and better wages. A stoppage ballot is being taken in the districts named, while negotiations are still on foot in other mining districts. The mines are, of course, dependent on the enginemen (who are not members of the Miners' Federation), and a strike would mean the rendering of the collieries idle.

Discharge Notes in Shipyards.—The conference between the Shipbuilding Employers' Federation and the Standing Committee of the federated shipyard unions was held at Carlisle last week, on the question of the discharge note system. After prolonged discussions, during the course of which proposals passed between the employers' and the workmen's representatives, it was mutually agreed to adjourn until Tuesday, February 6th, so as to permit of both parties to consult their respective sides.

State of the Skilled Labour Market.—The Labour Department of the Board of Trade, in their report on the state of the labour market in December, states that employment was good on the whole, and showed little change as compared with a year ago. There was an improvement in most of the principal industries, especially in the iron and steel, engineering, and shipbuilding trades. In 394 trade unions, with a net membership of 789,000, making returns, 24,000, or 3·1 per cent., were returned as unemployed at the end of December last, compared with 2·6 per cent. at the end of last November, and 5 per cent. at the end of December, 1910.

Railway Development in New Zealand.—In an account of railway development in New Zealand, the United States Vice-Consul, General H. D. Baker, states that on March 31st, 1911, 2,761 miles of railway were open for traffic, as against 2,717 miles the previous year. In addition to £97,200 to be expended during the next four years on grade-reduction work alone on Government railways, other contemplated large expenditures are covered in the Loan Bill, which has passed the New Zealand Parliament, providing authority for raising £286,000 for railway construction and £291,600 for additional rolling stock. The electrification of the railways of New Zealand in certain sections is now under contemplation by the Government, especially where there are long tunnels.

Trade Circulars and Catalogues.—We have received from the Baldwin Locomotive Works, Philadelphia, a brochure (Record No. 71) describing and illustrating a number of locomotives recently built by them for industrial and contractors' service.—Alfred Herbert, Ltd., Coventry, send us a booklet describing and illustrating their automatic stud machine.—The General Electric Company, Ltd., 67, Queen Victoria Street, London, send us a sectional catalogue dealing with fire alarms, water levels, and electric clocks.—From The Union Electric Company, of Park Street, Southwark, London, S.E., we have received a catalogue of arc lamps, dynamos, switch gear, and meters.

Copper.—Messrs. James Lewis & Sons, in their annual review, estimate the world's production of copper last year at 875,000 tons, as against 851,000 tons in 1910, an increase of less than 3 per cent., the output alone of the United States being 500,000 tons. While the output of Europe has advanced about 30 per cent. during the last ten years, of Chili about 14 per cent., of Australia about 40 per cent., and of Canada less than 30 per cent. The consumption has gone up 80 per cent., and we are still largely dependent upon the increasing yield of the United States. Prices during last year have ruled low, but with an expected larger demand in the States, consequent on trade expansion and cheaper money, and with a continuance of the shipyard activity, dearer copper during 1912 is looked upon as certain.

Machinery Trade in India.—The official "Indian Trade Journal" of 14th December contains an article on the trade in machinery in India. In that country, it is stated, it is often difficult for a local capitalist to obtain the expert advice and assistance needed for estimating the requirements for and cost of a plant for any given purpose. In recent years, however, the Central Government and certain of the Provincial Governments in India have appointed commercial intelligence officers, one of whose functions it is to procure and supply information of this kind. These officers report that they receive many bona fide enquiries from persons qualified financially and by intelligence to establish useful works, and the article suggests that British manufacturers would do well to get in touch with the officers and assist them with estimates and quotations.

Scottish Tube Combine.—The scheme for uniting the Scottish iron and steel tube makers in one undertaking has, we understand, been completed, and the following firms have agreed to join hands: Caledonian, Coatbridge; Clydesdale, Rutherglen; Coat, Coatbridge; Glasgow, Bridgeton; David Richmond & Co., Hutchesontown and Govan; Tradeston Company, Tradeston; and Wilsons and Union, Coatbridge. Stewarts and Lloyds enter the partnership as shareholders, and one of the firm will join the new board. The capital of the company, which will be known as the "Scottish Tubes," is fixed at £750,000, in debentures and preference and ordinary shares; only the debentures (£250,000) are to be offered to the public, and they have been already fully underwritten. The vendors take the preference and ordinary shares, less £150,000, which are to be held in reserve for future disposal.

Accidents in Mines.—The Home Office have issued a general report with statistics dealing with fatal accidents in and about mines and quarries of the United Kingdom during the year 1911. Under the Coal Mines Regulation Act there was a total of 1,206 separate fatal accidents. Of this total 1,064 of the fatal accidents were underground. The deaths caused by these accidents reached a total of 1,259, as compared with 1,775 in the preceding year, a decrease of 516. There was a total of 1,111 deaths ascribed to underground accidents, 615 from falls of ground, 36 from explosions of firedamp or coal dust, 98 due to shaft accidents, and 148 occurred on the surface. Under the Metalliferous Mines Act last year there was a total of 41 separate fatal accidents, causing 45 deaths. The figures respectively for the preceding year were 38 and 43. Twenty of the accidents occurred in the midland and southern districts.

Cleveland Mine Owners' Association.—The annual meeting of the Cleveland Ironstone Mine Owners' Association was held at Middlesbrough on the 15th inst. Sir Hugh Bell, Bart., who occupied the chair, was re-elected president. Representatives of the miners attended to discuss the question of wages. The owners pointed out that according to past formula wages should be reduced by 0·8 per cent. as the average net selling price of No. 3 Cleveland pig iron last quarter was 47s. 4·61d. per ton. The men's representatives intimated that they were prepared to settle the wages question for the ensuing quarter if the owners would forego the reduction named. It was ultimately agreed to leave the wages unaltered for the first quarter of the year, but the owners intimated that the reduction now due must be taken into consideration in the next settlement, if the ascertained price of pig iron should entitle the men to an advance.

British and Foreign Trade.—The Commercial Department of the Board of Trade has issued the usual monthly account relating to the trade and commerce of certain foreign countries and British Possessions, including figures received up to December 31st last. A comparison of the total figures for the 11 months ended November 30th, 1911, is possible for five countries, as follows:—

	1911. £		1910 £
IMPORTS.			
United Kingdom	521,634,000	...	515,421,000
Germany	425,823,000	...	396,382,000
France	293,828,000	...	253,468,000
United States	290,115,000	...	297,124,000
Belgium	150,209,000	...	141,023,000
EXPORTS.			
United Kingdom	415,711,000	...	393,166,000
Germany	360,089,000	...	332,383,000
France	223,696,000	...	225,183,000
United States	382,444,000	...	333,837,000
Belgium	121,225,000	...	114,217,000

Shipbuilders and Rebate System.—A conference of Clyde Shipbuilders and Scotch steelmakers took place in Glasgow on Monday last, at which the shipbuilders stated their objections to the system of rebates on steel to which they are opposed. They pointed out that merchants had frequently been able to give delivery of material when it could not be had promptly from the makers, and they were unwilling to give up the relations between them and the merchants, and bind themselves to take steel only from the makers. The shipbuilders also stated that they did not think the advantages of the rebate system would compensate them for the inconveniences that would accompany its adoption. They, there-

fore, requested the steelmakers to give up that system and revert to the former practice of selling freely either to merchants or customers. A request was also made by the shipbuilders that the steelmakers should undertake not to sell shipbuilding material for export at lower prices than they charged to the home trade. The conference was adjourned so that the steelmakers might have an opportunity of considering the questions raised, and they promised to intimate their decision to the shipbuilders.

World's Shipbuilding.—The "Annual Summary" of shipbuilding at home and abroad during 1911, issued by Lloyd's Register, states that 772 merchant vessels of 1,803,844 tons gross were launched in the United Kingdom. Of these 700 were steamers of 1,782,908 tons and 72 were sailing vessels of 20,936 tons. The warships launched at both Government and private yards amount to 50 of 230,786 tons displacement. The total output of the United Kingdom for the year has, therefore, been 822 vessels of 2,034,630 tons. The output of mercantile tonnage in the United Kingdom during 1911 shows the enormous increase of 660,675 tons on that of the previous year. It is the highest total ever recorded by the society with the exception of that for the year 1906 (1,828,343 tons). As regards war vessels, the total for 1911, which constitutes a record, is 96,141 tons more than in 1910. The mercantile output of the world (2,650,140 tons) is higher by 692,000 tons than the figures for 1910. It shows a net increase in the world's mercantile tonnage of about 1,787,000 tons, steam having increased by 1,940,000 tons, and sail diminished by 153,000 tons. The number of large steamers launched in the United Kingdom during 1911 greatly exceeded the average of recent years. The returns show that 53 vessels of 6,000 tons and above were launched. Of these 17 were over 10,000 each, the largest being the White Star steamer Titanic, of 43,300 tons, the Cunard steamer Laconia, of 18,150 tons, and eight vessels of over 11,000 tons each. With regard to the output of the leading ports, it is stated that the Newcastle district occupied the first place among the shipbuilding centres of the country, showing an output of 412,959 tons. In warship tonnage, Glasgow led with 71,166 tons displacement, followed by Barrow 36,740 tons, and Newcastle 28,120 tons. At the end of December there were under construction, including a number of vessels already launched but not completed, 51 vessels of between 6,000 and 10,000 tons; 15 of between 10,000 and 15,000 tons; three of between 15,000 and 20,000 tons; and three of over 40,000 tons each. The vessels under construction included one of 2,000 tons and two others of 500 tons, for which the propelling power will be internal combustion engines. Attention is drawn to the statistics of vessels launched abroad during 1911. Among foreign countries the leading places were held by Germany (255,532 tons), the United States of America (171,569 tons), France (125,472 tons), Holland (93,050 tons), Japan (44,359 tons), Austria Hungary (37,836 tons), and Norway (35,435 tons). The total output of war vessels abroad (119, of 538,083 tons displacement) exhibited an increase of about 362,000 tons on the displacement for the preceding year.

METAL QUOTATIONS.

TUESDAY, JANUARY 23RD.

Aluminium ingot		63/- per cwt.
,, wire, according to sizes, &c.	from	102/- ,,
,, sheets ,, ,,	,,	120/- ,,
Antimony	£27 10 to	£28/- per ton
Brass, rolled		7¾d. per lb.
,, tubes (brazed)		9½d. ,,
,, ,, (solid drawn)		8d. ,,
,, ,, wire		7¾d. ,,
Copper, Standard		£62 7 6 per ton
Iron, Cleveland		48/10½ ,,
,, Scotch		54/10½ ,,
Lead, English		£16/-/- ,,
,, Foreign (soft)		£15/15/- ,,
Mica (in original cases), small		6d. to 2/- per lb.
,, ,, ,, medium		2/6 to 4/- ,,
,, ,, ,, large		4/6 to 8/6 ,,
Quicksilver		£8/-/- per bottle.
Silver		2s. [illegible]d. per oz.
Spelter		£26 1[illegible] per ton
Tin (cash)		£188 15 ,,
Tin plates		13/6 ,,
Zinc sheets (Standard)		£30 10/- ,,
,, Silesian, Vieille Montagne		£30/15/- ,,

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1910.

Variable speed gear. Kent & Mitchell. 22783.

1911.

Driving of aerial propellers driven by internal combustion motors. Isaacson. 83.
Motor vehicles. Vallat. 91.
Extraction of copper from ores containing that metal. Bussey. 100.
Carburetter for internal combustion engines. Martin. 131.
Propulsion of ships. Jensen. 135.
Composition for removing incrustations from boilers. Carl. 139.
Exhaust silencers for internal combustion engines. Richards and Redrup. 167.
Rock drills. Rayner. 231.
Internal combustion engines. Malloch. 525.
Means for treating metals and liquids by heat. Bone, Wilson, and McCourt. 625.
Tramway rails. Crudgington. 646.
Preventing the creeping of railway rails. Dienstfertig & Haase. 1064.
Speed recorders. Whitehead. 1298.
Starting apparatus for internal combustion engines. Thompson and Netter. 1607.
Rotary engine. Sweetzer & Urry. 3376.
Gas crucible furnaces. Yates. 3640.
Mechanism for relieving compression in internal combustion engines. Triumph Cycle Company and Franklin. 4772.
Manufacture of metal tube. Evans. 6460.
Condensers. Fisher & Peck. 7059.
"Cut off" expansion valve gear for steam engines. Barclay & Barclay. 7333.
Automatically operated by pass valves. Marks. 13172.
Evaporation apparatus. Soc. d'Exploitation de Procedes Evaporatoires Systeme Prache and Bouillon. 14492.
Apparatus for the liquid transmission of power for controlled movements. Barbey. 14763.
Gas producers. Dor Delattre. 14774.
Motor vehicles. Twombly. 19278.
Automatic coupling for railway vehicles. Haseler, Izon, and Lacey. 21207.
Apparatus for testing gas. Dragerwerk Heinr. & Bernh. Drager. 24654.

ELECTRICAL, 1911.

Alternating current arc lamps. Ogilvy Webb, Booker, and Reinecke. 16.
Electric generating systems of vehicles. Seal. 152.
Electric motors and pumps connected thereto. Gwynnes, Ltd., Breeze, and Macdonald. 594.
Electric motor reversing switches. Stobie. 672.
Electric transformers. British Thomson Houston Company. 711.
Boxes for use with electric cables. Dickinson. 1302.
Polyphase alternating current dynamos. Allgemeine Elektricitats Ges. 1912.
Resistances for electrical heating and cooking apparatus. Cooper. 3745.
Circuit connections for electric current distribution with auto-transformers. Kesselring. 4618.
Sparking plugs for internal combustion engines. Player and Hill. 7789.
Electric time switches. Mehne. 11238.
Combustion bridge for arc light electrodes. James. 11436.
Electromagnetic ignition device for internal combustion engines. Ritter. 12369.
Switch for electric illuminating devices. Grabe & Lehrbach. 13341.
Construction of magneto-electric ignition machines. Robert Bosch. 13705.
Electrical wall sockets. Fricker. 14110.
Process and arrangement for forming an electrical arc. Duschnitz. 16992.
Holders for electric lamps. Siemens Bros. Dynamo Works, Ltd. 17869.
Methods of mounting overhead wires for electric railways. Siemens Schuckertwerke Ges. 20031.
Electrical water heaters. Katz. 23830.
Regulating device for polyphase current arc lamps. Heimann and Schaller. 25586.

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Smoke-prevention Enthusiasts.

AT present there seems to be an outburst of the agitations that periodically afflict large manufacturing centres with respect to the smoke question. It is impossible to say anything on the subject from the scientific point of view that has not been often repeated, but this does not prevent the crop of extravagant statements respecting waste of fuel, injury to health, buildings, &c., put forward by smoke-prevention enthusiasts being reiterated on every conceivable occasion. Bradford and Sheffield are at present suffering from agitations of this kind, and Prof. Arnold, of the latter city, has been taken to task by certain critics for venturing to set forth in a series of articles in "The Sheffield Daily Telegraph" a few of the elementary facts of the smoke question, and for pointing out that the contemplated action of the officials of the National Smoke Abatement Society in the shape of a Bill giving greatly extended and drastic powers for the prevention of smoke may seriously interfere with the prosperity of large manufacturing centres. The smoke-prevention enthusiast views the atmosphere with a purely æsthetic eye, with a profound ignorance of chemistry and of manufacturing requirements. The visible smoke particles that obscure light, or come 'twixt the wind and his linen, are the only ones that annoy, and hence the only products of combustion that concern him, and in concentrating his abuse of manufacturing chimneys and processes, appears ignorant of the fact that in large towns 50 to 60 per cent., and in some cases more, of the smoke or fog troubles that occur are due to domestic chimneys. Ignorance of chemistry must be the reason for his failure to recognise that, whatever kind of fuel is burned, the deleterious and invisible products of combustion in the form of carbonic acid or sulphurous acid gas remain unaltered, even when combustion is perfectly smokeless. In this respect a clean chimney can be just as poisonous as a dirty one, but it may impose a serious task upon a manufacturer in some cases to maintain the pres-

emitted from a chimney in a state of invisibility. We cannot here discuss at length the conditions necessary for efficient and smokeless combustion in a boiler furnace, as we have dealt with it so often. Briefly, they consist in maintaining a high temperature and a proper adjustment of the air supply. The latter is a somewhat delicate matter, and the correct balance may be easily disturbed. An insufficient quantity may cause smoke, though not necessarily any loss of efficiency, for the solid particles in a cloud that would obscure the sky over a decent sized township would, if collected and compressed, probably go in a wheelbarrow, and certainly would not represent the "awful waste" of fuel so often pictured by the smoke enthusiast. On the other hand, an excessive air supply may conduce to a smokeless chimney, but it often puts a toll on efficiency that is only too clearly visible in the coal bill. The margin of regulation between a smoky and a smokeless chimney from a boiler furnace is not a wide one, and even with the best plant, if regard is to be paid to economy and efficiency, it is difficult to avoid occasional trespass on the smoky side owing to the ordinary contingencies of working, represented by the cleaning of fires and accidental stoppages of machinery, and restrictions which pay only a scrupulous regard to the appearance of the chimney top and none to ordinary interferences with working may not only be very harassing to steam users but a serious tax on industry. Further, if every factory chimney stood in saintly purity, the innumerable army of domestic chimneys would remain as dirty as ever. The only method of dealing with them appears to be the substitution of gas fires for coal fires in the household grate, and experience of this change does not so far justify unqualified worship. It is true gas fires can be better regulated than coal fires, and that less heat goes up the chimney, but it is equally true, and in fact a consequence of this, that they give less ventilation and increase the risk of obnoxious gases escaping into the rooms in which they are situated—gases, by-the-way, which are not the less poisonous because they are invisible, whether poured into the outside atmosphere or into a room. The question of preventing smoke in furnaces used in steel-making is largely one of cost, but, as Prof. Arnold points out, in dealing with steel in certain stages of its manufacture, it is essential that the heating flame, if it comes into contact with the steel at all, must be non-oxidising flame, or, in other words, a more or less smoky one; and any attempt to interfere with this would mean either completely different methods of heating many classes of steel or the cessation of manufacture. It is easy for enthusiasts to present all kinds of alternatives and urge that while smokeless they would be equally efficient for steel-manufacturing purposes, but these individuals too often talk from the book and not from practice, and forget that a manufacturer in these strenuous days is only too keenly alive to his own interests, and is never averse to adopting improvements if they can be shown to be profitable. There are, of course, methods of heating steel besides direct contact with coal flames, but the extent to which these are applicable is a question for steel manufacturers rather than smoke-prevention enthusiasts, and any attempt to impose harassing restrictions should be vigilantly watched.

The Risk of Bursting of Turbine Condensers.

Some of our readers may be able to recall an appeal to the Court of Survey in Glasgow made by Messrs. Denny, of Dumbarton, on account of a refusal by the Board of Trade to grant a passenger certificate to a turbine steamer constructed by them owing to their refusal to submit the condenser to certain pressure tests which the Board of Trade desired to impose. We gave an outline of the facts at the time,* and are reminded of them by a failure of a turbine condenser recorded in the December issue of "Power." The details of the actual condenser construction are somewhat meagre, but the explosion was, from the photo views given by our contemporary, evidently very violent and destructive. The cast-iron shell of the condenser, which was apparently circular, and contained 2,200 tubes, ⅝in. diam., by 16ft. in length, and worked in conjunction with a 500 kw. vertical Curtis turbine lighting plant, was blown to pieces. What the precise combination of circumstances were that led to the accession of pressure to the condenser are not known, as the engineer was, unfortunately, killed; but it appears that he had experienced some trouble in the maintenance of the vacuum, and had gone into the pump pit beneath it to try and locate it when the disaster occurred, and he was buried in the débris. It is obvious that the condenser must have been subjected to steam at considerable pressure, but whether this was due to a fault in the air pump or to failure elsewhere could not, our contemporary remarks, be determined by the evidence available. The accident, however, indicates the possibility of turbine condenser explosions, and in view of the disorganisation which such a failure might cause on board ship thus, to some extent, support the attitude adoped by the Board of Trade at the time of their dispute with Messrs. Denny. It cannot, we think, be denied that steam turbines do afford greater possibilities for the advent of excessive pressure than with reciprocating engines, and the contention of the Board that to secure a reasonable margin of safety, turbine condensers should be submitted to an hydraulic pressure of 30lbs. on the inch did not, as we stated at the time, appear to us unreasonable. The Glasgow Court of Survey sustained Messrs. Denny's appeal on the ground that the Board of Trade's action was a new departure in survey practice, and that the onus lay upon them to show that the new circumstances justified it. On the other hand, Messrs. Denny's opposition was apparently dictated by a reluctance to establish a precedent with regard to condenser testing which would place turbine vessels at a disadvantage as compared with ordinary vessels rather than by a belief that testing was not necessary, for it transpired that they had for their own satisfaction tested the condenser in question to a pressure of 25lbs. on the inch, *i.e.*, within 5lbs. of the pressure demanded by the Board of Trade. So far turbine condenser explosions have been a rare occurrence; the only other instance we can recall was one that occurred about four years ago (August, 1907), on board H.M. cruiser "Euryalus," but in view of the comparatively limited number of vessels fitted with turbines it would be unwise to rely too much on this immunity. The chance of explosion may be remote, but the failure just recorded shows it is not impossible, and having regard to the consequences on board ship, the Board of Trade view that they should be constructed to resist to a certain extent internal pressure is not unreasonable.

* See "The Mechanical Engineer," June 4th, 1904, p. 809, Vol. XIII

Steam Pipe Explosion at Yarmouth.—On Saturday night last the main steam pipe in the electricity station at Yarmouth burst, resulting in two of the employés being scalded, one so severely that he had to be taken to hospital. The accident caused considerable inconvenience to residents, as the tramway service was brought to a standstill and the lighting service [illegible]

DEVELOPMENT OF FOUNDRY PRACTICE.

At the meeting of the Sheffield and District Branch of the British Foundrymen's Association on the 23rd ult., Mr. Percy Longmuir, who was re-elected president, gave an interesting address on "The Development of Iron and Steel Foundry Practice." He remarked that there were many branches of the foundrymen's art still needing careful research and study. Moulding alone offered a big field for such work. The knowledge of this branch was far from complete and it was doubtful whether it would be complete in their time. They ought to tackle it to a greater extent than had been done, because it was of the greatest importance in any foundry. In core-making there was a field almost equally as great for study. They would also agree that the question of melting wanted much greater attention. One was often amazed, whether dealing with the ordinary foundry cupola, the Siemens' furnace, or the Bessemer converter, when producing steel for castings, at the extraordinary fluctuations under apparently the same conditions. Some two years ago he had the opportunity of studying closely several German foundries which were flooding England, Sheffield included, with light steel castings, all the product of the electric furnace. They might say electric melting was too costly. So it was for certain classes of work, but not for light steel. Iron founding or brass founding, in view of their present knowledge of electric heating, was out of the question, but for light steel work this class of heating was worthy of serious consideration.

In regard to cost of production, business men recognised the importance of securing accurate costs, and he questioned whether many foundries could do that to-day. Referring to the after-treatment of malleable iron and heat-treatment of steel, he said they had only touched the fringe of these subjects. The question of mass was of vital moment, and he was afraid that this point had up to now received little serious study, and one of the finest fields for research lay in the study of failures and wasters, with a view to prevent future errors. The man on the foundry floor each day acquired knowledge which could not be gained in the best-equipped laboratory in the world. To make progress, they had to couple up the work of the scientist, the engineer, and the foundryman, and by properly combining the experience of these three much valuable knowledge could be gained

APPLICATIONS OF ELECTRO-METALLURGY.

At a recent meeting of the Sheffield Electro-Metallurgical Society, Mr. F. Mason, in a paper on the above subject, said electro-metallurgy dated back to the beginning of the nineteenth century, but the practical applications of electricity to metallurgy were confined almost to the last 30 years. Within that period electricity had become an indispensable agent in the bullion, aluminium, copper, and sodium industries. He could not for one moment venture to advocate the immediate total demolition of its elder brother of the fuel type. The conditions which exist to-day in and around Sheffield did not warrant such drastic measures being taken if cost of production was alone to be considered. Dealing with the question of cost, Mr. Mason said they had it from Prof. J. W. Richards that 1 kw. hour melted in practice approximately 7lbs. of brass or bronze. This was 50 per cent. below the theoretical value. In Sheffield to-day the lowest rate at which electricity was supplied by the Corporation (without special or particular agreement) was ·6 of a penny per unit. From these figures they arrived at the following conclusion: That in large quantities alloys could be melted under present conditions at the cost of 1d. per 11·71lbs. of metal by means of the electric furnace. On the authority of eminent metallurgists, the electric furnace was bound to influence non-ferrous metal industries. The advantage of electricity over fuel for some branches of non-ferrous metallurgy was amply demonstrated in the manufacture of aluminium. In 1887 this metal was £3,788 per ton, to-day it could be bought at under £80 per ton, and this remarkable reduction was due to the use of electricity in its production.

THE CENTRAL HEATING AND POWER PLANT OF McGILL UNIVERSITY, MONTREAL.

At a meeting of the Institution of Civil Engineers, held on January 30th, a paper on the above subject by R. J. Durley, M.Inst.C.E., was read, of which the following is an abstract:—

Economic and other conditions have led in many places to the development of central plants for the distribution of heat to large groups of buildings or to districts in towns, and these installations are in successful operation both with and without accompanying electric generating stations. The present paper describes the arrangement and equipment of a central heating plant, combined with an electric light and power station, designed to serve the various buildings of McGill University. Although only of moderate size, the installation is of interest on account of the somewhat severe climatic conditions and the unusual nature of the service. Attention is called to the fact that the economic possibilities of such a station depend very largely on the relation between the demand for heat and that for electric current.

The University buildings were, up to 1908, heated individually by their own steam or hot-water equipment, and took current from the local electric supply company. The coal used for the heating service was necessarily of an expensive kind, and the cost of current was rather high. Economy and improvement in service, therefore, were sought by utilising cheaper coal in a central boiler plant and heating the various buildings from one source, employing for this purpose as far as possible the exhaust steam from electric generating sets. The buildings which will ultimately be served have a total volume of about 7,570,000 cub. ft.; they contain 81,000 sq. ft. of direct radiation heating surface, need 185,000 cub. ft. of warmed air per minute for ventilation, and require as a maximum about 475 kw. for light and power. The greatest demand for steam for heating and ventilation for all the buildings in cold weather would be about 30,000lbs. per hour. The station as at present working supplies current to 11 buildings and heats five; and the heating service will be extended to all the buildings as opportunity serves.

A brief discussion of the systems of heating and ventilation in general use in Canada for large buildings, and a description of the nature of the demand for steam and current for the University purposes, is followed by notes as to some of the problems arising in the design and construction of underground piping systems for steam and hot water. The McGill power house itself is not of an unusual type, its equipment including four water-tube boilers, three steam-electric generating sets, the necessary heaters and auxiliary machinery, and the ordinary apparatus for the switchboard and electric accessories. The heat distribution to the buildings being largely by means of forced-circulation hot water, as well as by steam, the heaters and circulating pumps are installed in the engine-room, and are at present capable of supplying hot water to 60,000 sq. ft. of direct-radiation heating surface. Means are provided for obtaining a record of the heat delivered to the heating systems of the various buildings. The electric distribution is by underground cables throughout, the cables as well as the heat-distributing pipes being carried partly in tunnel and partly in conduit. Secondary heaters have been installed in two of the buildings, in order to avoid the expense of renewing their existing heating pipes and radiators. The paper closes with a description of the methods of operation adopted, and the systems of temperature regulation employed, together with some notes as to working costs.

Action of Vanadium on Cast Iron.—A meeting of the Birmingham Branch of the British Foundrymen's Association was held on Saturday last, when a lecture, entitled "Some Facts as to the Action of Vanadium on Cast Iron," was delivered by Mr. J. Kent Smith, of Liverpool. The lecturer dealt with the subject more especially from the point of view of the application of vanadium in commerce to grey and chilled iron. He showed the best means of using vanadium in the commonly-known processes of foundry work, and emphasized the fact that the two most important effects of vanadium on iron were: (1) Its extraordinary resistance to abrasive wear, and (2) that it eliminated almost entirely the porosity difficulty so often met with in high-service castings. The lecture was illustrated by a number of lantern slides.

TRACTION ENGINE BOILER EXPLOSION AT CRAWLEY.

BOARD OF TRADE ENQUIRY AT WINCHESTER.

At Winchester, on Tuesday last week, a Board of Trade formal enquiry, under the Boiler Explosions Act, 1882 and 1890, was held into the circumstances attending the explosion of an agricultural traction engine boiler on April 24th last year at Manor Farm, Crawley, by which one man was killed and two others injured. The explosion was extremely violent, as will be seen from the accompanying photo views of the wreck reproduced by kind permission of our contemporary, "Vulcan." The Commissioners at the enquiry were Mr. F. Sims Williams, LL.B., barrister-at-law (president), and Mr. G. Fullerton Bell (engineer). Mr. George C. Vaux appeared on behalf of the Board of Trade, and Mr. Percy Snelling, of Winchester, on behalf of Messrs. L. & T. Morecroft, the owners, and also for Messrs. George Thurlow & Sons, the lessors of the boiler.

The case is of considerable importance to users and dealers in portable locomotive boilers in agricultural districts.

Mr. Vaux, in opening the enquiry on behalf of the Board of Trade, said the parties to the enquiry were Messrs. George Thurlow & Sons, Ltd., Messrs. Lewis and Thomas Morecroft, who were partners in the firm of Messrs. L. & T. Morecroft, contractors, of Sutton Scotney; Mr. Thomas Oswald Newman, who was a machinist and contractor, of Stanstead, Essex, and Chas. Wells, a boilermaker. The boiler which exploded formed part of a steam ploughing traction engine, made by Messrs. John Fowler & Co., Ltd., of Leeds, in 1878. It was constructed for a working pressure of 100lbs. per square inch, for a Mr. Hartwell, of Scoles, Yorkshire, who sold it in 1893 to a Mr. Newman, who kept it until September, 1909. The boiler was fitted with one lever safety valve with a Salter spring balance, which was said to blow off at a pressure of 100lbs. per square inch.

Messrs. George Thurlow & Sons, Ltd., were merchants at Stowmarket, and a part of their business appeared to be the financing of contractors who required machinery for doing agricultural work. Messrs. Lewis & Thomas Morecroft, of Sutton Scotney, were contractors for doing ploughing and cultivating work, and they were financed by Messrs. Thurlow and Sons. During the summer of 1909, Messrs. Morecroft wanted to obtain another ploughing tackle set, and requested Messrs. Thurlow & Sons to buy a set for them. As a result of negotiations, the boiler and engine was bought from Mr. Newman by Messrs. Thurlow, who had their name plate put upon the engine, and from whom Messrs. Morecroft purchased the engine on a hire-purchase agreement. Mr. Newman did not appear to have given any guarantee as to the safe working of the pressure boilers, but it was said that at the time of delivery the safety valve was set to blow off at 100lbs. per square inch. There appeared to have been some conversation between Mr. T. Morecroft and Mr. Newman with regard to the necessity for re-boilering the engine, and it seemd certain that at the time the engine was handed over to Messrs. Morecroft a patch had been fitted on the top of the boiler, where the plate had become thin. After obtaining possession, Messrs. Morecroft appeared to have worked the boiler on and off at a pressure of about 110lbs. for a period of about 10 days, until October 28th, 1909, when it was laid up for the year. During the winter following, the boiler was examined by Mr. Thomas Morecroft. No repairs were effected, but a Salter spring balance was fitted to the boiler, and was set by Mr. Thomas Morecroft to blow off at a pressure of 120lbs. per square inch. The boiler was not insured, and no outside persons were called in to examine and report on its condition. On April 17th, 1911, Mr. Thomas Morecroft appeared to have last seen the boiler at work on the Manor Farm, Crawley, belonging to Mr. Philippi, where Messrs. Morecroft had contracted to do some ploughing work. On Monday, April 24th, the fire was lit about six a.m. by Percy Morecroft, a brother of the lessees of the engine, who was acting as driver, and who had had 16 years' experience. At about 9.40 a.m., while the pressure gauge was said to be showing 110lbs., the boiler exploded. A carter in charge of the water cart was killed instantaneously; Percy Morecroft was scalded and thrown out of the engine cab, and a boy standing near suffered injuries, and a fitter, standing five or six yards away, was blown for a distance of about 30 yards, but by a miracle, beyond a severe shaking, suffered no injuries, while fragments of the engine and boiler were carried long distances.

Mr. George Gosey, traveller for Messrs. John Fowler and Co., of Leeds, said the engine was a 14 h.p. normal, single-cylinder ploughing engine, and he had been able to ascertain that the boiler was constructed by his firm for 100lbs. pressure.

Percival Morecroft, driver in charge, and brother to Lewis and Thomas Morecroft, gave evidence of having worked the engine, and bore out the details of the explosion as given by Mr. Vaux. He said that the gauge of the engine showed a steam pressure of 110lbs. immediately before the explosion. On the previous Saturday the boiler blew off at 120lbs., which was the same pressure the safety valve spring balance indicated.

Mr. Arthur Tarrant, engineer surveyor to the Board of Trade, who held the preliminary enquiry after the explosion, put in a report giving a detailed description of the engine and boiler, and the flight of the fragments. The back end plate of the boiler, the smoke box, and a tube were blown in a direct line 39ft.; the steering axle and left wheel, a distance of 15ft.; the right front wheel was disconnected, and landed 63ft. from the engine to the right hand of the smoke box; the cylinder and other parts, with control valve and lower part of the dome, were thrown a distance of 90ft.; fragments of the dome cover and the upper part of the dome, including the safety valve and lever, were detached and found 174ft. from the engine; the safety valve funnel, tool box, companion wheel, and four pieces of barrel plating, together with a number of small parts of the engine and boiler lagging, were strewn around within a radius of 60ft.; the governor brake was found 420ft. from the engine; and four large pieces of shell plate at distances varying from 195ft. to 510ft. The original thickness of the barrel plates was ⅜in., but they were wasted by external corrosion. Internally the boiler was in good condition. There were no indications of shortness of water. The boiler was only ⅛in. thick at the top of the barrel, close to the smoke box, and on this an external patch had been placed, attached by bolts 3in. apart. The patch was never any good, as it was not carried far enough. The heads of the rivets were not substantial, and they had very little hold, while there was considerable play in them. From his examination he came to the conclusion that the weakest part of the boiler was under the patch, where the bolts weakened the plate to the extent of 21 per cent., and that the initial fracture took place in this weak portion, which was corroded, and brought about the other fractures. In his opinion, the explosion was caused by the thinning of the shell plating of the barrel by external corroding, which reached such a point that it could not resist the working pressure. He thought the corrosion was caused by the water dripping from the cylinder. Asked if the hammer test could have been applied to the weak part, he replied that he did not see how it could have been done without taking off the cylinder.

Mr. George Reader Thurlow, managing director of Messrs. Thurlow & Sons, Ltd., gave evidence showing that the engine was hired to Messrs. Morecroft on a hire-purchase agreement. He was not an engineer or boiler maker. They did not put in new boxes or boilers, but got other people to do it for them. Occasionally they financed second-hand machinery, but with the exception of this case they had had every engine through their shop. It was not their practice, until last year, to have every engine examined by an insurance company. They had never examined engines while out on a hire-purchase agreement, but they now examined every boiler through an insurance company. When his firm let out engines it was their practice to examine them all before they left their shop, but in the case of this boiler they did not do so. In the hire-purchase agreement there was no clause which compelled the hirer to insure against explosion. Messrs. Morecroft, in a letter before the purchase, said the condition of the engine was extra good. He arranged for the engines to be handed over to Messrs. Morecroft by Mr. Newman, and left it to Messrs. Morecroft to decide how and what pressure was to be used. He did not see the engine after the explosion; he had never seen it from first to last. There was no stipulation in the agreement as to insurance against explosion.

Mr. Vaux: Don't you consider there was some responsibility on you if you buy an engine, before setting it to work to see if it is safe to be set to work? — I never knew that, but I believe now what you say is true.

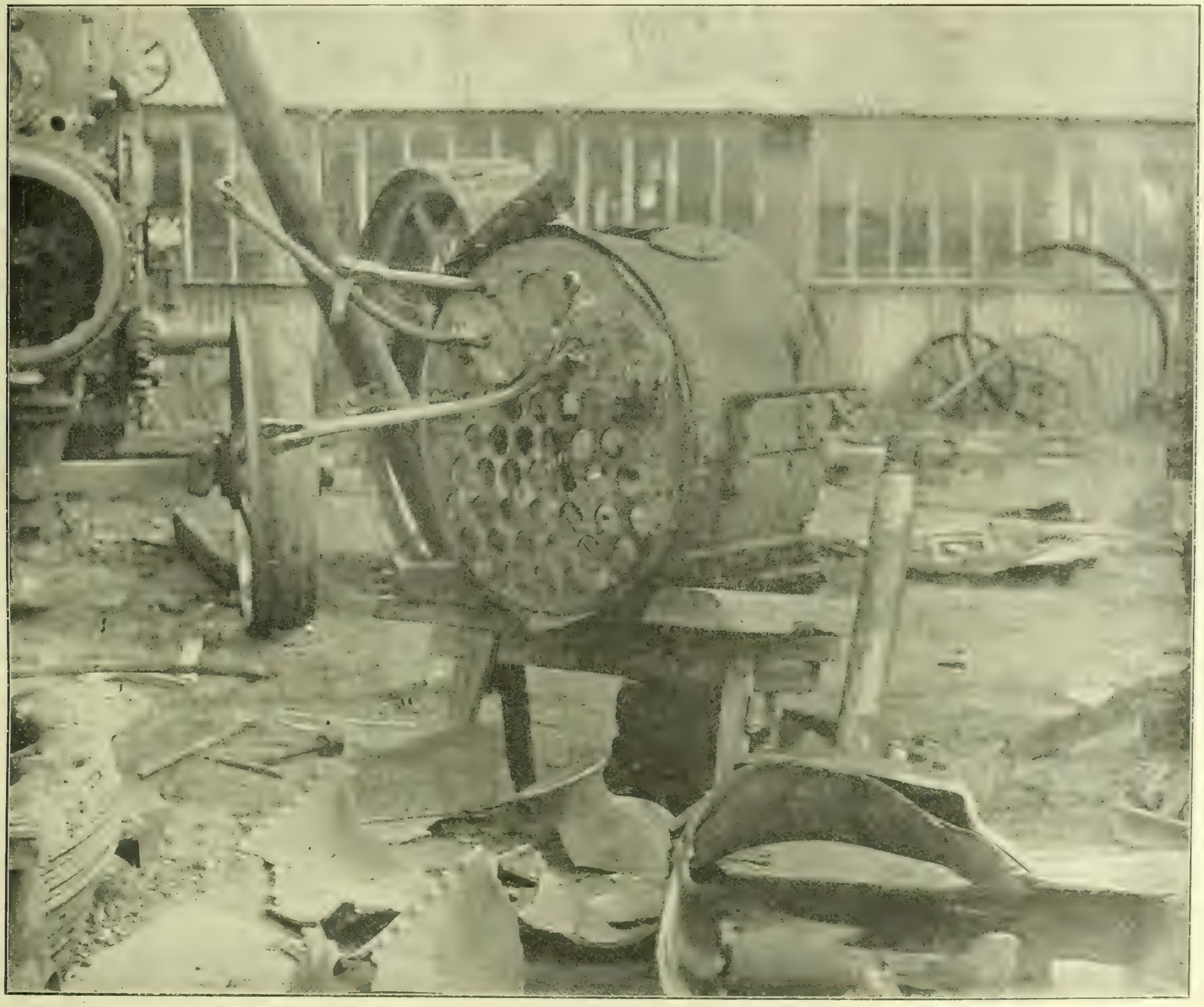
Witness agreed with the President that a mere external examination was not sufficient to ascertain the condition, but

said it was a very troublesome job to take the lagging off. He had bought some hundreds of engines, and had never had the lagging off, but if he had known the boiler had been patched he would not have bought it.

Thomas Oswald Newman, machinist and contractor, of Stanstead, Essex, bore out Mr. Vaux's opening statement as to the history of the engine. He had it for 16 years in his possession. For eight years he leased it out on hire. When it came back at the end of the eight years he did not examine it, and he did not remember ever having the lagging off before he sold it. He set the gauge at 100lbs., and worked the boiler at that. He had a ferrule put underneath the spring balance of the safety valve, so that it could not be screwed down lower; 100lbs. was the pressure for the boiler when new. He advertised it as in good order, and for all he knew it was in good order. He did not examine the barrel boiler, nor did he have the lagging off. When the engines were dispatched to

with Mr. Newman as to the working pressure. He thought that when the engine was delivered the safety valve was loaded to 120lbs. No guarantee was given by Mr. Newman, and nothing was said about re-boilering the engines. After they were received in September they were worked for about three weeks at the pressure set by Mr. Newman, and when they were used again the following April he set the gauge at 120lbs., because that was the pressure they had always been using. During the winter of 1909-10, the engine No. 3,489 was stripped of its lagging, and the outer plating of the boiler was scaled and painted. He did part of this himself. He then found the boiler had been patched, but took no steps to ascertain the thickness of the plates.

Lewis Morecroft, brother of the last witness, said he conducted the correspondence and book-keeping part of the business, and left the other to his brother. He generally bore



EXPLOSION OF A TRACTION ENGINE BOILER AT MANOR FARM, CRAWLEY, HAMPSHIRE

Messrs. Morecroft, the safety valve was adjusted to 100lbs. During all the 16 years he had the boiler, no complete examination was made.

Thomas Morecroft, partner in the firm of Messrs. T. and L. Morecroft, of Sutton Scotney, said the only experience of boilers he had had was in using them. His business was that of a machinist and contractor. In 1909 they had work for another pair of ploughing engines, and he answered an advertisement of Mr. Newman's, and arranged with Messrs. Thurlow to purchase the one in question, but the latter never saw it. He did not know the age of the boiler, and never asked, but went by the number on it. They had no conversation

out the statements made by him, and corroborated as to the 120lbs. pressure at which the safety valve was set when the engine was delivered.

Mr. Robert McCririck, inspector of boilers, engines, &c., for the National Boiler and General Insurance Company, Ltd., said he inspected the remains of the exploded boiler on April 27th and 28th last year. In his opinion the cause of the explosion was the weakening of the shell by the external wasting and the boiler reputured at ordinary working pressure. He had looked at the patch on the boiler and had come to the conclusion that it was placed there at a fairly recent date—within the last five years. It had been put on the boiler after

the severe wasting of the plate had occurred. There was no corrosion on the inner side of the patch.

Mr. Vaux then put in and read the following list of questions, which the Commissioners were asked to answer:—

(1) When, by whom, and for what working pressure was the boiler constructed? When and to whom was it sold by the makers?

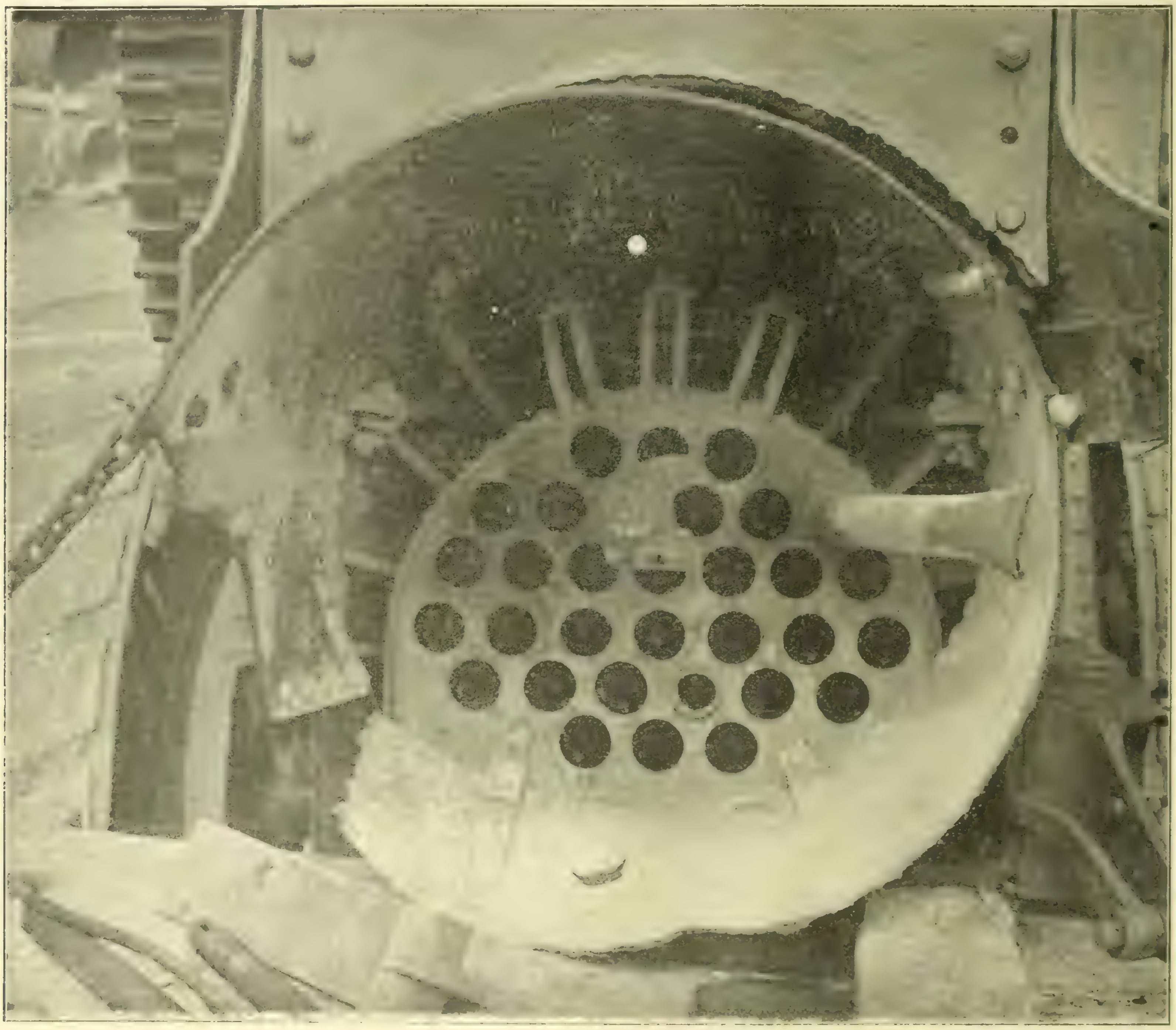
(2) When was the boiler purchased by Mr. Thomas Oswald Newman? During the time it was in his possession, at what pressure was it worked? What repairs were effected to it? Were they properly executed? Was the boiler ever tested by hydraulic pressure?

(3) What were the circumstances in which the boiler was sold by Mr. Thomas Oswald Newman to Messrs George Thurlow & Sons, Ltd., in the year 1909?

Was any guarantee given by Mr Thomas Oswald Newman to Messrs. George Thurlow & Sons, Ltd., or Messrs L. and T. Morecroft, or did he lead both or either of them to understand that the boiler was suitable for a working pressure of 120lbs. per square inch?

(4) Were proper measures taken by Messrs. George Thurlow & Sons, Ltd., and Messrs. L. & T. Morecroft before using the boiler to ascertain the pressure at which it could safely be worked?

(5) During or after September, 1909—(*a*) Was Mr T. Morecroft justified in fixing the working pressure of the boiler at 120lbs. per square inch? (*b*) Was the management of the boiler entrusted to a competent person? (*c*) Was the boiler thoroughly and efficiently examined by a competent person?



EXPLOSION OF A TRACTION ENGINE BOILER AT MANOR FARM, CRAWLEY, HAMPSHIRE.

(6) Were proper measures taken by Messrs. George Thurlow & Sons, Ltd., and by Messrs. T. & L. Morecroft to ensure that the boiler was worked under safe conditions?

(7) What was the cause of the explosion?

(8) Are Mr. Thomas Oswald Newman and his boiler maker, Mr. Charles Wells, Messrs. George Thurlow & Sons, Ltd., and Messrs. Thomas & Lewis Morecroft, or is any, and which of them to blame for the explosion? Should any, and which of them, pay any and what part of the cost of this formal investigation?

Mr. Vaux said the evidence had amply justified the necessity for that formal investigation. There seemed to be a curious lack of business method in the purchase and sale of boilers of this description in this neighbourhood. As regarded Messrs Thurlow, it seemed a dangerous proposition, from the public point of view, for anyone to buy boilers of this description and to delegate the responsibility of seeing that they were fit for a working pressure to any kind of person, one who might be quite ignorant of how to examine and determine for himself whether a boiler was safe or not to work. The evidence showed the necessity for men like Messrs Morecroft, who had no knowledge, to call in expert evidence and to have their boilers examined by a person who really knew whether they should be set to work at the pressure at which they had worked them or not. This should be done periodically. Another point which stood out by itself was that it was a prevailing idea that the fire box and the engine must be looked after and repaired, and that the barrel was a portion which seemed to bear a charmed life and required no inspection at

all. If that enquiry did nothing else but prove the fallacy of such an idea, it was justified.

The President then delivered judgment. He said the Court thought the boiler was originally constructed for a working pressure of 100lbs. per square inch. There was no satisfactory evidence that the boiler was ever tested by hydraulic pressure during the period from 1901-8, nor even examined during that time, either externally or internally, by a competent person. None of the parties knew that the patch was on the barrel of the boiler which exploded, nor that the plate under it had been reduced in parts by corrosion to $\frac{1}{8}$in. There was a difference of opinion as to what the safety valves were set to when they were delivered to Messrs. Morecroft, but whatever the pressure was, the engine was worked at 120lbs. for three week. During the winter the lagging was taken off, and Mr. Thomas Morecroft then saw the patch on the barrel plate near the cylinder, but to him it conveyed nothing whatever, and no examination worthy of the name was made externally or internally of the barrel plates either by Mr. Morecroft or anyone else. Messrs. Thurlow never inspected the boiler or called upon Messrs. Morecroft to repair it, but left everything in the latter's hands. The engine was worked at 120lbs. without consideration as to what would be the safe working pressure, and Mr. Thomas Morecroft was certainly not a competent person to fix it. He acted perfectly honestly, but without adequate knowledge and without seeking, as he ought to have, competent advice. Referring to the patch, he said there was no evidence as to who put the patch on, and, continuing, said that in the opinion of the Court the explosion was caused by the plates along the line of fracture at the top of the boiler being so reduced by external corrosion as to be unable to resist the working pressure. He then proceeded to answer the questions submitted on behalf of the Board of Trade as follows:—

(1) The answer to this we have already given.
(2) Ditto.
(3a) Ditto.
(3b) Our answer is in the negative.
(4) Ditto.
(5a) Ditto.
(5b) Mr. Percy Morecroft was a competent engine driver.
(5c) Certainly not.
(6) Ditto.
(7) This we have already dealt with.

(8) As to Mr. Newman and Mr. Wells, we do not think they are to blame for the explosion; although we strongly deprecate the lax way in which the boilers were worked by Mr. Newman without any proper examination of the barrel plates of the boiler. With regard to the second clause, in our judgment Messrs. L. & T. Morecroft are to blame for the explosion for the following reasons: (1) No proper measures were taken by them before using the boiler to ascertain the pressure at which it could be safely worked or to ensure the boiler was worked under safe conditions; (2) Mr. Thomas Morecroft was not justified in fixing the working pressure of the boiler at 120lbs. per square inch; (3) the boiler was not thoroughly and efficiently examined by a competent person or tested by hydraulic pressure. As to Messrs. Geo. Thurlow and Sons, they were the owners and lessors of the boiler, and we think they were to blame for allowing this second-hand old boiler to be used without any examination whatever by a competent person. In our opinion, a thorough examination by a competent person would have disclosed the fact that it was unsafe to work the boiler with the barrel plates in their wasted condition. We wish, therefore, to say in regard to all these three gentlemen—Mr. Thurlow and Messrs. L. and T. Morecroft—that they gave their evidence very fairly, and rendered every assistance to the Court to enable it to arrive at the cause of the explosion, but we cannot hold them free from blame. We should also add that Mr. Lewis Morecroft left the matter entirely in the hands of his brother, although this does not release him from his responsibility.

Boiler explosions are nearly always due to preventable causes, and there certainly was no unavoidable accident in this case. We think that the explosion would have been averted by reasonable precautions and by the exercise of ordinary care in the examination, inspection, and supervision of the boiler. As already stated, the boiler was made of iron, and was 33 years old at the time of the explosion, part of the plates being reduced by corrosion from $\frac{3}{8}$in., the original thickness, to $\frac{1}{8}$in. at the time of the explosion. We would also point out that in our judgment a boiler should be thoroughly examined and tested by a competent person periodically, to ensure that it is worked under safe conditions. The cylinder and lagging of such a ploughing engine as this should be removed, and a thorough internal and external examination of the boiler should be made, and the soundness and efficiency of the stays tested, and the boiler also should be tested under hydraulic pressure with the lagging off, accompanied by gauging, careful observation, and inspection.

The explosion of steam boilers is still frequent, and even fatal to those whose duty it is to attend to them, and the hardship of working an old worn-out boiler until it explodes is that not only those whose duty it is to attend to them, but strangers who may be casually passing by or even far away from the place of the explosion, are liable to be killed or injured. Children sleeping in their beds or playing in the fields have been killed on the spot or maimed for life by the flying fragments of an exploded boiler. Only a few years ago a boiler exploded, and a portion, weighing two tons, was projected over streets and houses for over 200 yards, two men being killed and several injured by the explosion. In that case, as in this, the original thickness of part of the plate had been reduced by corrosion to one-eighth of an inch, and in that case, as in this, the worn-out condition of the boiler was only discovered after the explosion, and not before, as it ought to have been by a thorough and effective examination.

This is not the first explosion of a ploughing engine, atended by fatal loss of life. As the result of this explosion one man has been unfortunately killed and others injured. We are expressing no opinion as to legal liability, which may involve the consideration of matters foreign to this enquiry, but we think both Messrs. Thurlow and Messrs. Morecroft are responsible before this Court for the efficiency of the boiler and for the exercise of adequate examination, supervision, and inspection by competent persons during its use. The Act of Parliament gives this Court complete discretion over the costs and expenses of this enquiry. We have taken into consideration what has been ably urged by Mr. Snelling on behalf of his clients and all the circumstances of the case, and we think the justice of the case will be met by ordering Messrs. Lewis and Thomas Morecroft to pay £50, and Messrs. George Thurlow & Sons, Ltd., to pay £25 towards the costs of this enquiry. In conclusion, we would wish to thank Mr. Tarrant, the engineer and surveyor to the Board of Trade, for the great assistance he has given us in this case, and to express our sympathy with the relatives of the man who was unfortunately killed, and to the other persons who were injured by the explosion.

The enquiry, which extended three days, then closed

Hydro-electric Power Station for Chester.—The Chester Town Council has adopted a scheme under which the water of the River Dee at the weir at Chester will be used for the generation of electricity. The scheme has been prepared by the City Electrical Engineer (Mr. S. E. Britton), and has been confirmed by an expert. The Electricity Committee recommended that permission should be obtained to borrow £13,000 for the construction of works on the site of the old Dee mills. The Town Clerk reported that he thought the Waterworks Company would offer no opposition to the power scheme. The scheme proposes to utilise the water power of the old Dee mills for generating electricity by means of three water turbines and three electrical generators. It is estimated that 1,500,000 units can be obtained, and that the sale of electricity so generated will produce £5,000 a year, yielding a surplus income of something like £3,000, so that the committee would be able to repay the capital involved in [illegible] years. No water scheme in England at present exists on so large a scale. The power at the Dee mills had been used for centuries to some extent by the mills at present situated at Chester. A certain amount of opposition to the scheme was expressed at the meeting, but two amendments for deferring it were defeated, and the scheme adopted.

PARSONS' CENTRIFUGAL PUMP.

WHEN centrifugal pumps are used to deal with fluids in which fibrous or solid matter is present, the operation of the pump is seriously impaired by the presence of such material, this trouble frequently arising, for instance, in the pumping of sewage. In the endeavour to overcome this difficulty, a screen has been employed at the inlet to the pump for the purpose of excluding this solid and fibrous matter. Such a screen, however, soon becomes choked, and its cleansing is a matter of considerable trouble and expense, and in some cases is impracticable. With a view to overcome this difficulty, the construction of pump shown in the accompanying illustrations has been designed and patented by The Hon. R. C. Parsons, M.A., 3, Victoria Street, Westminster, London.

Referring to the illustrations, Figs. 1 and 2 show an outside elevation and an end view of the pump, with the part of the casing containing the suction pipe removed. Fig. 3 is an end sectional elevation through the shearing plate carrier on the line 1 of Fig. 1. Fig. 4 is a sectional view on the line 2 of Fig. 3. Fig. 5 is a sectional elevation of the pump on the line 3 of Fig. 2. The casing of the pump is of usual form, with suction and delivery pipe, B and C, respectively. The blades D are attached on one side only to a circular plate E, carried by the pump driving shaft F, while the edges of the blades D, adjacent to the inlet pipe B, are so formed that their surface of revolution is entirely or partly that of a cone having the shaft F as axis. The shearing plate G has an edge H, in a line situated in a plane passing through the axis of the cone. The plate edge H is a straight line, and being in contact or nearly in contact with the edges of the blades D, forms therewith pairs of cutting edges. In order to prevent any fibrous or other material lodging against the shearing plate G, the side of the plate facing the direction of inward flow to the pump is provided with an inclined web K, attached to the inlet pipe and projecting radially as far as, or beyond, the centre thereof, as shown in Fig. 4. By this means, solid or fibrous material is prevented from lodging against the plate G, and is passed into the pump. The shearing plate is fixed in such a position that its plane does not pass through the axis of the cone formed by the rotating blades D, but is some distance therefrom, so that the edge of the rotating blades, in rubbing against the shearing plate, always maintain a sharp cutting edge, H, on the latter. The shearing plate is arranged in such a manner that it can be moved forward towards the edge of the rotating blades when desired, in order to compensate for wear.

The method of effecting this is illustrated in Figs. 3 and 4, in which the conical cover is formed by a portion of the pump casing with a cylindrical casting M, between the pump inlet pipe and the main part of the casing. The open end of the casing M is closed by a cover plate N, held in position by eye bolts and nuts, the cover plate carrying a web Q, which projects into the pump casing for the purpose of supporting the shearing plate G, and which is provided with planed faces against which the plate can bear. The shearing plate G is securely held in position by a plate R, placed against the plate G, on the side remote from the web Q, and secured partly by lugs S, which engage in projections cast on the web Q, and partly by a screw T, passing through the wall of the cylindrical casting M, and pressing upon the plate R. The screw T thus acts to transmit directly to the casing of the pump any pressure produced by the cutting action. The web Q and plate R are provided with projecting parts, U and V, respectively, as shown in Fig. 3, and in such a manner that when in position these projecting parts form a continuation of the inner surface of the inlet pipe B and of the conical portion W of the pump casing, so that, with the exception of a small slit through which the shearing plate G protrudes, there is no interruption in the internal surface of the pump casing. Consequently the loss of power through the formation of eddies round the cutting edge is reduced to a minimum. The position of the shearing plate is adjusted by means of a screw-threaded bolt X and locking nut, the former passing through the cover plate N, and having a head which engages in a notch in the shearing plate G.

Owing to the curvature of the rotating blades, each blade

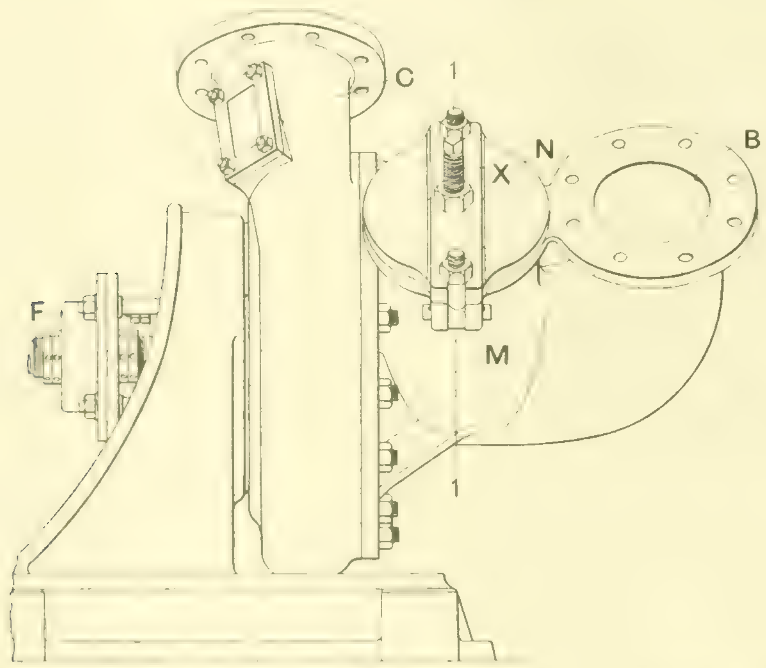


FIG. 1.

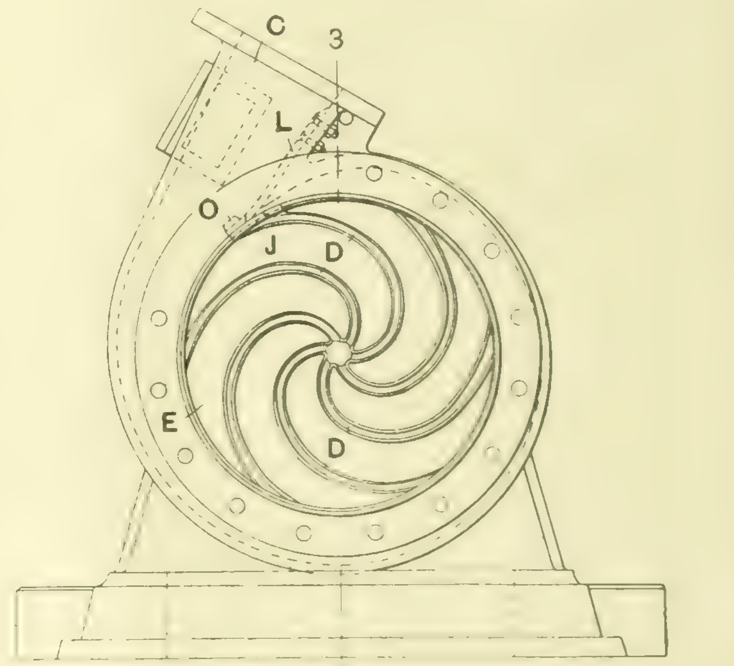


FIG. 2.

PARSONS' CENTRIFUGAL PUMP.

will only contact with the shearing plate at one point at any given instant, and this point of contact will move along the cutting edge H of the plate G as the blades D are rotated. By this relative motion, between the rotating blades and the shearing plate, any solid or fibrous matter which is unable to enter between the rotating blades is pushed forward and cut into pieces of such dimensions as will allow it to pass through the pump. In order to ensure that no solid or fibrous matter shall become fixed in the passage between the rotating blades, or in any other orifices of the pump, the inlet passage in the vicinity of the shearing plate is arranged to be of smaller dimensions than those of any other part of the pump, the passages of flow diverging therefrom to the delivery of the pump. In this way any solid or fibrous matter which is unable to pass between the rotating blades is cut, and re-cut if necessary, into portions that are small enough to pass easily through any other passage of the pump. The shearing plate may in some cases extend throughout the whole radial dimensions of the rotating blades, or may be arranged to terminate at any less radial distance. In the latter case a groove A, of spiral form, and having square edges, is formed in the internal surface of the pump casing beyond the end of the shearing plate, for the purpose of facilitating the passage of the matter and prevent it from becoming jammed between the edges of the blades and the conical casing after passing the cutting edge.

Usually, the junction of the walls of the volute or spiral chamber of the pump with the wall of the delivery pipe is

continued as near the blade outlet edges as possible, in order to provide a volute continuous from the blade outlet edge. It is preferable, however, to form the above continuation by means of a removable plate L, as shown in Fig. 2, and purposely of less strength than the blades D and attached to the pump casing. The removable plate is curved so as to lie in the path of the outer edge of one of the blades D, and is provided with a V-shaped groove, the sides of which form cutting edges. The outer edge J of the blade which contacts with the plate L is shaped, as shown, so as to form, together with the

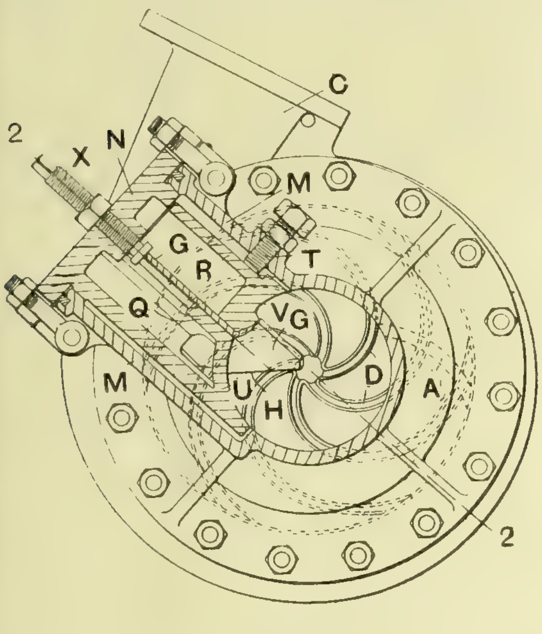


FIG. 3.

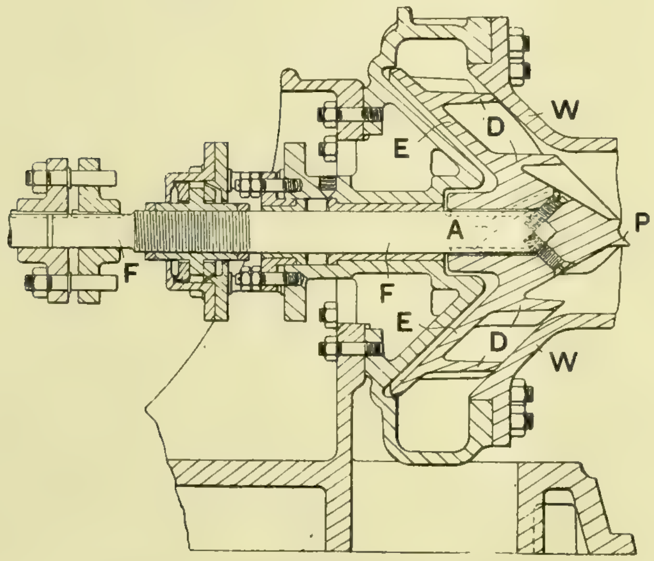


FIG. 5.—PARSONS' CENTRIFUGAL PUMP.

plate L, a pair of edges capable of cutting any hard or fibrous substance which might become entangled with the plate L. This plate is supported by a projection O, cast on the sides of the pump casing, with or without a similar projection on the cover M, or the plate may be kept free of obstruction by means of prongs formed upon the edge of the blades D, and touching or nearly touching the plate L, and thereby removing any substance adhering to the latter in their passage past the plate during the revolution of the disc E. These prongs are so placed upon the blades D that while all of them would effectively clear the whole width of the plate L, the number of prongs upon each of the blades D would be so small as to cause only a negligible obstruction to the passage of liquid through the pump. It will thus be seen that should any hard substance pass accidentally between the impeller blades and the plate L, so as to cause undue stress to either of them, the latter will break first, thereby preventing injury to the impeller, and allowing the pump to operate as before, the broken plate L being subsequently replaced by a new one. As shown in Fig. 5, the apex of the cone formed by the disc E is provided with teeth P, made eccentric, so as to dislodge or disintegrate any solid matter which may rest against the disc, and so ensure that such matter is carried to the cutting edge H of the shearing plate. Provision is made for adjusting the longitudinal position of the rotating blades, so as to provide for wear of the blade edges.

ASSOCIATION OF CONSULTING ENGINEERS.

We have received the following official report of the recent meeting of this Association :—

On Monday, the 15th ult., the inaugural meeting of the above Association took place for the purpose of formally receiving the rules which had been drawn up by the committee appointed for this purpose at the opening meeting some 18 months ago. Between 60 and 70 engineers were present. The chair was taken by Mr. James Swinburne, who was supported by the majority of the committee, which consists of the following engineers: John S. Alford, H. Percy Poulnois, Edward M. Eaton, Robert Hammond, Joseph H. Harrison, Baldwin Latham, Charles Lomax, Sidney R. Lowcock, Ernest L. Mansergh, Arthur J. Martin, Thomas L. Miller, William M. Mordey, William H. Patchell, W. Llewellyn Preece, Henry Rofe, John F. C. Snell, E. Herbert Stevenson, James Swinburne, A. A. Campbell Swinton, Gotfred Midgley Taylor, and Alfred H. Dykes, honorary secretary.

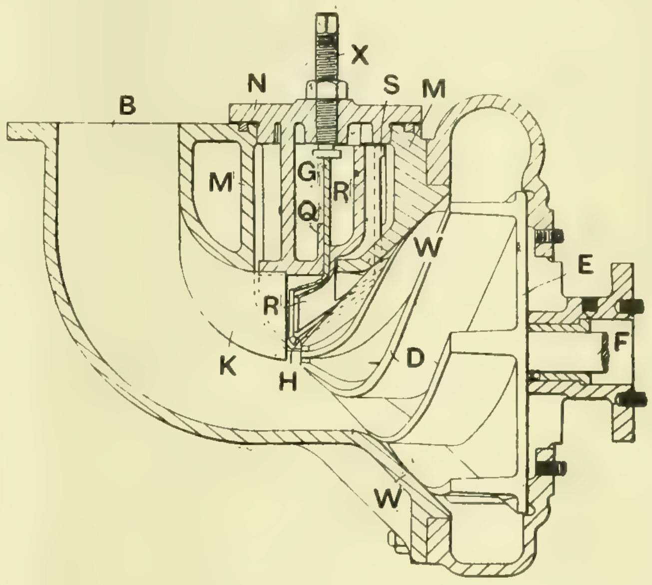


FIG. 4.

The Chairman, in opening the proceedings, said that it was his first business to explain the objects of the Association, but that he did not think he need say very much in that direction, because they all knew what the objects were. The Association should have been launched 50 years ago; in the present state of things, however, it was very difficult to form an Association in such a way as to be satisfactory to everybody. At the same time, he was of opinion that if consulting engineers did not take this opportunity of uniting themselves together there was no chance of their ever doing so. It behoved them, therefore, to proceed very carefully and to build on sure foundations.

Most institutions had begun by taking in everyone they could get, with the idea that the more members they got the more powerful the institution would be, and the result was that after they had been in existence some time they had to narrow down. He thought that they should, in the present case, go to the other extreme. If they began by making it very small, perhaps in the opinion of many, too small, then, when the Association was in active existence, it could always enlarge itself in any direction it desired, should it be thought advisable.

One of the qualifications for membership in the rules was that the applicant should be a full member of the institution controlling the branch of engineering in which he practised. It was true that the rules provided that, in addition, members should be of such standing as, in the opinion of the committee of the Association, entitled them to admission to the Association; but in the initial stage in which they were at the moment (namely, of having formed the Association and appointed the committee, drawn up rules, and received applications for membership, but not having yet actually any members), the committee were of opinion that it would be wise to adopt some recognised standard of qualifications and to limit the first members to those possessing the qualification of corporate membership of the Institution of Civil Engineers.

They were aware that this restriction might be criticised by some people, who might say that they were mechanical engineers or electrical engineers, and of eminence in their profession, and did not see why the fact that they had not joined the Institution of Civil Engineers should prevent them from joining the Association. On the other hand, it must not be overlooked that the Institution of Civil Engineers was not only the oldest institution, but was the parent engineering institution, and that the majority of consulting engineers already belonged to it in addition to the institutions representing the particular branch in which they practised.

If any competent consulting engineer, who was not a member of the Civils, felt aggrieved that he could not belong to the Association, surely it was not asking a very great deal

of him to ask him to join the Civils. If the Association, starting as a young society, could use a body like the Institution of Civil Engineers, which had always been fairly strict in the selection of its candidates and was getting stricter every year, and thus throw the responsibility of deciding as to a candidate's qualifications upon an established institution, leaving the Association merely to decide as to his qualifications in other respects, they were solving one of the greatest difficulties.

Later on, when the committee would be in a position to know the feeling of consulting engineers in general, and when the members had had time to become acquainted with the working of the Association, they might find it advisable to make some change, but that was a matter for the future. At anyrate, the present committee felt strongly that the lines he had indicated should be followed for the moment; he himself believed that they were the right lines, and probably the permanent lines.

There was another direction in which they thought the committee ought to be very narrow, which was also a matter of considerable difficulty, and that was with regard to the admission to the Association of engineers, many of whom were of the highest eminence, who were receiving a salary and were giving practically the whole of their time to some corporation or some public body. The committee wished to be logical in carrying out their idea of starting on the narrowest lines, and felt that they should confine the Association initially to those regularly in practice as consulting engineers and having their own separate office and staff.

The Association did not aim at stopping competent consulting engineers who might not join them from doing consulting work, nor did they wish to claim a monopoly. The committee felt, however, that engineers falling within the class he had outlined were entitled to associate themselves together and to form an association which would gradually, through its own standing and character, become recognised as the body of consulting engineers.

After the proposed rules had been introduced by Mr. Midgley Taylor and Mr. S. R. Lowcock, a general discussion took place, the speakers being Messrs. B. M. Jenkin, W. Fairley, A. Williams, A. G. Hansard, Cawley, Robert Hammond, E. J. Silcock, H. P. Boulnois, A. S. E. Ackermann, H. P. Raikes, F. W. Hodson, Moss Flower, Druitt Halpin, and P. Griffiths. The main points to which speakers referred were the scope of the Association, the desirability or otherwise of the membership being restricted to corporate members of the Institution of Civil Engineers, registration of consulting engineers, solicitation of work, and the desirability of consulting engineers being free from trading or manufacturing interests. In the course of the discussion the Chairman pointed out that the rules were put forward subject to legal revision.

In conclusion, at the suggestion of Mr. Lomax and Mr. W. Duddell, the Chairman put a motion to the meeting to the effect that corporate membership of the Institution of Civil Engineers be a condition of membership of the Association* (with discretionary power to the committee) and that the committee have power to elect members from among those who have applied. This motion having been duly carried, the proceedings terminated with a vote of thanks to the Chairman. It is hoped that all consulting engineers possessing the necessary qualifications will join the Association and communicate at once with Mr. A. H. Dykes, the honorary secretary, at 11, Victoria Street, Westminster, S.W. This will enable a list of first members to be made without delay. A meeting of members will then be called to ratify the Rules and to appoint the Executive Committee.

* Rule 5 (a) now reads as follows: "He shall be a full member of the Institution representing the particular branch of the profession in which he practises, and a corporate member of the Institution of Civil Engineers."

ELIMINATING VIBRATION IN HIGH-SPEED INTERNAL-COMBUSTION ENGINES.

In high speed, multi-cylinder, internal-combustion engines, such as are used in vehicle propulsion, the elimination of torque variations is effected in the usual way by the use of a heavy flywheel secured to the crank shaft. Such crank shafts present a new problem to the designer, however, for at certain speeds of rotation it is found that objectionable, and sometimes dangerous, torsional vibrations are set up. With the object of eliminating such vibrations, Mr. F. W. Lanchester, 53, Hagley Road, Edgbaston, Birmingham, has designed and patented the arrangements illustrated herewith.

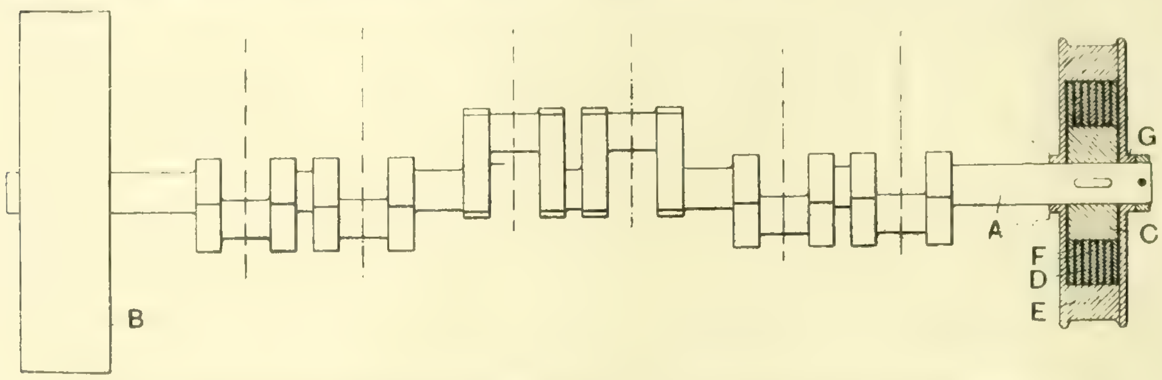


FIG. 1.—ARRANGEMENT FOR ELIMINATING VIBRATION IN HIGH-SPEED INTERNAL-COMBUSTION ENGINES.

In Fig. 1, which shows one arrangement applied to a six-cylinder motor, there is keyed to the rotating shaft A at the end furthest from the flywheel B a coupling piece C, provided with discs D projecting outwardly. Over the coupling piece C there is fitted a heavy wheel E having internally projecting discs F projecting between the discs D of the coupling piece. The heavy wheel E is provided with a bearing G on the crank shaft. A suitable oil film is formed between the heavy wheel E and its ribs and the coupling piece C. In this arrangement, if the shaft is rotating uniformly, the heavy wheel E is carried round at the same velocity as the shaft. If, however, owing to the action of the connecting rods on the shaft there is at any given speed a tendency to set up torsional oscillations at the end A of the shaft, these oscillations cause variations of speed between the end of the shaft A and the uniformly moving heavy wheel E, and the pull between the coupling piece C and the heavy wheel E through the oil film will tend to damp out these oscillations. In the

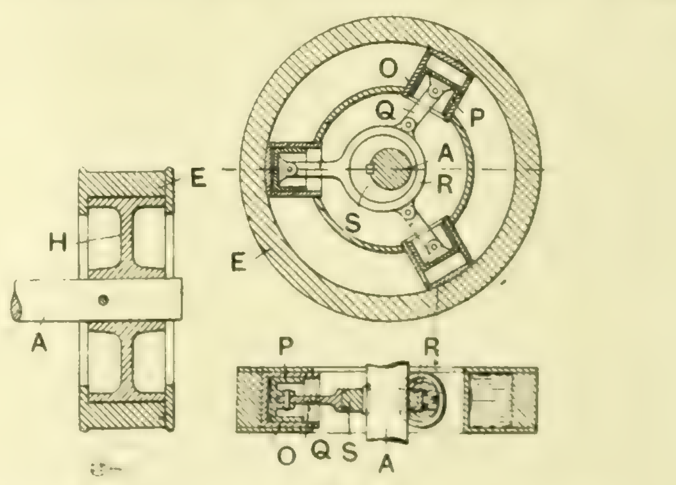


FIG. 2. FIG. 3.
ARRANGEMENTS FOR ELIMINATING VIBRATION IN HIGH-SPEED INTERNAL-COMBUSTION ENGINES.

form shown in Fig. 2, the heavy wheel E is formed so that it takes a bearing on the wheel H keyed to the shaft A, an oil film being provided between the wheels E and H.

In the arrangement shown in Fig. 3, the coupling is effected by means involving the flow of liquid through restricted apertures. The heavy wheel E is provided with a number of cylinders O in which work pistons P, connected by connecting rods Q with a sleeve R on an eccentric S keyed to the shaft A. The space between the pistons and the heads of the cylinders is filled with a suitable liquid, and restricted passages are provided whereby this liquid can be forced out or in should there be a tendency to relative movement between the shaft and the heavy wheel. In this design it is essential that the wheel should do some work, in order that the rate of efflux may be such that given increments of velocity result in substantial increments of resistance.

HERRINGBONE GEARS.*

WITH SPECIAL REFERENCE TO THE WUEST SYSTEM.

BY PERCY C. DAY.

(Concluded from page 95.)

IN order to obtain a simple rule for finding the proper dimensions, the results of experience in the matter of safe working loads under given conditions have been reduced to a relationship between pitch line velocity and the shearing stress on the pitch line thickness of an imaginary straight tooth, assuming only one tooth in engagement at a time. The shearing stress is a measure of the specific tooth pressure, and the relationship referred to affords a convenient means of arriving at reliable dimensions. The curves, Fig. 6, give values of shearing stress K in pounds per square inch on pitch line section of an imaginary single tooth for corresponding pitch line velocities V in feet per minute. The values are entirely empirical, but they are based on the results of extended experience, and lead to dimensions which are safe and reliable. Different curves are given for different materials, and it is necessary to use that curve which corresponds to the lowest grade material of the combination. The dimensions of gears can be derived from the curves in the following manner:—

h.p. = brake horse-power transmitted
N = revolutions per minute
D = pitch circle diameter, inch
p = circular pitch in inches (use nearest diametral pitch)
W = total width of face, inch
V = pitch line velocity, feet per minute
P = total tooth pressure at pitch line, pound
K = stress factor (from curve)

$$V = \frac{\pi DN}{12} \qquad (1)$$

$$P = \frac{\text{h.p.} \times 33{\cdot}000}{V} \qquad (2)$$

$$P = \frac{pWK}{2} \qquad (3)$$

$$P = 3p^2K \left(\begin{array}{l}\text{in normal gears of moderate ratio, and face}\\ \text{width equivalent to 6 times the circular pitch}\end{array}\right) \qquad (4)$$

$$p = \sqrt{\frac{P}{3K}} \qquad (5)$$

For high ratio gears take $W = Rp$ (R = ratio to 1) up to maximum of $W = 10p$.

$$p = \sqrt{\frac{2{\cdot}5\,P}{RK}} \qquad (6)$$

Usually the values of h.p. and N are known. In many cases the diameters or centre distances are fixed, and there is no choice of dimensions. When the diameters are not fixed there are many solutions to the same problem and it becomes largely a matter of experience which to select in order to obtain the most economical and satisfactory gears.

In normal gears it is safe to aim at pitch line velocities between 1,000ft. and 2,000ft. per minute, with 1,500ft. as a fair average. If the pinion is to be fixed to a motor shaft without external support, the diameter must be greater than when it can be supported on both sides. Cast iron is preferable to cast steel for gears of large diameters and moderate power, but the latter will be found more economical for high tooth pressures. Pinions are usually made from steel forgings of 0·40 to 0·50 per cent. carbon. Soft pinions should never be used for herringbone gears. Besides being bad engineering practice, they are unnecessary, because steel pinions run without noise and last much longer.

The following is a typical instance of the range of choice in dimensions: A pump which requires 150 h.p. at 50 revs. per minute is to be driven from a motor at 500 revs. per minute, with shaft end 4½in. diam. If the shaft is unsupported, it is not desirable to use a pinion of less than 10in. If the shaft is extended to a third bearing a 7½in. pinion can be used. If the pinion is cut solid on its shaft and coupled to the motor, its diameter can be reduced to 5in. The three arrangements work out as follows:—

	Material for Gear.	V.	P.	K.	Diametral Pitch	Face Width.
A 10in. and 100in. ...	Cast iron	1,300	3,800	500	2	9½
B 7½in. and 75in. ...	Cast iron	975	5,100	530	2	12
C 7½in. and 75in. ...	Cast steel	975	5,100	1,060	2½	7½
D 5in. and 50in. ...	Cast steel	650	7,600	1,150	2½	12½

Any of the above gears will do the work satisfactorily. *C* is the most economical, but *B* or *D* would make the least noise. If a gear case is to be provided, then *D* will give the most economical combination.

The foregoing data can be used for finding the required dimensions of herringbone gears for all general applications. In most cases it is sufficient to calculate the tooth pressure from the average working load. When the maximum load is very far in excess of the average, it is usual to take a mean value between the two. Gears for electric mine hoists and single-throw pumps fall within this category. Machine tools, when driven from variable-speed motors, are required to perform maximum duty at minimum speed only for short periods at long intervals. It is sufficient, when getting out gears for a drive of this kind, to reckon with the rated output of the motor at the mean between its maximum and minimum speed.

There are two special cases where the ordinary methods of calculation should not be used. Rolling-mill gears are subjected to stresses which are so far in excess of the average working load that it is necessary to consider carefully the strength of the teeth in regard to possible overloads. Extra high velocity gears, such as are used for steam turbines, require additional wearing surface, and are characterised by extreme width of face combined with abnormally fine pitch. These are two extremes in gearing, and their design is best left to those who have made a special study of them.

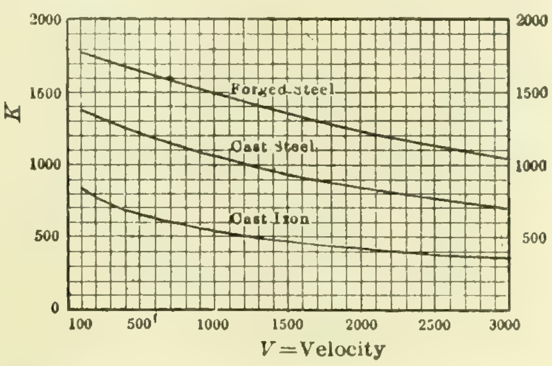


FIG. 6.—SHEARING STRESS IN RELATION TO PITCH-LINE VELOCITY.

Before describing some special applications of these gears to the needs of various industries and machines, it may be of service to summarise the salient features of the gears and the changes of view-point which these features have engendered.

The smooth and continuous action is virtually independent of the diameter or number of teeth in the pinion. Extremely high ratios of reduction can be used without fear of uneven driving or undue wear, and without need for unwieldy gear diameters which would be disproportionate to the general design. High-ratio gears of this type transmit power with practically no more loss than low-ratio gears. They are far more efficient than belts, ropes, worm gears, or compound trains of spur gearing, while their adoption results in a wholesale reduction of countershafts and bearings, which reduces the power consumption and running costs to a remarkable degree.

There are many instances where spur gears cannot be used because the vibration which they set up has a detrimental effect on the driven machine or its product. The inconvenience of a cumbersome system of belts or ropes has usually to be borne in such cases, but it is not too much to say that the requirements of almost all of them are fully satisfied by this type of herringbone gears.

The application of spur gears has been much restricted by the noise which they make when run at high velocities. The use of rawhide or other soft materials has only proved moderately successful for comparatively light work, and is quite unsound for heavy gear practice. Herringbone gears

* Paper read before the American Society of Mechanical Engineers.

in combination with durable steel pinions make less noise than soft pinons and spur gears when new, and while the former become quieter with use, the latter soon begin to rattle as they become worn. It should be noted that the use of soft pinions, while mitigating the nuisance of excessive noise, does not reduce vibration or unevenness of motion.

There is a limit to the pitch-line velocities at which spur gears can be operated, beyond which it is unsafe to use them. This limit is far below the minimum velocities which can be used in connection with steam turbines of economical design and high power.

Accurate herringbone gears operate quite smoothly at velocities which are impossible for other types. This feature

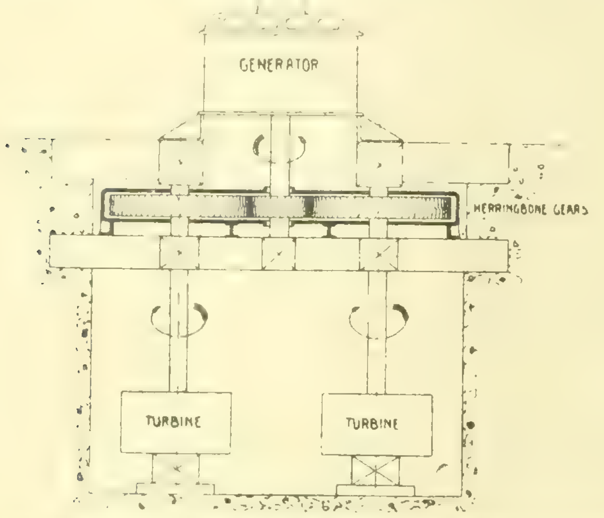


FIG. 7.—DIAGRAM OF GEAR CONNECTION BETWEEN HYDRAULIC TURBINES AND AN ELECTRIC GENERATOR.

would appear to reserve for them a field of application which has great possibilities, and is likely to cause some great changes in the standard practice of to-day.

Application to Steam Turbines.—There are many instances when the power of the turbine can be more conveniently applied in mechanical form than through electrical transmission. The advantages of high-power turbines have been discounted in many instances by the necessity for expensive electrical outfits with their attendant losses of generation, distribution, and conversion.

Direct-connected steam turbines for marine propulsion have been only partially successful in a very limited field. The screw propeller, working in a dense medium, has an economic speed of rotation which is far below the best speed for a steam turbine of corresponding power. It is only when the power required is very great and the speed of the vessel usually high that the direct-connected turbine can be applied, and even then the application does not do full justice to either turbine or propeller, while the first cost is much higher than it need be. The use of direct-coupled turbines is confined to ocean fliers and ships of war. Ordinary vessels of commerce, which are built in vastly greater numbers, cannot be adapted to turbine power in this form. Mr. Parsons attacked the problem of applying the turbine to an ordinary freight steamer of moderate power. To this end he purchased the s.s. "Vespasian," a modern tramp with triple-expansion engines of about 1,000 h.p. and a speed of 11 knots with propeller running at 75 revs. per minute. As a preliminary to the installation of geared turbines on this vessel, the original engines were overhauled and tuned up and a series of coal-consumption trials made under regular sea-going conditions.

The engines were then removed, and for them were substituted a pair of steam turbines connected to the propeller by herringbone gears. Each turbine develops about [illegible] h.p. at 1,500 revs. per minute. The propeller runs at the original speed of 75 revs. per minute. Each turbine is coupled to a herringbone pinion with teeth cut solid on a shaft of soft-grade chrome nickel steel. The two pinions mesh with rolled-steel gear rings mounted on a cast-iron spider which is keyed to the propeller shaft. The whole gear system is enclosed in a case, and the teeth are kept lubricated by oil jets. The great width of the pinions in proportion to their diameter made it necessary to provide room for bearings between the right and left hand teeth. The proportions of this remarkable gear unit are as follows: Pinions, 20 teeth; gear, 398 teeth, four diametral pitch; teeth of involute form, 20° pressure angle, 23° spiral angle; over all face width, 34in. including 10in. space for bearing; actual face width, 24in.; ratio of reduction, 19·9 to 1.

This gear has now been running regular voyages for more than a year and has covered over 20,000 miles. The results have been interesting and satisfactory. The efficiency of the gear is fully 98 per cent., including the losses in the bearings on the gear case. The geared turbine shows a sustained all-round saving in fuel consumption of more than 25 per cent. over the original engines. The gear runs with remarkable smoothness and without noise or vibration. The wear on the teeth is negligible after 20,000 miles, being only 0·002in. at the pitch lines of the pinions. Even this small wear is nearly all traceable to inadequate arrangements for freeing the oil from grit during the first runs.

Not by any means the least important gain is in the behaviour of the vessel in rough water. There has been no racing of the propeller under circumstances where this disagreeable feature was painfully evident with the original installation. This is due to the high rate at which the turbine motors store up energy with change of speed, which makes it impossible for a large change to occur during the time when the propeller is partially uncovered. Such a record as this is so conclusive that the use of geared turbines for marine propulsion must shortly become general. Herringbone-geared turbines aggregating 3,600 h.p. have recently been fitted to the U.S. s.s. "Neptune" by the Westinghouse Machine Company. The performance of this vessel will be awaited with interest.

Mr. Parsons has made a successful introduction of herringbone gears in combination with a steam turbine for driving a continuous plate mill. This is a proposition which few engineers would have considered seriously, yet it has proved a success from every point of view. The mill is of the 3-high type with rolls 28in. by 84in. running at 70 revs. per minute. The turbine is designed for mixed pressure, running at 2,000 revs. per minute with exhaust steam at 16lbs. absolute or live steam at 60lbs. absolute, and giving 750 b.h.p. The turbine is coupled to the rolls through a double train of herringbone gears. The first train consists of a chrome nickel steel pinion, cut solid on its shaft, and cast-steel gear. Pinion and gear have 25 and 131 teeth, 3½ diametral pitch, by 24in. face. This train reduces from 2,000 to 375 revs. per minute, and is coupled to the second train through a flexible coupling. The second train includes a high carbon steel pinion of 23 teeth

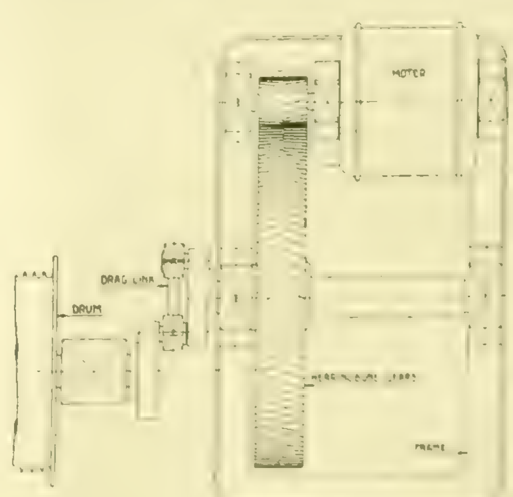


FIG. 8.—ELECTRIFICATION OF MINE HOIST FORMERLY STEAM DRIVEN.

and cast-steel gear of 127 teeth, 2in. circular pitch by 16in. face. This train reduces from 375 to 70 revs. per minute. The final gear is overhung on the end of a flywheel shaft 22in. diam., which carries a flywheel of about 100 tons between two bearings and is coupled to the main pinion through a pair of wobblers. Both sets of gearing are enclosed in casings and are lubricated by oil jets from a pump provided for the purpose. This mill has been running without a hitch of any kind since September 15th, 1910. The gears are noiseless, the installation shows remarkable efficiency, the rolls run with extreme smoothness, and the pinions do not show appreciable wear. The success of the geared turbine for such an application as the one described makes it certain that similar arrangements can be used with advantage for driving textile and other mills where the conditions are less severe.

The geared turbine is making rapid progress for driving

direct-current generators, and several large sets are now running and in course of construction. Hitherto, it has been usual to couple the turbine to a high-speed alternator and to convert to continuous current through a motor generator or rotary converter. The geared turbine unit costs less money, takes up less space, and has an over-all efficiency at least 6 per cent. better than the A.C.—D.C. combination. Geared turbines have another field of application for driving centrifugal pumps. Direct-driven units of this kind have poor efficiency because a compromise has to be made between turbine and pump speed which is detrimental to both. The interposition of a set of herringbone gears allows both ends to be constructed for the highest economy, and since the loss in the gears does not exceed 2 or 3 per cent. there is a large all-round gain in efficiency. This applies also to turbine-driven blowers and fans.

Geared Hydraulic Turbines.—The speed of hydraulic turbines is controlled by the available head of water supplied to them. The greater number of turbines are required to operate under low heads and must run at slow speed. Hydro-electric power has usually to be transmitted to a considerable distance, and is produced in the form of alternating current of definite periodicity. The speed of the turbines may be as low as 50 revs. per minute, or even less. A large direct-coupled alternator for this speed is an expensive proposition. Herringbone gears can be used to speed up from the slow-running turbines to generators of normal design, speed, and efficiency. The smooth action of these gears is unimpaired when the wheel drives the pinion, and high ratios of speed increase can be obtained from them without noise and with less loss than direct-coupled units will give. A typical installation of this kind is outlined in Fig. 7. This arrangement shows two slow-speed vertical turbines driving one generator. A herringbone gear is mounted on each turbine shaft and both gears mesh with a pinion which is coupled to the generator.

Rolling Mills and Rod Mills.—There are two advantages in the use of accurate herringbone gears for this class of work. The absence of shock in transmission renders breakages much less frequent than with cut spur or moulded helical gears. The even transmission and entire elimination of vibration allows the finishing rolls to be gear driven for the finest work without showing gear marks on the finished product. Herringbone-geared mills run with very little noise. This may be of less consequence in rolling mills than in most other applications, but it is an improvement. Rod mills, with their quantities of high-speed gearing, can be completely transformed by using herringbone gears and mill pinions.

Machine Tools.—The field for accurate herringbone gears in connection with machine-tool driving is too extended to be considered in detail. For individual motor drives this gear gives a positive transmission which is free from vibration and less noisy than so-called silent chains or rawhide pinions, while there is no trouble from slipping belts or slack chains. But the real advantage of these gears lies in the better finish that can be obtained when they are used for the entire main transmission, and in the higher output combined with reduced maintenance which they give to heavy machine tools. Chatter is eliminated. Even the speeding up to the wheels of grinding machines has been successfully accomplished. Reversing gears for heavy planers are a revelation to those familiar only with the ordinary spur drive.

Pump Driving.—Electrically-driven plunger pumps have not enjoyed the popularity that might be expected, due to the noise and vibration caused by the gearing between motor and pump shaft. These objections are obviated by accurately-cut herringbone gears, which not only give silent and vibrationless transmission but admit the use of high ratio single reductions with compact dimensions. The single reduction drive has a much higher efficiency than the ordinary double train, quite apart from the lower gear losses, because at least one countershaft can be dispensed with. Similar drives are successful for air compressors and vacuum pumps, which present similar difficulties to those met with in plunger pumps.

Application to Mining.—One of the features in the recent electrifications of the Eckstein group of mines on the South African Rand is a train of herringbone gears between motor and drum in the main hoists. These hoists are driven by reversing asynchronous motors; the geared countershafts being connected to the drums by drag links from the original crank pins that were used when the hoists were run by steam power. The arrangement is shown in Fig. 8.

In installations of this type there are no slipping clutches, and the strains on the gears are very severe, some of them having to transmit 3,000 h.p. to 4,000 h.p. at pitch line velocities ranging from 2,000ft. to 3,500ft. per minute. The large coal mines in Northumberland, Yorkshire, and South Wales are rapidly adopting high-tension 3-phase current for the distribution of power below ground. Some very large main and tail, and endless, haulages are used in these, and herringbone gears have become a standard for this class of work. The hoists range from 30 h.p. up to 1,000 h.p., and invariably use a high reduction with ratios which are sometimes as high as 15 to 1. Simplification of design and saving of space is obtained in this way, since ordinary spurs require a double train. The gain in efficiency and absence of noise are remarkable, while the first cost of the whole outfit is often less than when cheaper gears are used. The elimination of all vibration prevents crystallisation of the shafts and disintegration of the insulating material in the motors. These gears offer the same advantages for endless haulages. A higher speed motor can be used when they are adopted, while no more than two trains of gears are required.

An application of especial interest is for driving tipplers. These gears for this purpose have replaced worm gears because they stand up to the heavy strains without excessive wear

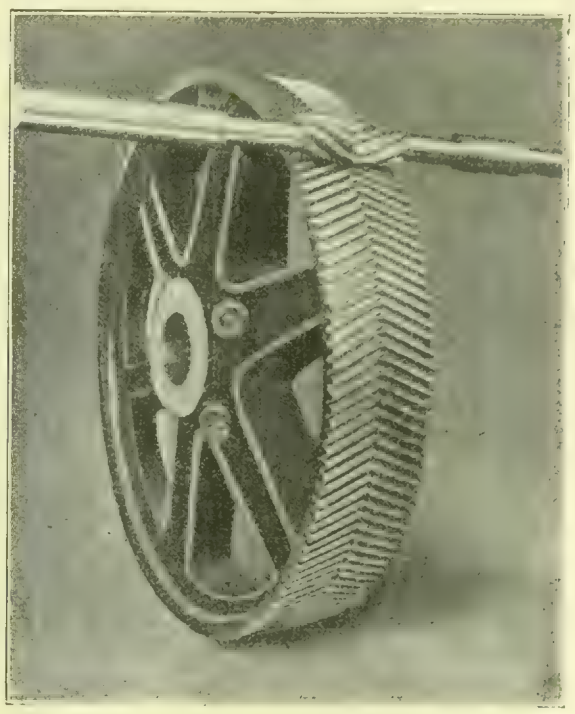


FIG. 9.—TYPICAL HIGH RATIO GEAR AND PINION, THE LATTER WITH EIGHT TEETH.

The available space for the gears is always limited in such cases. A typical high-ratio gear is shown in Fig. 9.

Elevators.—There are very few high buildings in Europe, and the elevators there run at comparatively low speeds. As a consequence, worm gears predominate there for this class of work. The Wuest type of gear was brought out with a view to overcoming the losses inseparable from worm gears with high ratios. The needs of American sky-scrapers have caused the development of elevators in this country to run on different lines, so that the popular type of to-day has the rope sheave direct connected to the motor. Needless to say, the motor runs at exceedingly slow speed, usually not more than 50 or 60 revs. per minute as a maximum. Such a motor is expensive and inefficient. The system of control is wasteful to a degree. Field regulation is out of the question, and the speed control is obtained by shunting the main current through a resistance so as to reduce the volts across the armature of the motor. The survival of so uneconomical a type of machine is due to there having been no satisfactory gear system which would fit the peculiar conditions. A number of elevators are now being equipped with herringbone gears. The motor is geared to the sheave through a single train with a ratio of about 10 to 1. The maximum motor speed is about 500 revs. per minute, and the speed control is nearly all obtained by simple field regulation. The following advantages are claimed: The power consumption is not more than 60 per cent. of what is required for direct-connected motors, the electrical switch-gear is far more simple, has less to do, and is not so liable to get out of order; the motor can be repaired without interfering with the car or its suspension.

ELECTRICAL FURNACES.

A PAPER on electrical furnaces as applied to the manufacture of steel and steel alloys was read by Mr. C. Myers at a meeting of the Manchester Association of Engineers held on Saturday last. The ever-increasing demand for the highest grades of steel, the ease by which comparatively low-quality steel could be converted into steel selling at high prices, and the use of low-quality raw materials had, the author stated, brought the electric furnace to the position it had reached to-day. Electric furnaces employed in the manufacture of steel were, he observed, of two distinct kinds, the arc furnace and the induction furnace. In the arc furnace the current flowed inside the furnace chamber from one set of carbon electrodes to another set, either directly through a small air space which intervened between the electrodes of opposite polarity as in an arc lamp, or indirectly from one set of electrodes through the metal bath to the other set. In this second method, the electrodes which took the current from the furnace were usually not carbon. In the induction furnace no electrodes were used, and the heating agent in the bath was not the actual supply current. It was well known that if an alternating electric current was passed through a circuit in the neighbourhood of another circuit the former or primary current induced a secondary current to circulate in the latter circuit, without any contact between the two circuits. On this principle the induction steel-melting furnace was designed. The metal charge was placed in an annular hearth, almost like a steel-melting crucible in section, but in the form of a ring. The primary coil of many turns was placed in the centre round a core of laminated iron. The bath of molten metal acted as a secondary circuit of a single turn. The current in the secondary was in ratio to the current in the primary multiplied by the number of turns in the primary. The secondary circuit acting as a resistance, the heat was thus produced in the charge itself without contact with electrodes.

After describing the various types of arc and induction furnaces, the author furnished some interesting figures relating to the number of furnaces in use or under construction. In June, 1910, there were, he said, about 118 furnaces of all types, of which 70 were in use, 10 not working, and 38 being built. There were 77 of the arc furnace recorded, of which 29 were Heroult, 17 Girod, 13 Stassano, 6 Keller, and 9 others. There was also one furnace at Domnarfiet, Sweden, for the production of 2,500 tons of pig iron per annum; also one in Norway, and one at Trollhatton, Sweden, both in course of construction, and each designed to produce about 7,500 tons of pig iron annually. Of the Heroult furnaces, the total capacity per charge of those working was about 80 tons, of those in course of construction about 50 tons. The total capacity of the Girod furnaces (the great competitors of the Heroult) was recorded at about 30 tons for those in work and 26 tons for those being built. Similarly, the figures for the Keller were 13 tons and 8 tons, and for the others 20 tons and 13 tons respectively. Of the induction furnaces, the Kjellin furnaces erected totalled 14 with 35 tons capacity; and the Rochling-Rodenhauser 15 with 30 tons. That gave a total capacity of about 250 tons for the 11 arc furnaces, and 100 tons for the induction, or a grand total of 350 tons per charge for all electric steel melting furnaces. In June, 1910, comparing the Heroult only, as an example, there were 29 of these furnaces with a capacity of 80 tons, in work, and 50 tons in course of erection, 130 tons in all, whilst in September, 1911, there were 43 furnaces with a total capacity of about 242 tons. The output of electric steel in Germany, the United States, Austria and Hungary in 1910 amounted to about 112,000 tons, which is an increase of 63,000 tons over the figures for 1909.

Before the beginning of 1911 the Heroult furnace at Edgar Allen & Co.'s, in Sheffield, was the only arc furnace in steady operation. In January three Heroult furnaces were commenced in England, at Messrs. Vickers and Thomas Firth and Sons, Sheffield, and at Lake & Elliott's, Braintree, Eessex. A Kjellin furnace, for demonstration and manufacturing purposes also, started at about the same time in Sheffield, and the output of England for 1911 should amount to about 13,000 tons. A 15-ton Heroult furnace was working, or just about to do so, at Skinningrove, and was expected to turn out 200 tons per day. Kjellin induction furnaces also had been working during this period satisfactorily at Messrs. Vickers and at Messrs. Jessop's, in Sheffield, and an experimental furnace at the University of Sheffield. Great progress was expected to be made in Germany with electric furnaces during this year, when Heroult furnaces of 25 and 22 tons capacity per charge were to be constructed. In September, 1911, the largest size was two 15 tons Heroult furnaces at South Chicago and Worcester, belonging to the United States Steel Corporation, who had recently acquired the Heroult patents for America and would probably erect several more furnaces shortly.

Referring to the chemical actions that take place during the refining, the dephosphorising and the desulphurising of the steel in the bath, the author stated that the action took place in two stages—in the first, which was the oxidation period, the carbon, silicon, manganese, and phosphorus were oxidised, and in the second, which was the deoxidation period, when the metal was dead melted and the sulphur eliminated. The first action was arrived at by adding to the charge certain quantities of lime and oxide of iron, which under the influence of the high temperature oxidised the carbon, silicon, and manganese and removed the phosphorus as calcium phosphate. The slag after this operation was removed from the bath and further quantities of lime (and sometimes carbon) were added; this was the second stage, when the sulphur passed into the slag as calcium sulphide which was not soluble in the

No. 1.

No. of Charge.	Time.		Weight of Steel charged in Kilos.	Ferro-Silicon.	Ferro-Mang.	Mill Scale.	Spiegel.	Tapping Weight.	Total Power Kw. Hours.	Total Power per 1,000 Kilos.	Analysis of Charge Basic Steel.		Analysis of Finished Steel.				
	Charge.	Tapping									P.	S.	C.C.	Mn.	Si.	P.	S.
2,668	4·55	8·36	5,673	35	2	90		5,800	1,681	291	·059	·065	1·04	·33	·18	·012	·024
2,669	9·00	12·20	5,472	35	3	90		5,600	1,688	301	·050	·067	0·79	·33	·26	·012	·029
2,670	12·35	3·50	5,385	25	—	90	100	5,600	1,781	318	·060	·069	0·16	·33	·015	Trace	·032
2,671	4·25	7·20	5,430	35	45	90		5,600	1,425	255	·054	·067	0·64	·89	·16	·020	·016
2,672	7·45	10·45	5,485	25	—	90		5,600	1,288	230	·072	·079	0·96	·33	·084	Trace	·014
2,673	11·25	2·20	5,480	30	—	90		5,600	1,321	236	·048	·059	1·20	·33	·12	·015	·020
2,674	2·55	5·40	6,030	35	45	90		6,200	1,371	211	·067	·067	0·51	·83	·15	·026	·018

No. 2.—*Analyses of Steel and Slag Taken at Different Periods of Heat.*

E 711.		No. 1.—When Slag was melted.	No. 2.—When Slag was white.	No. 3.—Just before Tapping.	Finished Steel.
Steel, Sulphur, per cent. ..		0·053	0·037	0·019	0·014
Slags at same periods.	SiO_2, per cent.	20·10	19·20	19·60	—
	FeO_3, per cent.	1·30	0·90	1·00	—
	Al_2O_3 ..	4·00	5·20	6·20	—
	CaO ..	60·00	64·20	61·30	—
	MgO ..	5·04	3·96	4·36	—
	S ..	0·63	0·90	1·26	—

metal bath. In the open-hearth furnace this calcium sulphide would very readily be oxidised into calcium sulphate which would combine with the iron to form sulphide of iron and so go back into the steel. In the reducing atmosphere of the electric furnace this could not take place, so that it was possible to remove the sulphur to almost any extent.

The author furnished some actual data relating to charges, additions, power used, &c. This is given in the accompanying tables, No. 1 being a copy of a report on seven consecutive charges from an 8-ton Rochling-Rodenhauser furnace, and No. 2 from the Heroult furnace.

There was very little doubt, the author stated in conclusion, that for many purposes in steel-making the electric furnace was the furnace of the future. There was no doubt now in the minds of steel-makers who have had the actual experience with up-to-date furnaces that it was possible to make steel equal to the best ever produced in Sheffield at less cost than it could be done in the crucible. It was of course just as necessary for care and skill to be exercised in working an electric steel furnace as it was in any other steel process.

BALANCING OF INTERNAL-COMBUSTION ENGINES.

WITH high-speed, two-stroke cycle internal-combustion engines of the vertical type, in which crude oil is used as fuel, there are large accelerations of the comparatively large, and therefore heavy, scavenging pump piston, in addition to those of its crosshead and connecting rod. These accelerations are particularly noticeable, as scavenging pumps work at a pressure only slightly exceeding that of the atmosphere, and this excess of pressure exercises practically no reducing influence on the piston acceleration. In the vertical types of high-speed

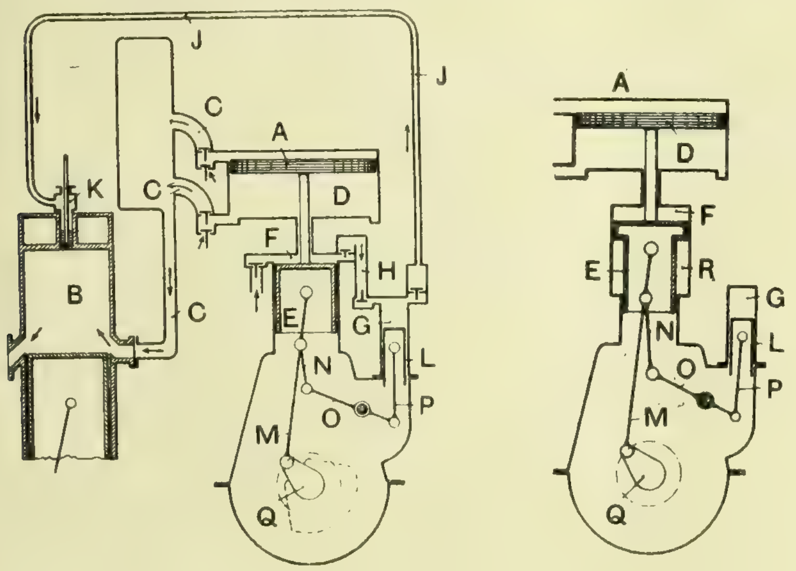


FIG. 1. FIG. 2.

BALANCING OF INTERNAL-COMBUSTION ENGINES.

engines these accelerations are transmitted to the engine frame, and, when the piston is at its highest point, cause considerable vibrations in the whole system. It has been attempted to obviate these drawbacks by arranging several smaller scavenging pumps, or by arranging two or more cylinders of the same alternately on a balance beam in such a manner that the vertically reciprocating piston accelerations neutralise each other. These arrangements, however, are complicated, and balance weights of the proper size could not be provided within the crank casing, even when the speed of the engine was high.

In the arrangements illustrated, the invention of Sulzer Bros., Winterthur, the scavenging pump is driven by a separate crank, and is arranged in such a manner that the pressure of one or more stages of the air-supply pump, arranged concentrically with the scavenging pump cylinder, considerably reduces, or even entirely neutralises, the momenta or accelerations of the pump pistons. The stages of the air-supply pump, which serves to balance the pump piston accelerations, are formed between the scavenging pump piston and its crank gear. In that way the reactions of the forces take place at a smaller distance from the rigid support of the engine, which considerably reduces the action of the horizontal components of the forces, owing to the centre of gravity of the whole movable system being placed lower, and thus facilitates balancing of the various masses.

Fig. 1 shows an arrangment where a two-stage air-supply pump is employed. In this construction A is the piston of the scavenging pump, which draws in atmospheric air, and then forces it with a small excess of pressure into the working cylinder B of the engine through the pipe C during the scavenging and charging operations. The low-pressure piston E of the air-supply pump also draws in atmospheric air and conveys it at a pressure of several atmospheres through the pipe H into the high-pressure cylinder G. From the latter the high-pressure air passes through the pipe J to the fuel valve K, through which the fuel is then injected in a finely divided state into the cylinder B. The driving of the high-pressure piston L of the air-supply pump is effected from the connecting rod M by means of a link N, rocking beam O, and connecting rod P, and the shaft provided with the crank Q can be driven in any desired manner from the main shaft. In this construction the pressure in the cylinder F opposes the piston acceleration of the scavenging pump during the up-stroke, and thus assists the balancing of the pump piston and prevents shock near the upper dead centre. The diameter of the piston E is determined in accordance with the equalising pressure required.

Fig. 2 shows a construction in which the momenta or accelerations of the reciprocating parts of the scavenging pump are equalised during both the down and up-strokes. Between the low-pressure stage F and the high-pressure stage G of the air-supply pump is inserted for this purpose an intermediate-pressure stage R. The piston E is formed as a double-acting piston, acting during its up-stroke as a low-pressure piston, and during its down-stroke as an intermediate-pressure piston, in the chamber R. The high-pressure stage G is driven separately by the connecting rods N, O, P.

In the construction shown in Fig. 1, the piston accelerations are equalised during the up-stroke by the pressure exerted by the piston E, and in the construction shown in Fig. 2 the momenta of the reciprocating parts are balanced on the up-stroke by the pressure in the low-pressure cylinder F, and on the down-stroke by the pressure in the intermediate-pressure cylinder R.

The Coal Mines Act.—It has come to the notice of the Home Office that certain institutions which give instruction in mining have issued, under a misapprehension, statements implying that they have power to grant the certificate which persons appointed or acting as firemen, deputies, or examiners after January 1st, 1913, will be required to possess under Section 15 (1) (b) of the Coal Mines Act, 1911. The Department desires to warn intending applicants for certificates that, in order to comply with the section, such certificate must be granted by "a mining school or other institution or authority approved by the Secretary of State," and a certificate granted by an institution not so approved will have no validity for the purposes of the Act. No institution has as yet been approved by the Secretary of State, and therefore no institution is at present in a position to grant these certificates. A list of approved institutions will be duly published in the press when it is finally decided upon.

Oil-driven Battleships for United States Navy.—The two battleships, "Texas" and "New York," which have recently been laid down for the United States Navy, will be unique vessels of their size and power, in that they will be driven by means of oil, and no coal will be carried. Reciprocating engines of a new type are to be fitted, which, it is calculated, are more economical at cruising speeds than turbines, and cost about the same to run at high speed. As compared with the new United States battle-ship "Delaware," of equal power, the machinery weights in the boiler compartments of the new vessels will be reduced by 300 tons, or about 30 per cent. The length of the space required for boilers will be reduced by one-half, and the fireroom force one-half that required for the "Delaware." By reducing the weights in the boiler-rooms it has been possible to increase the armour protection of these battle-ships. Each vessel will mount ten 14in. guns—throwing a shell of 1,400lbs.—and twenty 5in. quickfirers.

RECENT DEVELOPMENTS IN STEAM TURBINE PRACTICE.*

BY K. BAUMANN.

(*Continued from page 102.*)

MAXIMUM OUTPUT OF TURBINES.

THE maximum output for which steam turbines can be designed depends on the maximum weight of the steam which can be passed through the low-pressure part with reasonable efficiency. The greater the steam quantity the greater the output of the turbine.

The weight of steam is given by the following formula :—

$$G = \frac{V}{v} = \frac{\tau \pi D h c}{v} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

and the maximum output in kilowatts by

$$N = \frac{\tau \pi D h c}{v S} \; 3{,}600 \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where

- G = weight of steam flowing through the turbine.
- V = volume of steam flowing through the last blades.
- v = specific volume of steam at exhaust.
- D = mean diameter of last blades (see Fig. 20).
- h = length of last blades.
- c = axial steam velocity through last blades.
- S = steam consumption per kilowatt-hour.
- τ = thickness coefficient (0·90–0·95).

Hence the maximum output depends mainly upon :—

(1) The specific volume v at the exhaust of the turbine which depends on the vacuum.

(2) The outlet velocity c, which depends on the permissible leaving loss.

(3) The mean diameter D, which depends upon the maximum permissible peripheral speed.

(4) The maximum permissible blade height, which depends on the method of fixing the blade.

(1) **Influence of Vacuum.**—The specific volume of the steam depends mainly on the vacuum, and its value for saturated steam from 27in. up to 29in. is given in the following table :—

TABLE I.

27in.	27½in.	28in.	28½in.	29in.
231	274·5	338·6	440	654·5 cub. ft./lbs.
14·4	17·15	21·1	27·5	40·8 m.³/kg.

This table indicates that the maximum output which a turbine can be designed to give depends mainly on the vacuum, and is, other conditions remaining the same, about 2·83 times larger at 27in. than at 29in. vacuum. In order, therefore, to compare the drum with the disc turbine, as regards maximum output, we must assume the same vacuum for both.

(2) **Influence of Leaving Losses.**—In order to reduce the leaving loss to a minimum the blading should be so arranged that the absolute outlet velocity from the last wheel is in an axial direction.

If—

- i_2 = total heat drop available.
- c = the absolute outlet velocity from the last wheel.
- J = mechanical equivalent of heat.
  = 424 (metric units) or 778 (English units).

The leaving loss of the turbine is given by—

In metric units—

$$l = \frac{c^2}{2 g J i_2}$$

$$l = \frac{c^2}{91\cdot5^2\, i_2} \quad . \quad . \quad (3)$$

In English units—

$$l = \frac{c^2}{224^2\, i_2}$$

Allowing for the pressure drop through the governor valve, the total heat drop available with the standard high-pressure turbine conditions, mentioned later, namely 180lbs. per square inch gauge, 150° Fah. superheat, and 28in. vacuum, is 200 calories or 360 B.Th.U.

Therefore—

$$l_0 = 0\cdot6 \left(\frac{c}{100}\right)^2 \text{ per cent. for metric units}$$

$$l = 0\cdot0555 \left(\frac{c}{100}\right)^2 \text{ per cent. for English units} \quad . \quad (3a)$$

Hence the maximum output is proportional to the square root of the leaving losses, and we get :—

Leaving loss, per cent. ..	1	2	3	4	5
Outlet velocity	129	182·5	223·5	258	289 m./sec.
Outlet velocity	424	598	733	846	948 ft./sec.

(3) **Influence of Stresses in Drums and Discs.**—The maximum mean diameter D of a turbine depends on the peripheral velocity $u = \frac{\pi D n}{60}$, which itself is limited by the maximum stresses allowable. These are considered separately for drums and discs in the following investigation :—

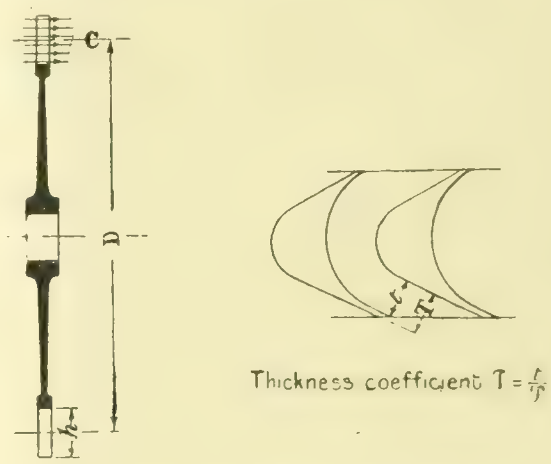


FIG. 20.—LAST WHEEL OF TURBINE.

(*a*) *Stresses in Drums.*—The stresses in rotating drums without blades can be calculated very easily by the formula used for calculating stresses in rotating rings—

$$\sigma = \mu\, u_d^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

- σ = tangential stress in drum.
- μ = specific mass of material. (For steel 8×10^{-6} kg. cm.$^{-4}$ sec.^{2} or $7\cdot35 \times 10^{-4}$ lbs.-inch^{-4} sec.^{2}.)
- u_d = mean peripheral speed of drum.

According to this formula the following table has been calculated :—

In metric units—

u_d	50	75	100	125	150 m. sec.
σ	200	450	800	1,250	1,800 kg. cm.^{2}.

In lbs.-inch units—

u	100	200	300	400	500 ft. sec.
σ	1,060	4,230	9,530	16,930	26,460 lbs. sq. in.

If the drum is loaded with blades we have to consider an additional stress which can be calculated from the expression :—

$$\sigma' = \sigma_r \frac{r}{\delta} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where—

- σ' = additional stress in drum due to the centrifugal force of the blades.
- σ_r = load on drum due to the centrifugal force of the blades per unit surface (lbs. square inch or kg. cm.^{2}).
- r = mean radius of drum.
- δ = thickness of drum.

At the low-pressure end of the drum this additional stress is generally about 25 per cent. of the stress due to the centrifugal force of the drum itself, so that the total stress is approximately—

$$\sigma_{tot.} = 1\cdot25\, \sigma = 1\cdot25 \times \mu \times u_d^2 \quad . \quad . \quad . \quad . \quad (6)$$

* Paper read before the Manchester section of the Institution of Electrical Engineers, January 1912.

The blade height of the last row is usually not more than one-fifth of the diameter so that—

$$\text{Mean D} = 1{\cdot}25 \ D_{ii},$$

and—

$$\text{Mean } u = 1{\cdot}25 \ u_{ii} \, ;$$

and therefore—

$$\sigma_{\text{tot.}} = 1{\cdot}25 \ u_{ii}^2 = \frac{1{\cdot}25 \ \mu \ . \ u^2}{(1{\cdot}25)^2} \quad . \quad . \quad . \quad . \quad (7)$$

or—

$$\sigma_{\text{tot.}} = 0{\cdot}8 \ \mu \ . \ u^2.$$

The maximum stress should not exceed—

One-third of the elastic limit, or about

One-fifth of the tensile strength of the material.

The physical properties of the steel available for commercial manufacture of drums and discs are given in the following table :—

TABLE II.

Material.	Breaking Strength. Kg./cm.²	Breaking Strength. Lbs./sq. in.	Elastic Limit. Kg./cm.²	Elastic Limit. Lbs./sq. in.	Elongation. Per Cent.	Maximum Stress. Kg./cm.²	Maximum Stress. Lbs./sq. in.
Forged steel..	4,700	67,000	2,840	40,000	20	940	13,300
3 per cent. Ni-steel ..	6,300	90,000	—	—	18	1,250	17,800

According to these stresses the mean blade velocity should not exceed—

u = 120 m./sec. or 400 ft./sec. for forged steel drums.

u = 140 m./sec. or 465 ft./sec. for 3 per cent. Ni-steel drums.

(*b*) *Stresses in Discs.*—In a rotating disc there are two different kinds of stresses—

σ_r = stress in radial direction.

σ_t = stress in tangential direction.

For any point on a circle of radius r the stresses σ_r and σ_t remain constant, and for plain steel discs of uniform thickness are given by—

$$\left.\begin{aligned} \sigma_r &= \frac{3{\cdot}3 \ u^2}{10^6}\left[1-\left(\frac{r}{r_2}\right)^2\right] \\ \sigma_t &= \frac{3{\cdot}3 \ u^2}{10^6}\left[1-0{\cdot}575\left(\frac{r}{r_2}\right)^2\right] \end{aligned}\right\} \quad . \quad . \quad . \quad (8)$$

The stresses reach a maximum in the centre of the disc where—

$$\sigma_r = \sigma_t = \frac{3{\cdot}3}{10^6} \ u^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Thus the maximum stresses in the case of a plain rotating disc are only—

$$\frac{3{\cdot}3}{8} = 41{\cdot}25 \text{ per cent.}$$

of those of a drum rotating at the same peripheral speed ; or, in other words, to obtain the same stresses a plain rotating disc must be run with a peripheral speed 55·5 per cent. higher than that of a rotating ring or drum. The distribution of the radial and tangential stresses in the disc are shown in Fig. 22 by curves σ_{r0} and σ_{t0}.

Unfortunately discs used for steam turbines must be provided with a hole at the centre for the purpose of fixing them on to the shaft. If the diameter of the hole be r_1, the stresses are given by—

$$\left.\begin{aligned} \sigma_r &= \frac{3{\cdot}3 \ u^2}{10^6}\left[1+\left(\frac{r_1}{r_2}\right)-\left(\frac{r}{r_2}\right)^2-\left(\frac{r_1}{r}\right)^2\right] \\ \sigma_t &= \frac{3{\cdot}3 \ u^2}{10^6}\left[1+\left(\frac{r_1}{r^2}\right)^2-0{\cdot}575\left(\frac{r}{r_2}\right)+\left(\frac{r_1}{r}\right)^2\right] \end{aligned}\right\} \quad (10)$$

The distribution of stresses in discs with holes of various diameters is plotted in Fig. 21. If the hole is very small the stress σ_r on its periphery will become zero, the stress falling according to the curve σ_{r1}. On the other hand, the reduced stresss σ_{r1} must obviously be balanced by an increased stress σ_{t1}, and from the formula given above calculation shows that the tangential stress near the periphery of the hole is increased to double the stress in a solid disc without a hole.

This means that a disc with a very small hole is only very little stronger than a ring rotating with the same peripheral velocity. For larger holes the tangential stresses increase still more (see Fig. 21), the radial stresses decreasing at the same time, and for a very large hole the disc finally takes the form of a ring, σ_r becoming very small and σ_t equal to the stress for a ring.

A plain disc with a hole in the centre is not, however, strong enough for turbine work, and it is therefore necessary to increase its strength. This may be done in the following manner: (1) Strengthening the disc near the periphery of the hole by a boss. (2) Increasing the thickness of the disc towards the centre in order to obtain as nearly as possible a disc of uniform strength.

The different kinds of disc shapes at present used in turbine practice are shown in Fig. 22. Fig. A shows a plain tapered disc with cylindrical boss in which $\frac{y_1}{y_2} = 1{\cdot}77$. Figs. B and C show a tapered disc with a hyperbolic profile, increasing the thickness towards the boss.

$$\text{For wheel B } \frac{y_1}{y_2} = 2{\cdot}35,$$

$$\text{For wheel C } \frac{y_1}{y_2} = 4{\cdot}17.$$

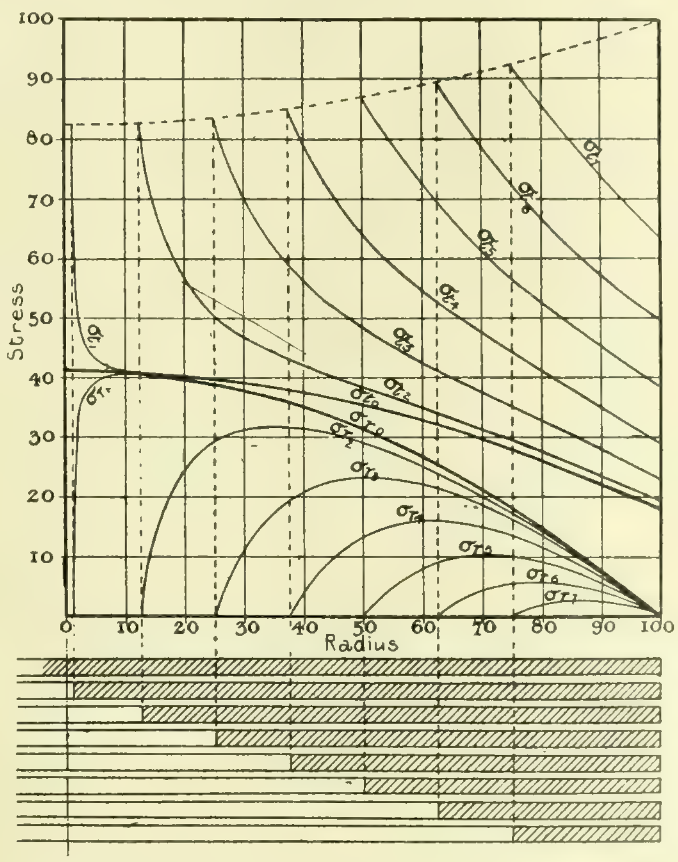


FIG. 21.—DISTRIBUTION OF STRESSES IN UNIFORM DISC WITH HOLE.

The values of the stresses in these cases are shown by the curves σ_r and σ_t. It has been found that the maximum stress is always a tangential stress and (for disc A) is given by the formula—

$$\text{Maximum } \sigma_t = 4{\cdot}4 \quad 10^{-6} \ u^2.$$

For disc B—

$$\text{Maximum } \sigma_t = 3{\cdot}3 \quad 10^{-6} \ u^2.$$

For disc C—

$$\text{Maximum } \sigma_t = 2{\cdot}7 \quad 10^{-6} \ u^2$$

This means that, compared with a plain disc of uniform thickness, disc B is of equal strength, disc A is 33 per cent. weaker, and disc C is 18 per cent. stronger.

Allowing maximum permissible stresses according to Table II., these discs can be run up to the peripheral speeds shown in the following table. Thus in the case of disc A the peripheral velocity can be 1·35 times, disc B 1·55 times, and disc C 1·72 times the maximum velocities for drums. Mild steel discs of shape B which represent usual practice can be run at peripheral velocity of 168 m./sec., so that for—

n = 3,000 revs. per minute the mean diameter would be = 42in.,

or—

n = 1,500 revs. per minute the mean diameter would be = 84in.

(4) **Influence of Stresses in Blading.**—It will be seen from the formulæ which we are discussing that the maximum steam quantity is proportional to the blade height. The larger the

Peripheral Velocity of Discs.

	Forged Steel.		3 per Cent. Ni-steel.	
	M/sec.	Ft./sec.	M/sec.	Ft./sec.
Disc shape A	146	478	168	552
Disc shape B	168	555	194	636
Disc shape C	186	610	215	705

blade the larger the steam quantity and also the output. The stress at the blade root is given by—

$$\sigma_b = 2 \mu u^2 \left(\frac{h}{D}\right) \quad . \quad , \quad . \quad . \quad . \quad (11)$$

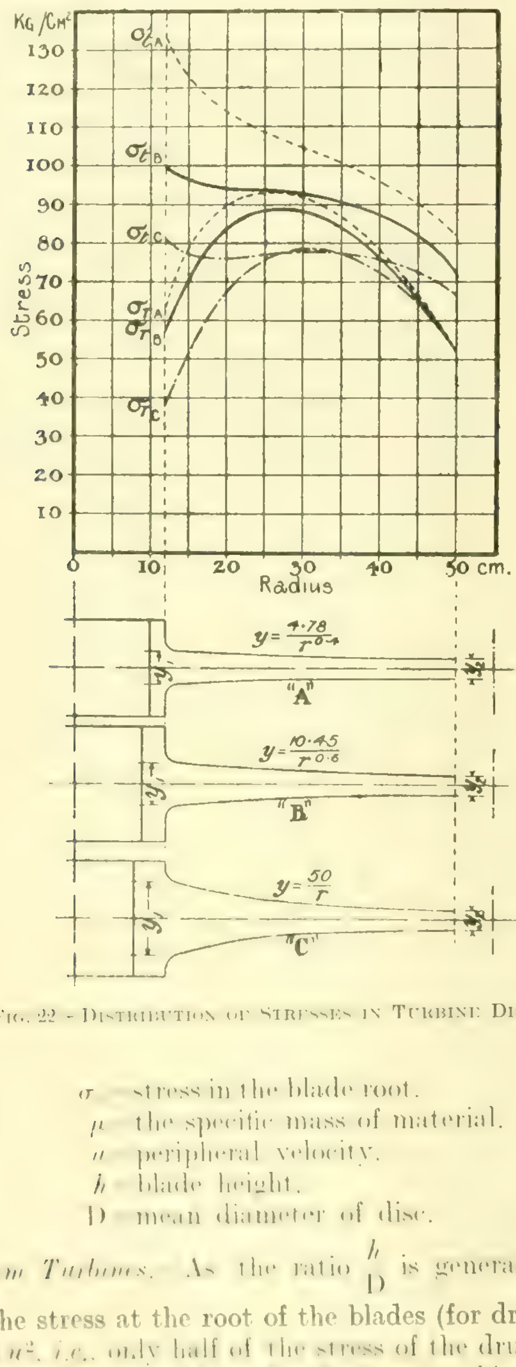


Fig. 22.—Distribution of Stresses in Turbine Discs.

where—

σ = stress in the blade root.
μ = the specific mass of material.
u = peripheral velocity.
h = blade height.
D = mean diameter of disc.

(*a*) *Drum Turbines.*—As the ratio $\frac{h}{D}$ is generally less than one-fifth, the stress at the root of the blades (for drum turbines) is $\sigma_b = \frac{2}{5} \mu u^2$, *i.e.*, only half of the stress of the drum which has been shown to be $\sigma = 0 \cdot 8 \mu u^2$. In drum turbines, therefore, the blade height is only dependent upon the reliability of the method employed for fixing the blades to the drum. If the turbine is to realise its maximum permissible output, blades of considerable length are required, and these cannot be held rigidly enough if the usual methods of caulking the distance pieces are used; consequently methods similar to those at present applied to impulse turbines must be adopted.

It can be shown that there are methods of fixing the blading existing with which no stress is produced in any part larger than that at the root, and since, as shown by the above formulæ, this stress is of no importance, the maximum height of the blades in drum turbines is limited by other considerations; in order to keep the difference of the peripheral speeds at the root and at the top of the blades within practical limits it is not advisable to increase the blade height above one-fifth of the mean diameter D, as already pointed out.

(*b*) *Disc Turbines.*—The blade height which can be used in disc turbines is dependent upon the stress at the root of the blade. Taking the maximum blade height of Rateau turbines to be one-fifth of the mean diameter, the stress at the root of the blade is

$$\left.\begin{array}{l}\sigma_b = \frac{2}{5} \mu u^2 \\ \quad = 3 \cdot 2 u^2 \times 10^{-6}\end{array}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

i.e., about the same as the stresses in a disc of shape B, Fig. 24.

The following table gives the values of this stress for different peripheral speeds :—

For u =

100	125	150	175	200			m. sec.
320	500	720	980	1,280			kg./cm.².
100	200	300	400	500	600	700	ft. sec
423	1,693	3,810	6,773	10,584	15,240	20,740	lbs. sq. in.

Assuming for disc turbines that $h = \frac{D}{5}$, formula (2) becomes—

$$\text{Maximum output in KW} = \frac{\tau \pi D^2 c}{5 \quad v S} \times 3{,}600 \quad . . \quad (12a)$$

Hence the maximum output is proportional to the square of the diameter.

5.—**Maximum Outputs of Disc as Compared with Drum Turbines.**—In order to compare the two different types of turbines, it is, of course, necessary to assume the same outlet losses.

From formula (2) it follows that :—

$$K W_{drum} = \frac{\tau \pi D_{drum} h_{drum} c}{v S} \times 3{,}600.$$

$$K W_{disc} = \frac{\pi \tau D_{disc} h_{disc} c}{v S} \times 3{,}600$$

c, v, and S being the same in both cases.

$$\frac{K W_{drum}}{K W_{disc}} = \frac{D_{drum} h_{drum}}{D_{disc} h_{disc}} = \left(\frac{D_{drum}}{D_{disc}}\right)^2 \quad . \quad . \quad . \quad (13)$$

as $h = \frac{D}{5}$ in both cases.

For a given number of revolutions of the turbine, the diameter is proportional to the peripheral speed and the output, and for the same stress in discs and drums

$$\frac{K W_{drum}}{K W_{disc}} = \left(\frac{u_{drum}}{u_{disc}}\right)^2 = \frac{3 \cdot 3}{6 \cdot 4} = \frac{1}{2} \text{ approximately} \quad . \quad . \quad (14)$$

which means that, other conditions remaining the same, a disc turbine can be built having twice the maximum output of a drum turbine.

The fact that some makers have recently begun to use solid drums, which, according to our investigation, would theoretically be stressed only to the same figure as disc turbines, does not alter the above statement with regard to relative capacity, because it is unsafe to run solid drums at a higher peripheral speed than ordinary drums. This is due to small faults in their interior which it is quite impossible to detect, and which it has been shown increase the calculated stresses to more than double. Both the disc and the ordinary drum construction have the advantage of allowing inspection to be made of each part, thus ensuring that the material is homogeneous throughout.

6.—**Maximum Outputs Obtainable from Disc Turbines.**—The maximum output of a disc turbine, being proportional to the square of the diameter is—for a given permissible stress—inversely proportional to the square of the revolutions per minute. Consequently the output of a disc turbine is—

Four times larger at 1,500 revs. per minute than at 3,000 revs. per minute.

Nine times larger at 1,000 revs. per minute than at 3,000 revs. per minute.

Sixteen times larger at 750 revs. per minute than at 3,000 revs. per minute.

In practice, however, it is not advisable or necessary to stress the material in large turbines to the same extent as in small turbines, so that the relation between speed and output may be taken as follows :—

Maximum output for 1,500 revs. per minute, three times larger than for 3,000 revs. per minute.

Maximum output for 1,000 revs. per minute, five times larger than for 3,000 revs. per minute.

Maximum output for 750 revs. per minute, eight times larger than for 3,000 revs. per minute.

These figures can be approximately obtained from the formula—

$$\text{Maximum output} = \frac{\text{Constant}}{n^{3\cdot 2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

from which the maximum output for any speed can be obtained, other conditions remaining the same if the maximum output for any one speed is known. As the stresses are proportional to the square of the diameter for a given speed, it follows that, other conditions remaining the same, the maximum output is proportional to the tensile strength of the material.

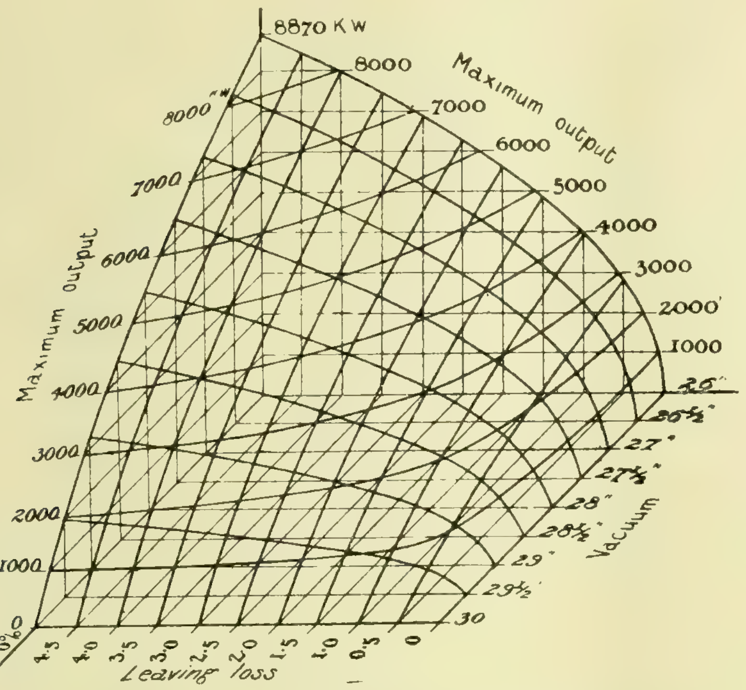


FIG. 23.—MAXIMUM OUTPUT OBTAINABLE FROM DISC TURBINES.

The maximum output is effected in the same way by the decrease of stress obtained by improving the disc and blade shape. For a given turbine of, say 42in. mean diameter, running at 3,000 revs. per minute, the maximum output only depends on the vacuum and the leaving losses. The relations between these quantities have been plotted in Fig. 23 in the calculation of which the following figures were assumed :—

Initial pressure . . . . = 180lbs./sq. in. gauge.
Superheat . . . . = 150° Fah.
Turbine efficiency . . = 70 per cent.
Generator efficiency . . = 94 per cent.
Specific volume as in Table I., allowing for 6 to 8 per cent. moisture.
Thickness coefficient for last wheel = 0·92 to 0·94 per cent.

(7) **Recent Development of Outputs of Turbo-generators.**—The question of the maximum outputs which can be obtained with the different types of turbines becomes very important in view of the great increase in the maximum capacities of turbo-alternators during the last three years. This is mainly due to the rapid development of the impulse turbine, the high costs of which for small outputs and great economy for large outputs have caused the manufacturers of these turbines to introduce designs of turbo-generators capable of giving very large outputs at relatively high speeds. Whereas four years ago 1,000 kw. was considered a very large output for 3,000 revs. per minute, manufacturers are at present prepared to go up to 3,000 kw., and even higher for this speed. The increase of the output of turbo-alternators has been more rapid in the United States and on the Continent than in this country. For example : The American Westinghouse Company recently built 5,000 k.v.a. running at 3,600 revs. per minute, and 15,000 kw. maximum rating at 1,800 revs. per minute. The A. E. G. Company is reported to have in work 215,000 k.v.a. at 1,000 revs. per minute, and Siemens-Schuckert Works 4,000 k.v.a. at 3,000 revs. per minute.

(To be continued.)

EMPLOYERS AND LEGISLATION re "PICKETING."

In an introduction to the report of their proceedings for the past year the Employers' Parliamentary Council emphasize the need for the closer co-operation of employers' associations. The session of 1911, they observe, has provided a lesson and a warning. The proceedings of the House of Commons in connection with the National Insurance Bill indicate that unless there is more cohesion among employers to resist encroachments upon the rights of trade and industry, party legislation in the future will be of a one-sided character. The refusal of the Government to give any assurance that steps would be taken to save the country from the grave evils that have followed the passing of the Trade Disputes Act, 1906, shows that the interests of employers are ignored for the simple reason that, regarded as an electoral group, they are of no account compared with the wage-drawing classes who make up the voting multitude. The House of Commons, it is stated, is no longer a deliberative assembly, but has degenerated into a mere machine for registering the arbitrary decrees of autocratic ministries whose will is supreme, and whose conduct of public affairs is marked by an utter disregard of principles of public policy.

The events of last autumn in connection with the so-called "national strike" more than justified the predictions of the opponents of the Trade Disputes Act, 1906. The country passed through a period of unprecedented terrorism, and witnessed the sorry spectacle of the Government pitifully suing for the permission of the strike promoters to use vehicles, horses, and men to carry the State mails, while the hospitals had to obtain a special permit from these conspirators before ice and other necessaries could be conveyed for the use of the patients. These incidents, together with the long reign of despotism, brutality, and incendiarism in South Wales, and the fact that under this gross and monstrous system of labour-union tyranny, legalised by the Trade Disputes Act, peaceful citizens were intimidated, molested, and maltreated in nearly every part of this so-called "land of liberty," provided an urgent reason for the total and immediate repeal of that charter of labour-union terrorism, violence, and outrage, which was enacted by Parliament in response to the demand of a powerful and organised minority which insisted upon the right to threaten, bully, and attack an unorganised majority under the sanction of the law of the land.

The council issued a lengthy memorandum giving the history and the results of the Act, and calling attention to the fact that the whole system of labour unionism is nothing short of a huge conspiracy against private freedom, industrial peace, and a national well-being. They presented to the Prime Minister a memorial, signed by 65 central associations of employers connected with the industrial, trading, and commercial interests of the country, urging—

(1) That picketing should either be rigorously suppressed or the number of pickets should be limited to two, and such pickets should be required to wear a distinguishing badge, and to attend only where a person works or carries on business.

(2) That unions, whether of workmen or masters, should be subjected to the ordinary law of the land, and made responsible, like all other classes of the community, for their actions.

(3) That a federation of unions for the purpose of "paralysing the country" by means of a general strike or lock-out, throwing all industries and communications into disorder, and stopping the food supplies of the nation, should be suppressed as an unlawful combination and immediately so proclaimed.

At the request of the council, questions were addressed to the Prime Minister in the House of Commons as to the intentions of the Government with regard to the matters urged by the memorialists; but beyond a vague intimation that the questions were receiving attention by the Government, no reply was given, but the Prime Minister promised, if the council would submit in writing the arguments it was desired to urge, he would give them careful consideration. When Parliament is again in session, the council will send to the Prime Minister such a statement as he suggests. The question will not be allowed to remain in its present position. The council will persist in its demand that the Trade Disputes Act shall be repealed, and that these labour unions, privileged by its provisions to do wrong, should be subjected to the

ordinary law of the land, and made responsible, like all other classes of the community for their actions.

Can employers, the council ask, do anything to remedy the present deplorable state of things, and guard the industrial and trading interests, which owe their existence to private initiative and personal enterprise, and which have been built up under conditions of freedom and security which it is the first duty of all civilised governments to uphold and defend? Only, they assert, by a united policy of firm determination and stern resistance on the part of employers as a class, adding that employers will have themselves to blame if something is not done to retrieve the past, and resist future attacks on their interests by office-holding or office-seeking political parties. The present state of things, they observe, has become intolerable, and, if not promptly checked, must inevitably lead to widespread disaster, in which employers and workpeople alike will be involved, and from which recovery may be impossible.

THE EVOLUTION AND PRESENT DEVELOPMENT OF THE TURBINE PUMP.*

BY DR. EDWARD HOPKINSON AND MR. ALAN E. L. CHORLTON.

TO-DAY the turbine principle seems to be the accepted ideal of almost all primary machines. It would appear that the age of the reciprocating engine, for the various duties of mechanical engineering, is passing, and that the rotary engine of the turbine type is steadily taking its place. In that of time available than by considering in particular one type only, and that the authors believe to be the original. As a description of the commercial application of the steam turbine is a history of the Parsons machine, so that of the turbine pump can be adequately portrayed by an account of the evolution of the Osborne Reynolds pump.

The rotary machine for raising water in the form of a centrifugal pump is a very old contrivance, and was the forerunner of pumps of the turbine type. At the beginning of the 18th century, Denis Papin, the French physician and physicist, afterwards a Fellow of the Royal Society, communicated to the Society a paper* in which he describes how "being busy for a coal mine, which has been left off, because of the impurity of the air," he had devised improvements in the Hessian bellows, with a view to applying them both to wind and water. His improved apparatus consisted of radial wings caused to revolve about an axis in a cylindrical chamber of which the portion external to the wheel was of a spiral shape. His drawings show clearly the volute casing of the modern centrifugal pump. Papin had no means of driving his fan or pump other than by hand power, and more than a century elapsed before his ideas were applied in practice.

Centrifugal pumps were in the past accepted by engineers as suitable appliances for easily and cheaply (as to first cost) raising water to low heads. It was not realised that they were capable of dealing with any but such heads; in fact, such a view became a canon of ordinary engineering practice, creating a tradition which took many years to remove. That

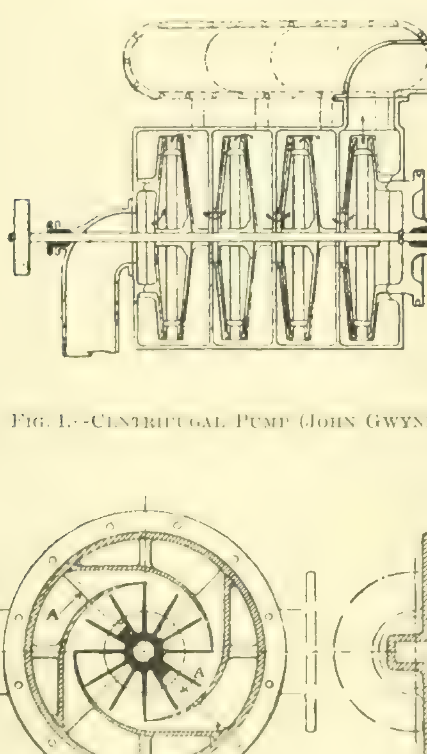


FIG. 1.—CENTRIFUGAL PUMP (JOHN GWYNNE, 1851).

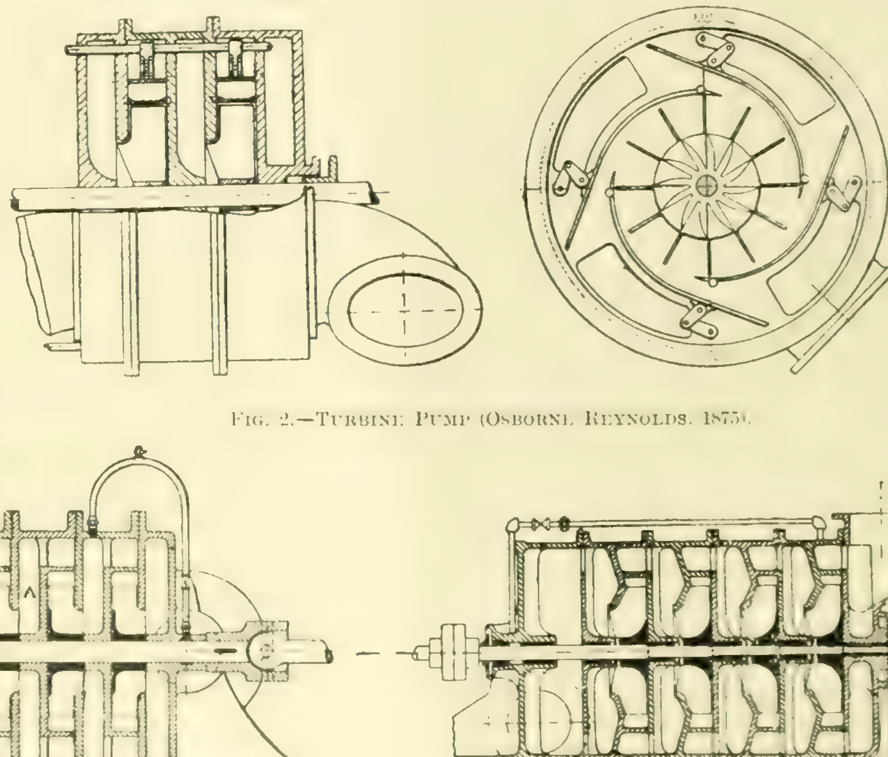


FIG. 2.—TURBINE PUMP (OSBORNE REYNOLDS, 1875).

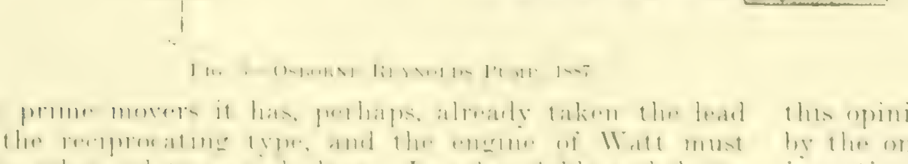


FIG. 3.—OSBORNE REYNOLDS PUMP, 1887.

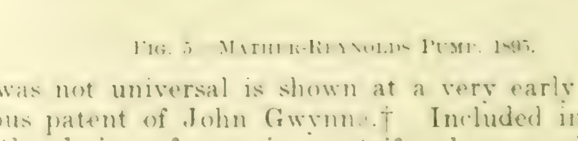


FIG. 5.—MATHER-REYNOLDS PUMP, 1895.

steam prime movers it has, perhaps, already taken the lead over the reciprocating type, and the engine of Watt must now be relegated to second place. In other fields and duties its progress to date is so great as to warrant the surmise that at no distant time a similar comparison of precedence will be made. In no domain, perhaps, has the turbine rotary principle achieved greater success in the last few years than that of high-lift pumping, though the realisation of its possibilities for such duties, by some, is perhaps as old as or older than the steam turbine itself. Still, its general acceptance as correct engineering practice is only a matter of the last five years.

At the present time the use of the turbine pump has become so extended that it is difficult to find services to which it cannot be advantageously applied. It will no doubt, therefore, be a matter of interest to trace the evolution and development of machines of this design, and this, perhaps, cannot be better done within the limits of a single paper and the

this opinion was not universal is shown at a very early date by the omnibus patent of John Gwynne.† Included in this invention is the design of a series centrifugal pump shown in Fig. 1.

Gwynne's specification contains many claims, and amongst other interesting designs he shows a reaction impeller, now used for self-regulation, and also a means of dealing with end thrust. This specification seems to be the first proposal to use centrifugal impellers in series, and though in the forms shown and having no guide vanes it could hardly be expected to attain even with low efficiency the heads now successfully dealt with, still it shows a conception of a machine very much in advance of the times. It is singular that, though the water turbine with its guide vanes was a matter of common knowledge at the time, no attempt appears to have been made to reverse its action with the prospect of obtaining a similar high efficiency and increase of head, for the purpose of raising water. There was, however, one exception in the invention

* Paper read before the Institution of Mechanical Engineers, January 19, 1912.

* Philosophical Transactions, Vol. XXIV., No. 300, 1705.

† Patent No. 13577 of 1851.

of Prof. Osborne Reynolds. It is the object of the present paper to trace and discuss the development of this invention.

In the year 1875 Prof. Osborne Reynolds invented a turbine pump* of the series type, fitted with guide vanes (Fig. 2). Comparison of this figure with illustrations following show how the essential features of his original proposition have been adopted in subsequent practice. In this pump the impeller delivered its water to tangent guide vanes, as shown in Fig. 2,† and the similarity to an inward-flow turbine of

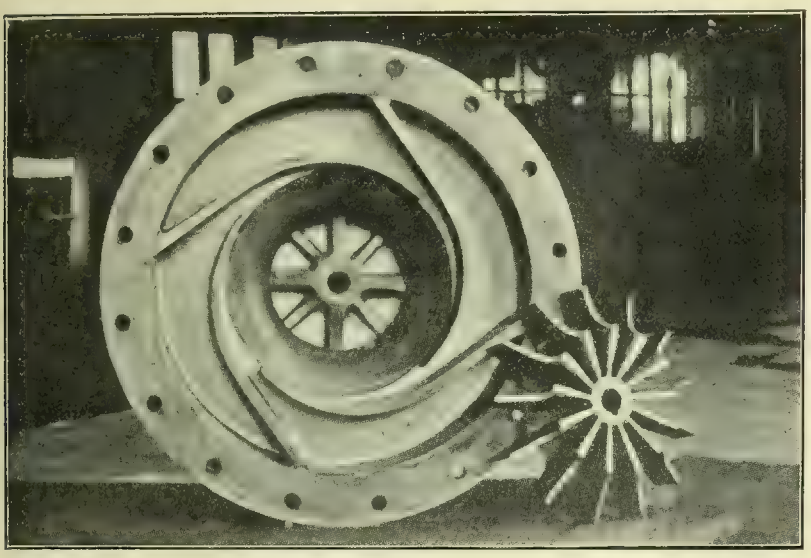


Fig. 4.—Impeller and Guide Passages, 1895 (Mather-Reynolds).

the Thomson type is noticeable, for, as in that machine, the mouths of the guide channels could be regulated to raise the efficiency of the pump for smaller outputs, a device, however, seldom adopted in later practice. He claims "the arrangement and combination of two or more centrifugal pumps or fans, in which the fluid, after leaving the moving passages, is received into fixed passages, so formed as to deprive it of all velocity of whirl."

Nothing of any commercial value appears to have been done with the invention for many years; in fact, the first pump of which records and tests are available was only con-

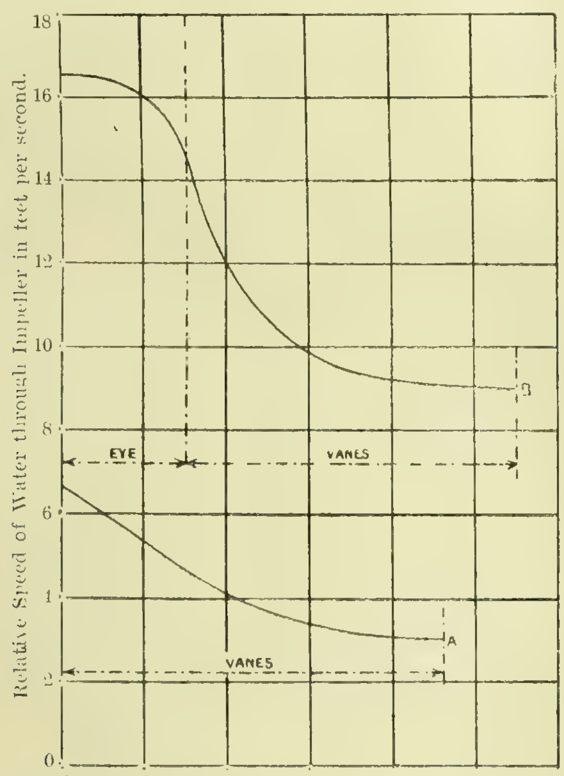


Fig. 6.—Curves Showing Relative Velocity of Water Through Impellers when Delivering their Most Efficient Quantity.

A.—Mather-Reynolds 1895 Pump. B. Modern High-lift Pump.

structed in the year 1887 by the firm of Mather & Platt, for the Engineering Laboratory of the Owens College, Manchester. This pump, shown in cross and longitudinal section in Fig. 3, had four impellers in series, and gave at 1,500 revs. per minute a total head of 148ft. or 37ft. per chamber. The average efficiency recorded in the tests made by Prof. Reynolds was 58·5 per cent., a high result, having regard to its small size, for a pump made 25 years ago. The readings were taken from a dynamometer fixed between the pump and the belt pulley, and, as no method of damping the indicating finger seems to have been employed, they may be liable to some error. Thus the maximum efficiency obtained, viz., 70

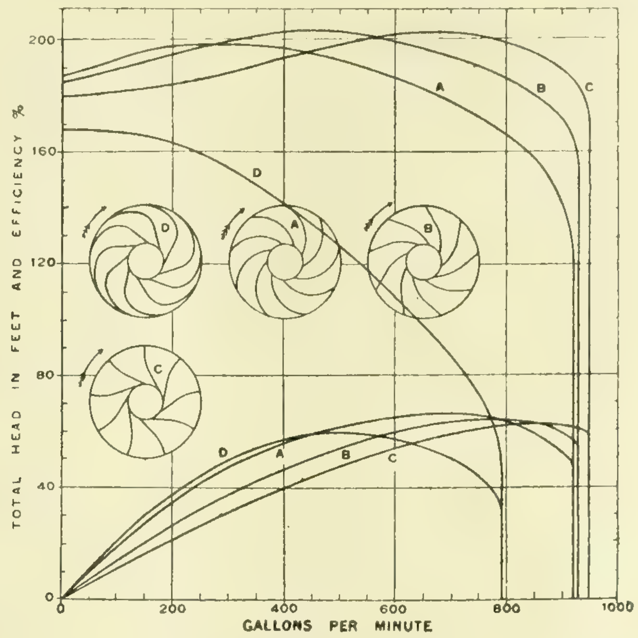


Fig. 7.—Head and Efficiency Curves. Comparison of Results with Different Impellers.

per cent., appears open to some doubt. The guide vanes, after leaving the wheel in a curve, reached the inner periphery of the outer shell of the chamber at an angle. The water, having had its velocity of whirl converted into pressure head in these passages, had then to pass sideways at right angles into radial-return passages formed in the back portion of the chamber and marked "A" in Fig. 3. In these passages the

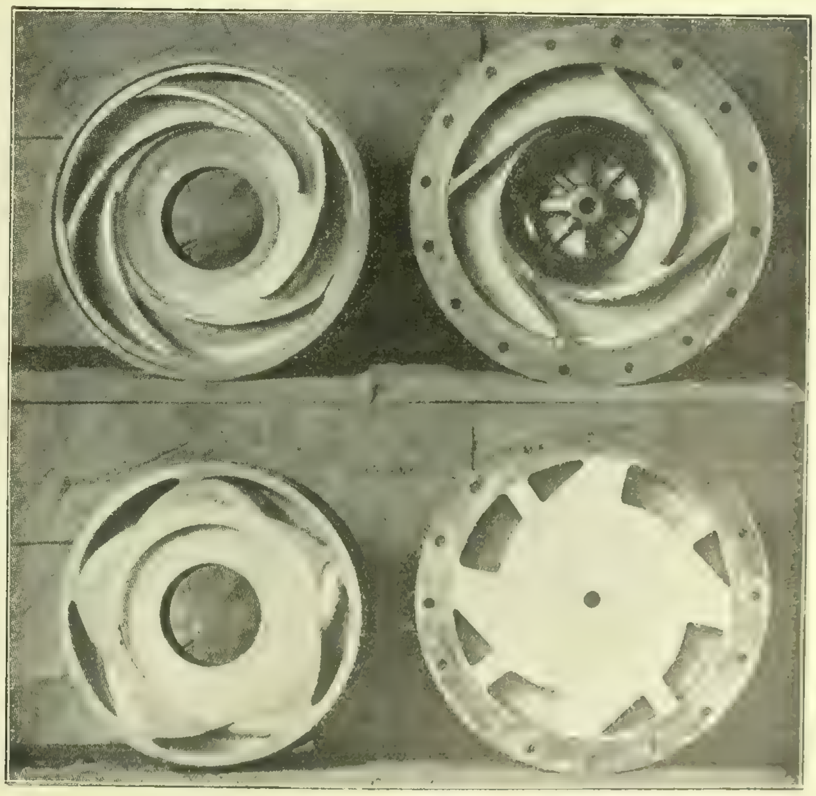


Fig. 8.—Guide Vanes of 1895 Pump (Mather-Reynolds) and Modern Pump.

water was guided and prevented from rotating by radial vanes. The water on reaching the centre passed into the eye of the second impeller, and so on until it was finally delivered at the pump outlet at the head pressure required. It will be observed from Fig. 3 that the impeller was of the open type with radial vanes.

The tests of Prof. Reynolds proved the capability of the pump to perform many duties previously thought impossible

* Patent No. 724 of 1875.

† See also Patent Specification 13578 of 1894. Osborne Reynolds, "Improvements in Rotary Pumps and Turbines."

by centrifugal pumps, and in 1893 the firm of Mather & Platt took up its commercial manufacture.

The mechanical construction of a standard Mather-Reynolds pump as built in 1895 is illustrated in longitudinal section in Fig. 5, and in photo, Fig. 4. It consists of four chambers working in series. At the one end these are secured by bolts against the circular flange of a frame carrying the driving pulley or shaft coupling, this having the suction branch and entrance to the first chamber cast with it. At

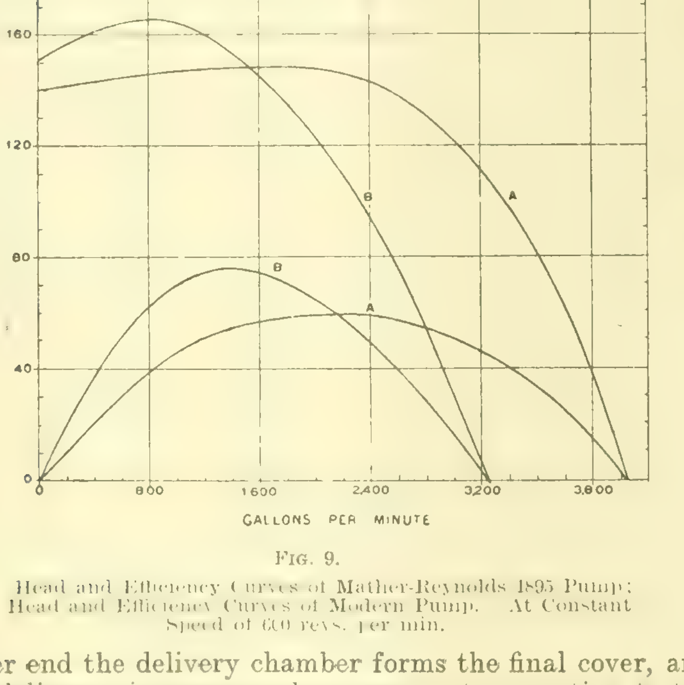


Fig. 9.

A. Head and Efficiency Curves of Mather-Reynolds 1895 Pump; B. Head and Efficiency Curves of Modern Pump. At Constant Speed of 600 revs. per min.

the other end the delivery chamber forms the final cover, and has the delivery pipe cast on the upper part connecting to the annular space into which the last set of guide passages deliver, and at this end a suitable stay is attached to support the pump from the floor. The chambers are secured to each other by bolts through external flanges, each chamber being recessed and spigoted so as to preserve correct alignment of the whole. This forms an inexpensive design, and permits of accurate

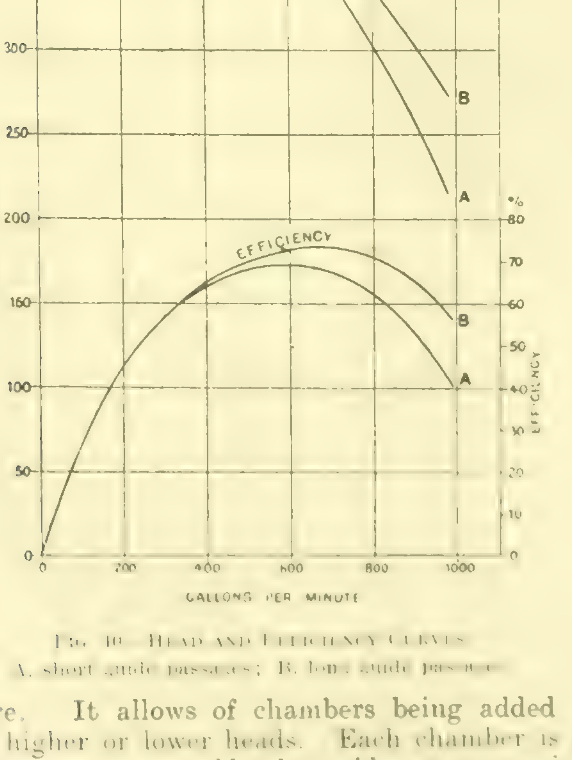


Fig. 10.—Head and Efficiency Curves.
A, short guide passages; B, long guide passages.

manufacture. It allows of chambers being added or subtracted for higher or lower heads. Each chamber is distinct in itself, and has on one side the guide vanes, receiving the discharge from the impeller, and on the other the return passage to the eye of the next impeller. This return passage is walled by a diaphragm integral with the casting. The water leaving the impeller, guided by the delivery vanes, passes to the next chamber and is there guided to the eye of the following impeller. As shown in photos, Fig. 4 and Fig. 8 (right-hand side), there are four guide passages in this particular pump, and their form is clearly illustrated.

In comparing such a pump with a modern one, it will be found that it is in the form of its impeller and its delivery casing that the original Mather-Reynolds pump differed most

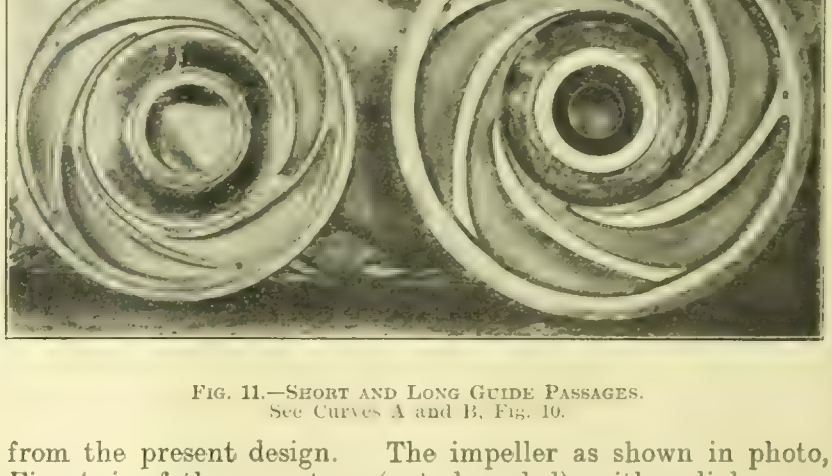


Fig. 11.—Short and Long Guide Passages.
See Curves A and B, Fig. 10.

from the present design. The impeller as shown in photo, Fig. 4, is of the open type (not shrouded), with radial vanes, the roots of which are carried across the openings of the eye into the boss, necessitating the use of a modified form of Francis entrance. This form was probably adopted in order to secure sufficient strength to drive the vanes, necessitating them being carried through full width to the boss on the pump shaft, and not starting level with the outer diameter of the eye as now. The impeller was turned all over, and revolved a close fit in its casing, which was turned to a corresponding form. This prevented leakage and loss of efficiency by the return of the water from the tip to the suction along the impeller sides.

The reasons that induced Prof. Reynolds to adopt such a radial impeller are not quite clear, as the shrouded form with curved back blades was in common use at that time, and is a

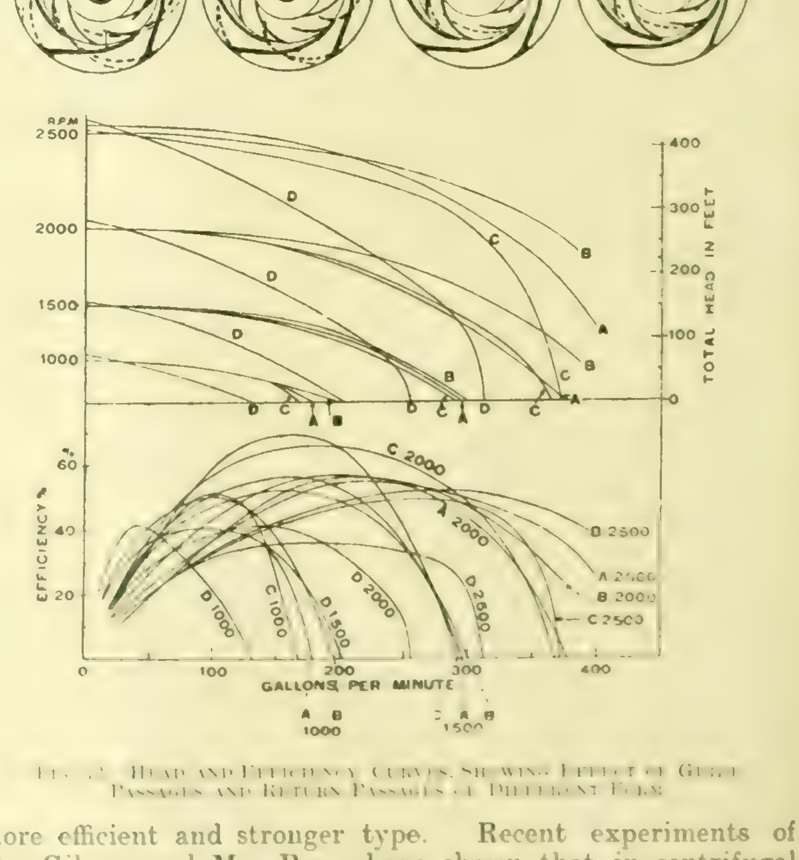


Fig. 12.—Head and Efficiency Curves, Showing Effect of Guide Passages and Return Passages of Different Form.

more efficient and stronger type. Recent experiments of Dr. Gibson and Mr. Ryan have shown that in centrifugal pumps with open-vane impellers the frictional resistance is three to five times as great as with closed or shrouded ones, though it must be noted that these experiments were made

with clearances considerably greater than obtained with the Reynolds impeller.*

In the 1895 pumps the speeds of the water through the impeller and passages were comparatively low, and large areas were therefore necessary (see Fig. 6). Each wheel being of the open type was nearly balanced as to end thrust in itself, and so with the moderate heads pumped against troubles with lateral end thrust were not experienced. There is no doubt, however, that end thrust did occur, and this caused the impellers to rub on the sides of their casings, with consequent friction, wear causing leakage and loss of efficiency, the varying conditions of which make the true comparison of various tests difficult. This, however, did not cause any serious trouble in practice on account of the large areas on which the end thrust was taken, and the low head per chamber.

Fig. 7 shows curves taken on the works test tanks from the impellers A, B, C, D, tested in the same single-chamber pump body, and with one set of short guide vanes. These impellers were not of the 1895 type, but shrouded. The curves are given solely for the purpose of showing the effect of different forms of impeller vanes working under similar conditions. They illustrate the advantage in efficiency of the impeller with the backward curved vanes,† and in head of the one with radial vanes. Impeller C most nearly corresponds to the radial vanes of Reynolds, and impeller A to the modern type. The reaction wheel D gives a gradually falling head curve as the quantity becomes abnormal, with smaller tendency to increase the driving power and lower efficiency. To obtain the best results of each impeller, different guide passages with suitable entrance angles should have been used.

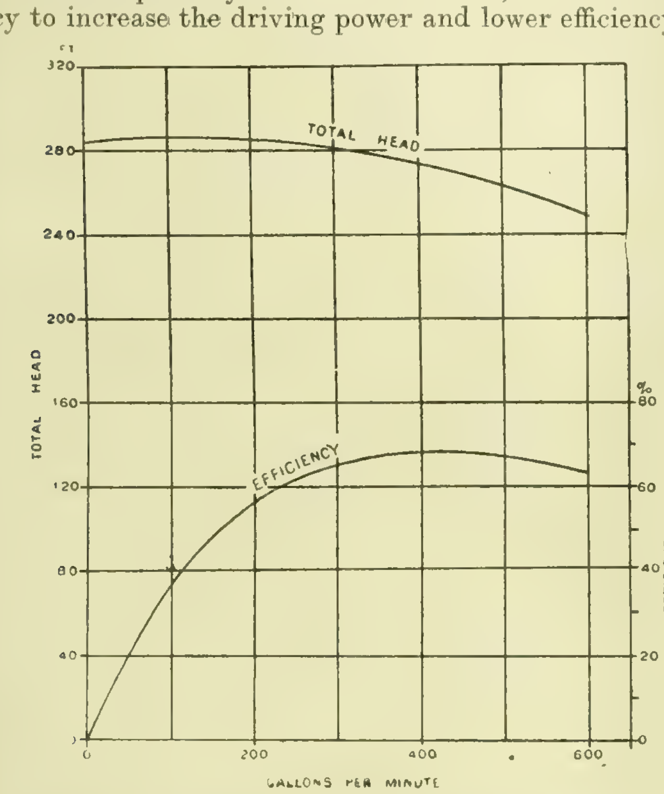


FIG. 14.—TEST OF FOUR-CHAMBER TURBINE PUMP (SULZER) WHEN RUNNING AT A CONSTANT SPEED OF 875 REVS. PER MINUTE.

Considering now the guide vanes, it will be seen that in the 1895 pump these are shorter, or rather open out quicker than in a modern pump (see photo, Fig. 8). They are obviously less efficient if judged from the analogy of a Venturi tube, which must have a certain (long) length if serious loss is not to be occasioned by converting velocity into pressure. The difference, therefore, between the efficiency of an 1895 and modern pump, as shown in curves (Fig. 9), is probably due to the form of the Reynolds impeller and its guides, with its cramped entrance at the eye with consequent shock to the entering water, and to the loss at the periphery from the radial vanes, also to the shortness or too rapid opening out of the guides. The importance of long and carefully formed divergent guide channels is shown by curves, Fig. 10, and photo, Fig. 11, the same impeller being used in each case. Fig. 11 shows photos of the short and long guide passages.

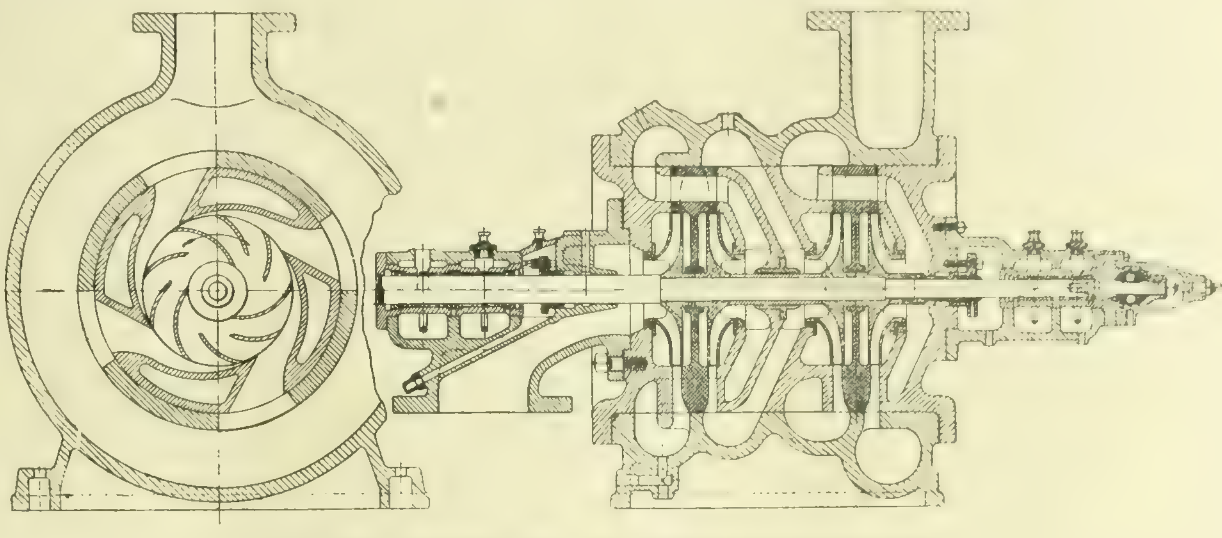


FIG. 13.—FOUR-CHAMBER HIGH LIFT CENTRIFUGAL PUMP (SULZER).

The effect of the curvature, length, and dimensions of entrance of the guide passages and of the curvature and angle of delivery of the return passages on to the eye of the impeller are shown in curves, Fig. 12. These curves have no relation to the curves of Fig. 7, being taken at an earlier date with a different pump.

Head and efficiency curves are given for four different designs of guide and return passages, the same impeller of standard shrouded type being used in each case. Design A has short guide vanes with wide opening on the radial line. The return passages are of similar curvature. Design B has similar guide vanes, but the return passages have a short curve becoming radial near the eye of the impeller. Design C also has similar guide vanes, and the return passages are similar in curvature to those of A, but are not extended to the outer periphery of the return chamber. Design D has a narrower opening on the radial line, one-half that in A, B, and C. The return passages are similar to C.

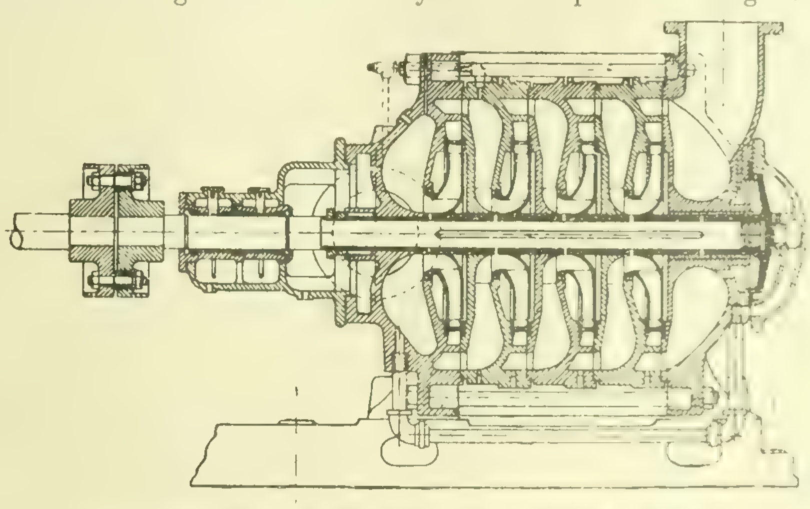


FIG. 15.—MODERN FOUR-CHAMBER PUMP (MATHER & PLATT).

The head and efficiency curves are given for speeds of 1,000, 1,500, 2,000, and 2,500 revs. per minute respectively. An inspection of the curves shows that design D is much inferior both in head generated and in efficiency, due to the throttling at the throat of the guide passages, and incidentally that self-regulation may be readily attained by such throttling, as it may also be obtained by throttling at the eye, or less effectively by a reaction form of impeller, as shown in curves, Fig. 7. Secondly, that design B is superior to both A and C in generation of head, especially with larger quantities, and superior to A in efficiency, especially at the low speeds, but it is much inferior to C in maximum efficiency, except at the high speeds. At these speeds eddying and whirling take

* Proceedings Inst. C.E., Vol. CLXXIX. 1910.

† For a discussion of the superior efficiency of curved vanes over radial vanes, see Dr. Stanton's paper, Proceedings Inst.M.E., 1903, "Centrifugal Pump Efficiency."

NOTE.—The authors are informed that in some tests on the efficiency of pumps, the kinetic energy of the water as delivered from the pumps is added to the energy as measured by the product of the head (measured by gauges fixed at the same level on the delivery and suction) and the quantity in determining the work done by the pump. This is obviously incorrect, unless the kinetic energy of the water entering at the suction side is deducted from the work done by the pump. As in general the velocity of inflow and outflow is the same the two factors balance each other, and the work done is truly represented by the product of the quantity and the head.

place in the whirlpool chamber of C, which is prevented by the guides forming the continuous passages of design B. Design B is most usually adopted as best meeting average conditions.

Thirdly, that design C, which approaches more nearly to the conditions of a single chamber pump, gives considerably higher maximum efficiency at speeds of 1,500 and 2,000, due to less power being absorbed by friction against the walls of the guide passages, and also to tangential motion imparted to the water as it enters the subsequent impeller by the tangential curvature of the return passages.

A considerable number of pumps of the 1895 form were constructed for installations in this country and abroad, some of which are described later. Meanwhile Messrs. Sulzer Bros., of Winterthur, had commenced the manufacture of multiple turbine pumps about the year 1896, and had evolved various modifications in the Osborne Reynolds design, whereby both the efficiency and the lifting capacity were considerably improved. They had established in 1898 an interesting and novel installation of these improved pumps at the Spanish mines of Horcajo, which attracted considerable attention. Two years later an agreement was concluded between Messrs. Sulzer Bros. and Messrs. Mather & Platt providing for an interchange of future improvements, and due acknowledgment of the original work of Prof. Osborne Reynolds and of the improvements made by the two manufacturing firms.

A four-chamber pump of the Sulzer design is shown in longitudinal and cross sections in Fig. 13. Comparing this with the 1895 design, three important differences are noticeable. Firstly, the body casting of the pump is constructed in one piece, with the intermediate pieces, guide vanes, and impellers put in from one end. Secondly, the impellers are shrouded and have backward curved vanes. Thirdly, the impellers are arranged back to back to compensate for the increased lateral end pressure set up by the higher heads worked against. This arrangement of the impellers involved the use of somewhat tortuous passages in the pump to bring the discharge of the first impeller to the eye of the second, and so on. Moreover, these passages passing several joints increased the probability of internal leakage from one stage to another. Curves of head and efficiency of such a pump are shown in Fig. 14.

The agreement between Sulzer Bros. and Mather & Platt came to an end by mutual consent in 1904, and after that date each firm further developed their pumps on their own lines. The authors deal now only with the improvements of Mather & Platt, not having knowledge of Messrs. Sulzer's work beyond what is generally available through publication.

Proceeding now to the discussion of later designs, a four-chamber pump is shown in longitudinal section in Fig. 15, its guide vanes in photo Fig. 8 (left-hand side), and its impeller in photo Fig. 16. It will be seen that constructionally this pump differs principally in that the extended suction end is shortened, and is similar to the delivery end. This enables various classes of drives, motor, belt, or steam turbine to be better negotiated with a standard pattern. Successive chambers, instead of being secured to their neighbours by bolts and flanges, are held together by long bolts extending the entire length of the pump body and held only at the two ends (suction and delivery). This construction secures, amongst other things, some economy in manufacture.

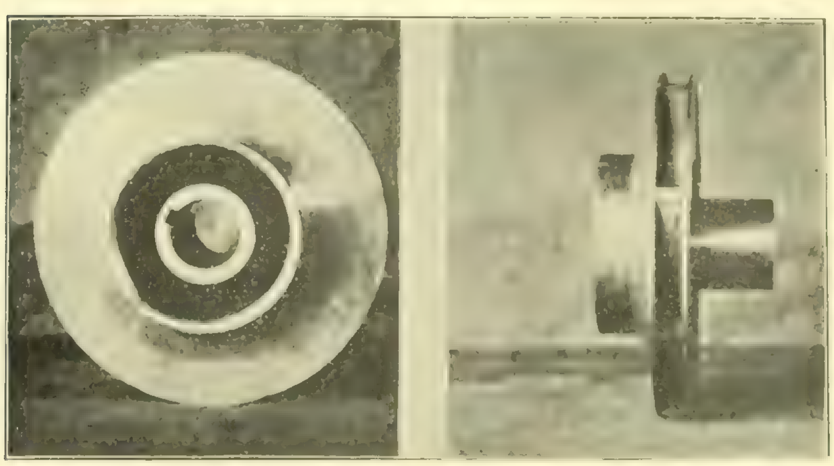


FIG. 16. IMPELLER OF MODERN FOUR-CHAMBER PUMP (MATHER & PLATT).

The impeller is of the shrouded type, having vanes bent well backwards, and the guide passages are longer and more correctly divergent, whilst the return way to the eye of the next impeller is of a curved form and more in line and continuous with the receptive ports, thus preventing the abrupt right-angle turn through the casing obtaining in the Reynolds pump. The losses in the Reynolds impeller through side friction in its casing are obviated, and any leakage from the periphery back to the suction is prevented or greatly minimised by the outer circumference of the impeller eye running in neck bushes with a very small radial clearance, amounting to less than 0·005in. The importance of preventing this leakage is very great if high efficiency is to be secured. The impeller is turned all over outside to reduce loss by skin friction,* and with the same object it is usual to use as many wheels as the circumstances will otherwise allow of.

The end or axial balance of the impellers is obtained by the automatic device shown, which acts well in practice, and compensates for wear and variable leakage taking place in the pump. In other respects the arrangement, direction of flow of water, and assemblage of the pump are the same as in the original Mather-Reynolds pump.

Representative curves of head and efficiency of such a pump are shown in Fig. 9.

* For a discussion of this skin friction see paper by Gibson and Ryan cited above.

(To be continued.)

CASTING STEEL AND ALLOYS IN A VACUUM.

BY E. F. LAKE.

WHILE casting metals *in vacuo* is an old principle, it has not been developed to any extent until quite recently. Occluded gases and those segregated in large enough volumes to form miniature bubbles or the larger blowholes, are only beginning to be recognised as the real injurious elements in metals of all kinds. The oxygen, nitrogen, and other elements that form these gases, enter into combination with the elements that are parts of the various alloys from which castings are made and form oxides, nitrides, &c., and thus detrimentally affect the strength, wearing qualities, and other properties that it is desirous to obtain in the various metal parts that are manufactured. By melting metals, or casting them in a vacuum, these gases can be almost entirely removed and the mechanical properties of metals or alloys greatly improved. This principle is fast growing in favour, and, therefore, it may not be very long before casting in a vacuum will be quite common.

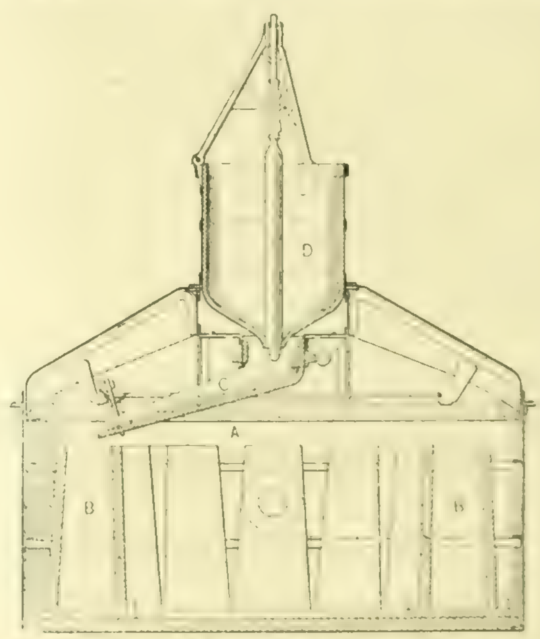


FIG. 1. TEEMING INGOTS IN A VACUUM CHAMBER.

A vacuum in connection with melting metals has been used to some extent with very good results. Some metals are very brittle substances, and when worked by ordinary methods, cannot be rolled and drawn. When melted in a vacuum, however, they have been drawn into wire for various purposes. Examples of such metals are tungsten and tantalum, which are made into wire for incandescent lamps. Another metal that is very difficult to melt in the open air is magnesium, and this has been readily melted in a vacuum furnace. This is accomplished by building an air-tight chamber around the melting pot or furnace and pumping out all the air. An electric current then generates the heat necessary for melting the metal, and no oxidisation can take place, as the oxygen has been removed, likewise the nitrides, sulphides, phosphides, &c., do not form, and the metal has a more dense, homogeneous grain than can be given it by any other process. No oxidising effect can, therefore, be given the metal when a good vacuum

is obtained and the reducing effect of the atmosphere in the furnace is very slight, even at the highest temperatures.

Even though the principle of casting *in vacuo* is very old, the first recorded invention of apparatus for this purpose was that patented by H. V. Barnum, in 1879, as shown in Fig. 2. Here, A is the vacuum chamber, and B a door through which

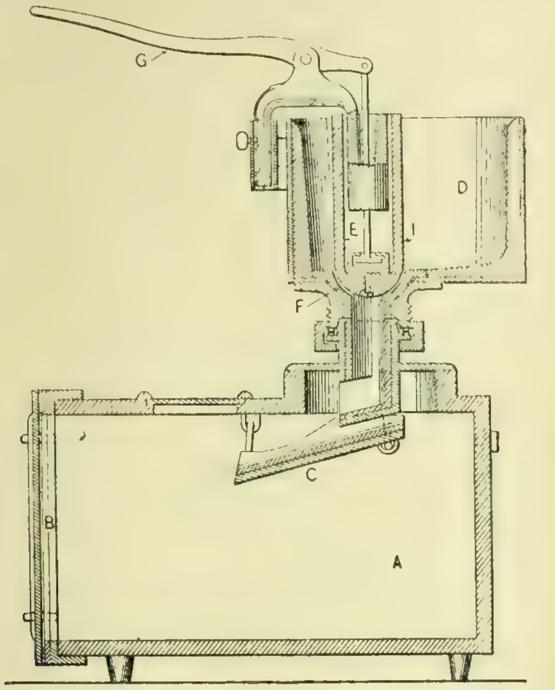


FIG. 2.—APPARATUS FOR CASTING IN A MOULD IN A VACUUM.

any kind of a mould can be inserted. This door covers the whole end of the vacuum chamber. A clay-lined pot D of molten metal is fastened to the top of the vacuum chamber in such a way that no air will be admitted, and when the mould is ready to pour, valve E, which is made of some refractory material, is raised by lever G out of valve seat F, which is also made of refractory material, and this allows the molten metal to flow from pot D through spout C and into the mould. Spout C is made fan-shaped so the vacuum may cause the escape of most of the gases out of the molten metal as it flows over the surface.

Casting Steel Ingots in a Vacuum.—Practically this same principle is used for casting steel ingots by the Ellis May Steel Syndicate, Ltd., of England. This apparatus is shown in Fig. 1. The vacuum chamber A is sunk below the floor line, and holds 12 ingot moulds B placed in a circle. The ladle of molten metal D is brought to the vacuum chamber and located in the centre of the cover over spout C. The apparatus is arranged so that when ladle D is dropped into position it makes the vacuum chamber air-tight, and the air is then pumped out of vacuum chamber A. When this has been done the spout underneath the ladle is made to revolve from one ingot mould to another until all have been poured. While the metal is flowing through the spout, any gases that may be in the molten metal are supposed to escape. It is said the pipe is thus considerably reduced.

In Fig. 4 is shown an American device for casting ingots *in vacuo*. In this the ingot mould and ladle are constructed in such a way that when the ladle of molten metal is placed on top of the ingot mould, it seals it air-tight. To remove the air from ingot mould A, a tank much larger than the mould is located at B, and vacuum pump C brings about a vacuum in tank B. Ingot mould A is connected by piping to tank B, and when the ladle of molten metal D is lowered to the top of the ingot, ready to teem, valve E is turned on and into tank B is exhausted the air in the interior of ingot mould A. The vacuum pump is kept working all the time the ingot mould is being filled. Thus, while the molten metal is falling into the mould and flowing around to different parts, the gases are carried away. With this arrangement a universal joint makes it easy to connect to each ingot mould in a short time, and thus very little time is lost.

Casting Sand Moulds in a Vacuum.—Another apparatus for casting sand moulds *in vacuo* was brought out in 1893; its construction and method of operating is shown in Fig. 3. In this, A is the vacuum chamber; B the top which lifts off to admit the mould; C the ladle container, which is also a vacuum chamber, and D the ladle. To operate it, cover E is swung back, as shown in the upper left-hand view, while the ladle of molten metal is lowered into its holder F. The cover E is then swung over the top and it fits air-tight, as shown in the other views. When the air has been exhausted from chambers A and C, ladle D is turned over in its trunnions H H, and pours the molten metal into the mould. In the ladle cover at I and in the top of the mould chamber at J J, are located glass plates, so the operator can see how the ladle is working and when the mould has been filled.

By pouring moulds in a vacuum chamber in this manner, the metal more readily flows to all corners of the cavity, filling all interstices, and thus producing sharp, clean castings. The vacuum proves a stronger attraction, so to speak, than the molten metal for oxygen, nitrogen, and other gases, and hence as the metal is being poured into the mould, most of the gases are drawn out of the metal. This overcomes any tendency toward the formation in the casting of blowholes, gas bubbles, air pockets, cold shuts, and like imperfections, and the losses from bad castings are greatly reduced.

While exhausting the air from vacuum chambers A and C, the gases and vapours rising from the molten metal are carried away, and this renders the metal dead by removing all tendencies toward ebullition. By removing the gases from the metal, a more dense and fine grain is given the castings, and as the molecules that form the mass are not separated by these gases they are held together with a great cohesive force.

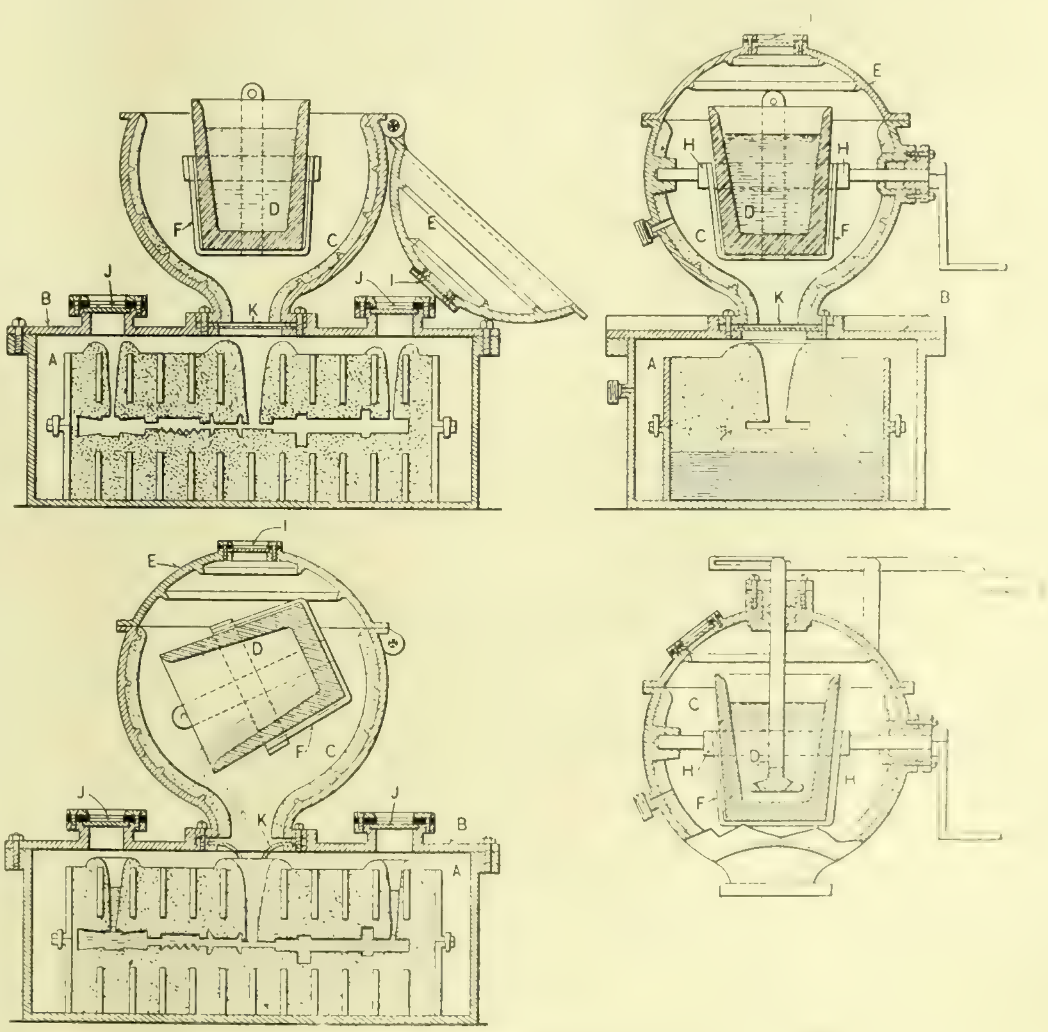


FIG. 3.—EQUIPMENT FOR POURING SAND MOULDS IN A VACUUM

Thus, vacuum castings excel ordinary castings by having greater strength, wearing qualities, and other mechanical properties, and by being more homogeneous, soft, and ductile.

If desired, an attachment could be easily put on cover E by which the metal in the mould may be stirred by a disc located on the end of a bar, passing through the centre of the

cover and attached to a lever on the outside. Such an arrangement is shown in the lower right-hand view of Fig. 3. It would hasten the pouring as the ladle is turned over as soon as the gases cease to rise from the molten metal. Stirring would bring all parts of the molten metal subject to the vacuum condition, and thus quicken the escape of the gases. To facilitate this, a fusible plate is located at K to separate

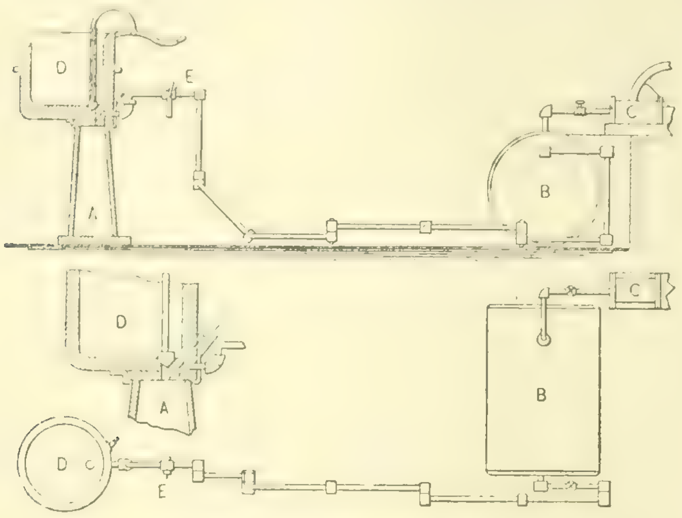


Fig. 4. Exhausting Air from each Ingot as Teemed.

the ladle chamber from the mould chamber. Thus, the air can be exhausted from each separately, and the gases drawn away from the ladle without interfering with the mould. As soon as the molten metal strikes this plate it melts and allows the metal to flow through, as shown in the lower left-hand view.

Application of Vacuum to Die-casting.—The most successful and largest application of the principle of casting in vacuum is in connection with the manufacture of die-casting. As permanent moulds that are made of metal are used to give the castings their shape, a vacuum can be established in their cavity without using a vacuum chamber, or the die-mould can be located inside of a vacuum chamber without specially constructing the mould, fear of injuring it, or altering its ability to make perfect castings. They can be made to operate automatically either inside or outside of a vacuum chamber, and very little additional apparatus is required on the die-casting machines. The vacuum overcomes faults that it is very difficult to get rid of in any other way when squirting molten metal into metal moulds under pressure.

When this is done in the presence of air, the continual churning that the die-casting alloy gets, both in the melting pot and when being squirted into the mould, causes it to absorb more or less of the oxygen, nitrogen, or other gases in the air, and generally it is more. These gases form compounds with the various metals composing die-casting alloys which greatly weaken them, and they also tend to fill them with gas bubbles and occluding gases. These bubbles usually form on the interior of die-castings, and make it spongy and porous, while the exterior may be smooth and have a perfect appearance. This is due to the fact that the molten metal squirted into the mould has a tendency to cling to the metal surface in the cavity that forms the outer surface of the castings.

The large majority of die-castings that are made outside of a vacuum are of this nature, and one has but to break them open to see these miniature blowholes or gas bubbles. They can very plainly be seen with the aid of an ordinary magnifying glass. When these are present, it means that some of the molecules that form the mass are separated by the gases and their inherent cohesive force is interrupted. Thus the mechanical strength is entirely destroyed at this point. This, together with the injurious compounds that are formed with the metals, have conclusively proved that such gases as oxygen, nitrogen, and hydrogen are the most injurious elements that can be present in metals, and it is, therefore, imperative that these should be reduced to the very smallest percentages if castings are to be made that have any strength properties.

To establish a condition of vacuum when manufacturing die-castings, several forms of machines attach piping directly to the casting cavity in the die moulds and connect this piping to an air pump. This removes the air from the mould just before squirting in the molten metal. This ensures that every corner and crevice in the die-mould is completely filled with molten metal, and good sharp castings with perfect exteriors are obtained. The losses from bad castings are also reduced to a minimum, as air pockets do not form to prevent the molten metal from flowing to certain parts of the mould.

A die-casting machine that uses this principle is shown in Fig. 5. In the upper view, die-mould A, which is in three parts, is connected by flexible hose B to air-pump C. In this position, the die-mould is ready to receive the molten metal that forms the casting. In the lower view, the mould is shown as it is opened for the ejection of the casting. As will be seen, the outer half of the mould is located on a carriage that rocks away from the inner half of the mould; while the upper part of the inner half is raised away from the lower part. This machine is driven by pulley and belt, and all of its movements are performed automatically by the aid of gears and cams. All the attendant has to do, therefore, is to keep the melting pot filled and carry away the castings.

While the extraction of the air from the die-mould, as shown in Fig. 5, has many good features, it is not possible to extract any of the gases that may be contained in the molten metal. In order to obtain a more complete vacuum, therefore, a die-casting machine like the vertical one shown in Fig. 6, was designed, and this is in daily use. Here a comparatively large vacuum chamber A forms the body of the machine, and the melting pot D, with its gas-heating furnace C, is located over it in a very similar manner to that of the sand mould casting aparatus shown in Fig. 2, and the ingot-casting apparatus shown in Fig. 1. In this case the driving shaft B, with its pulley R, and the cams that control the movements of the machine, are located in the base, below the vacuum chamber.

The die-mould E is located just below the melting pot and inside vacuum chamber A. To make such a machine successful, therefore, the mould must be opened and closed; the molten metal squirted in, and the casting ejected from the mould automatically, and that is the manner in which this

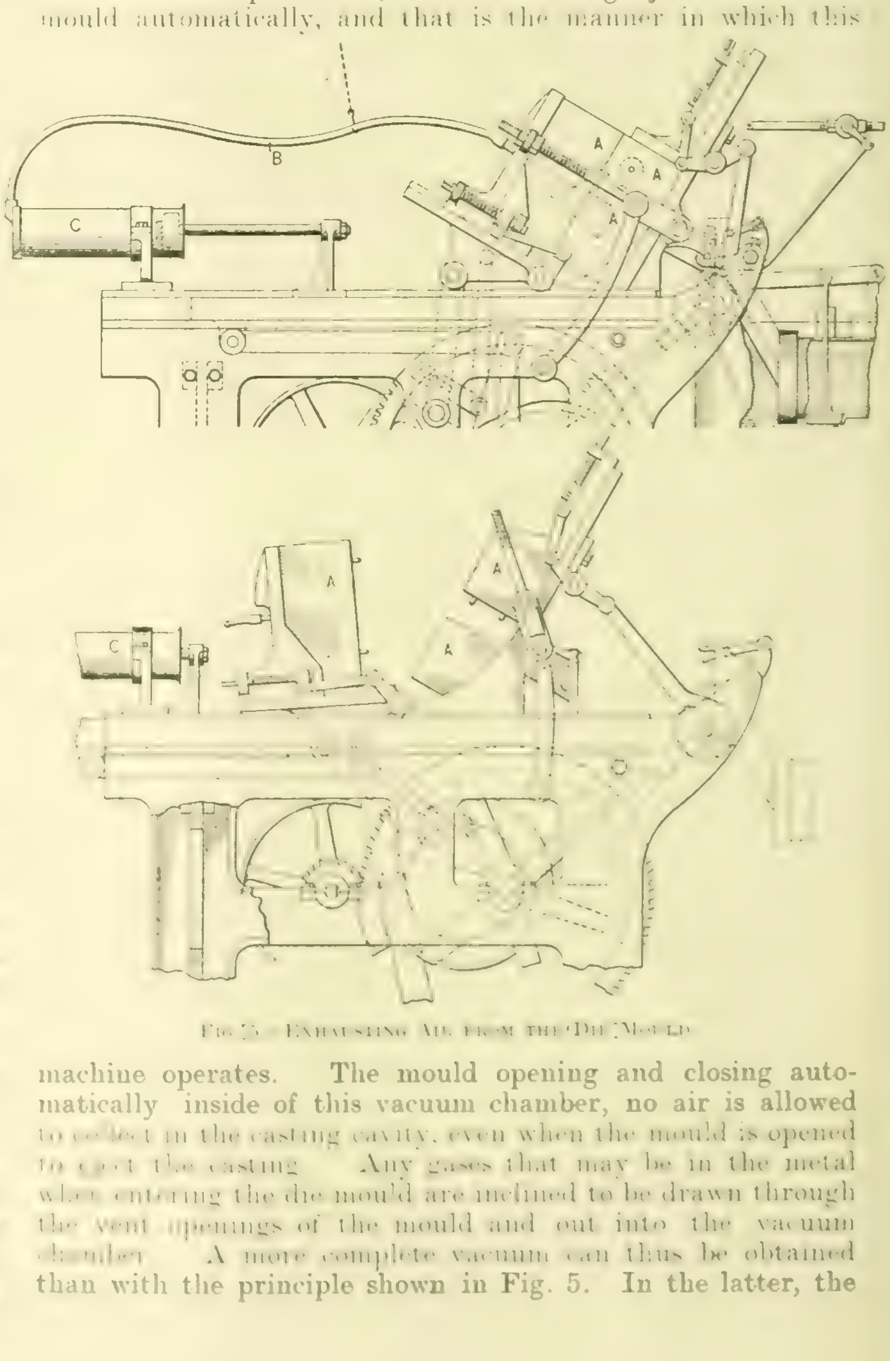


Fig. 5. Exhausting Air from the Die-Mould.

machine operates. The mould opening and closing automatically inside of this vacuum chamber, no air is allowed to collect in the casting cavity, even when the mould is opened to eject the casting. Any gases that may be in the metal when entering the die mould are inclined to be drawn through the vent openings of the mould and out into the vacuum chamber. A more complete vacuum can thus be obtained than with the principle shown in Fig. 5. In the latter, the

air must be pumped out of the mould before every casting is made. And, again, owing to the difficulty of making the die-mould air-tight on the parting surfaces, a high vacuum cannot be realised in the mould. If it were possible to make these surfaces air-tight, it would be exceedingly difficult to part the mould for the removal of the casting.

By placing the die-mould inside a vacuum chamber, as in Fig. 6, these troubles are overcome, as a continuous vacuum can be maintained in this chamber. By milling out sections, one or two thousandths of an inch deep, on the parting surfaces of the mould the mould will be vented, so a continuous vacuum can be maintained in its casting cavity. The mould is then easily parted, and these vent openings are not large enough to fill with metal and form fins on the castings. In addition to causing the metal to be drawn into all crevices of the mould, the molten metal is forced into the mould with from 80lbs. to 100lbs. per square inch pressure. This tends still further to refine the grain of the castings.

In the left-hand view of Fig. 6, the mould is shown closed; but when the double cams F turn over, rollers G on rods H operate levers I, and thus pull the halves of the die-mould apart. As there is always a tendency of molten metal dripping when the die-mould is pulled away or parted, a drip deflector J is immediately pushed under the nozzle and causes any drippings to fall into pocket T. This prevents molten metal from spoiling the finished castings. A second air cylinder L moves brush M over to brush out the casting cavity in the die-mould. To force the metal into the mould when it is closed, valve N is pulled away from its seat in the nozzle opening, and this closes another seat above it at O, where the metal enters the passage from the melting pot. When opening O is closed, plunger P is forced down, and this squirts the metal contained in the passage into the die-mould.

All of these motions are timed so the various operations will follow each other continuously and manufacture castings without any manual labour except that of filling the melting pot. They are turned out by this vacuum machine much faster than they can be made by any hand-operated machine. In fact, as fast as the metal will solidify in the mould, the casting is thrown out, and the mould closed for another without any lost time. As the mould is opened and the castings ejected, they fall into deflector spout R, which throws them into pocket S, and they are then easily taken away from the machine. This is doubtless the most perfect manner in which castings of any kind are made, and it shows the height of the development of the die-casting process and the perfection that has been reached in casting methods. With it more castings can be made in a day and the losses from bad castings are lower than with any other method that has been devised for casting metals. In addition to that, the castings are made with an absolutely smooth outer surface, and the necessity of machining in any of the various ways is done away with. Castings that go to make up the moving, as well as stationary, parts of various machines and instruments are taken directly from the casting machine, and assembled in their respective places.

A horizontal machine of this same type fastens one-half of the die-mould to the nozzle and locates the other half on a carriage that slides back and forth. Thus, the back half is drawn away from the forward half to eject the casting, the vacuum is established by two tanks, in which a continuous vacuum is maintained, located on each side of the mould. When the half mould moves to the closed position, connections are made to these vacuum tanks, and the air is sucked out of the cavity of the die-mould. The exact form of the machine is immaterial as long as the vacuum is successfully created in the casting machine.

Still another form of die-casting machine that removes the air from the mould before filling it with molten metal is shown in Fig. 7. This is a hand-operated machine connected to an air pipe at F. It does not produce such good castings as the machine shown in Fig. 6, but is being successfully used in the manufacture of die-castings. The two halves of the mould are drawn apart by raising lever D. Then a ladle, like that shown at A, is filled with metal at an ordinary melting furnace and placed inside of a cavity above the die-mould. Lever D is then brought down to close the mould. After that, a valve is opened that takes the air from the mould through outlet C and pipe F, and the ladle full of metal is then turned upside down. Compressed air is next turned on by opening valve B and the metal that has been dumped out of ladle A is forced into the casting cavity at H by this incoming current of air. The mould is then opened and lever I is pushed in to force the casting out of the mould, with ejector rods E. This is the only machine that uses suction to draw the air out in combination with compression to force the metal into the mould. As this machine is only hand-operated, it is much slower than the machine shown in Fig. 6.

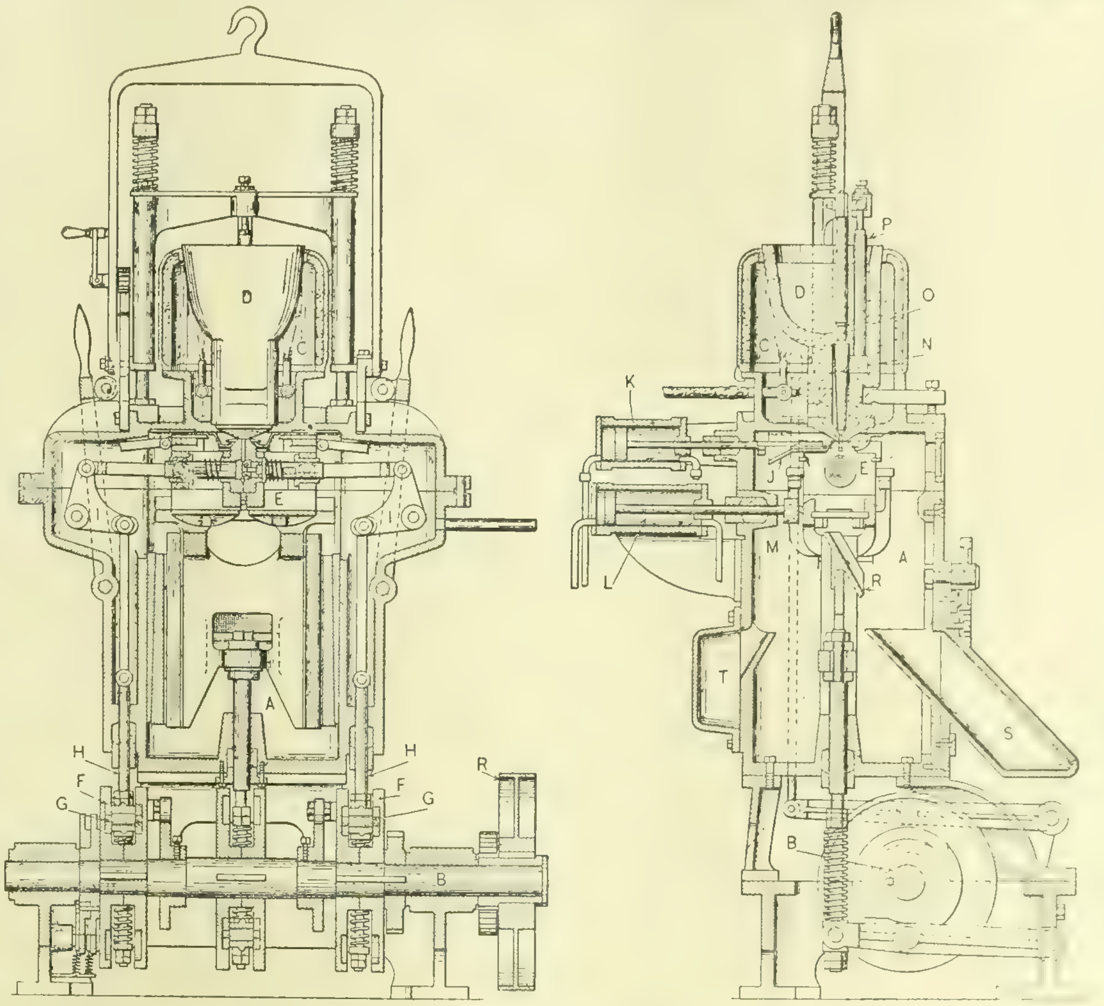


FIG. 6.—MACHINE WITH VACUUM CHAMBER IN WHICH THE DIE MOULD OPERATES AUTOMATICALLY.

With any of these die-casting machines, it is not possible to cast metals having a melting point that is over 1,200° Fah. This is largely due to the fact that no metal or material has been found that will withstand the action of any higher temperature and at the same time have wearing qualities that will enable one die-mould to make enough castings to be commercially successful. Consequently, castings with the strength of the bronzes and steels cannot be obtained in die-castings. Die-castings, therefore, are always made from the low melting, white metal alloys, and the yellow metals or any of the iron products cannot be successfully manufactured into castings in this way. The white metal alloys, however, can be made with a strength that is equal to yellow brass castings, and where such strength or wearing qualities will suffice, no better or cheaper method has been devised for manufacturing castings that will do away with machine work.

Parts that can be gotten into shape by the punch press or similar methods are much cheaper than those die-casted. Many intricate pieces, however, that cannot be punched out and

would necessitate machining, if cast in sand moulds, or forged are much cheaper when made by the die-casting process. The thing that has made it possible to manufacture die-castings of the strength of yellow brass is the application of the vacuum principle to die-casting machines. To construct a die-casting machine and moulds that will stand a high enough pressure on the incoming metals to make dense, sound, and strong castings would be very expensive, but by adapting the vacuum principle to these machines, this has been accomplished at a cost that is not prohibitive.

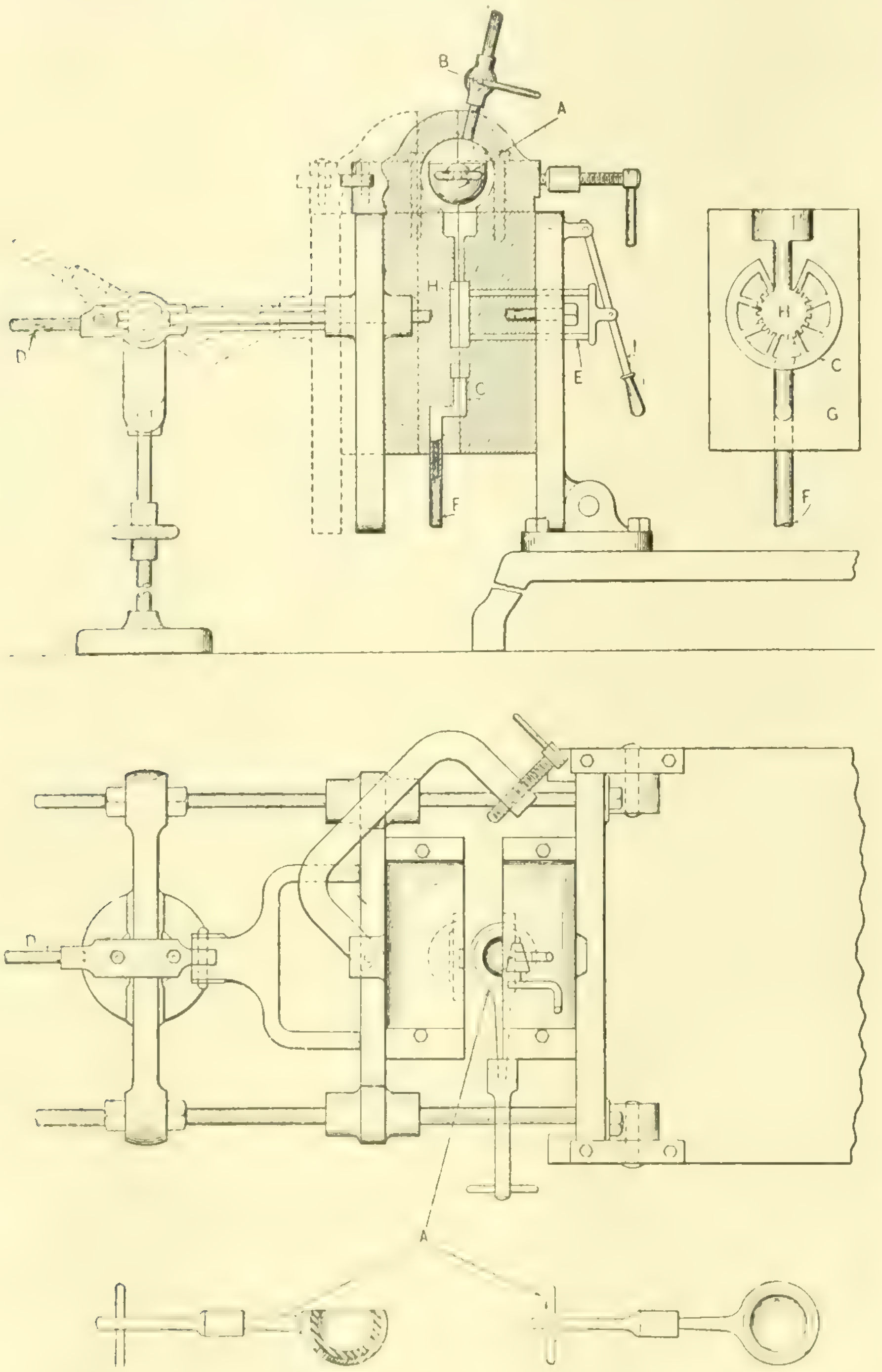


FIG. 7. AIR SUCTION COMBINED WITH AIR COMPRESSION IN DIE CASTING.

All kinds of castings are made so much better by casting them *in vacuo*, as well as by melting the metals in a vacuum, that this principle is bound to increase in commercial use, and, doubtless, vacuum castings will become more commonly made and used in the future. Improvements will probably be made in the methods of casting sand moulds in a vacuum that will make these cheap enough to be a commercial success, and where any kind of a permanent mould can be used, castings for machine parts or for various kinds of apparatus and instruments can be profitably made in a vacuum.—"The Iron Age."

The Pioneer Oil Tank Steamer.—The first steamship specially designed for carrying oil in bulk was the "Vaderland," built by Messrs. Palmers, at Jarrow, in 1872. Prior to that petroleum was shipped in barrels, although in the early sixties three iron sailing ships were constructed to carry oil in bulk. The modern petroleum steamer is very largely the outcome of the inventive genius and enterprise of the late Col. Swan, of Messrs. Armstrong, Whitworth, & Co., at whose Walker yard quite a fleet of oil carriers have been built. The first of these tankers was the "Gluckauf," launched in 1887.

RED BRASS INGOTS.

BY H. C. PARROCK.

RED brass ingots, properly made, offer the following advantages to the foundryman: (1) Uniformity; (2) known contents; (3) full value; (4) low shrinkage; (5) low handling cost.

Uniformity in ingots depends upon the stock, the amount of the charge, and the proper handling of the metals when melting and tapping. In this respect, the direct flame reverberatory furnace has advantages over the crucible. A charge of 50,000lbs. melted at one time on a large hearth, though made up from a carload of various sorts of scrap, will yield a carload of ingots that show only a negligible variation throughout. This follows naturally from the nature of the process. Each ingot is, for all practical purposes, exactly like every other ingot.

In the crucible made ingot, the uniformity of ingots from the same lot depends to a large extent upon the ability of the man employed to pile and quarter; or to select by judgment and experience, with the usual liability of human error. The large furnace is free from this chance, which means that in purchasing a carload of ingots one analysis will show the foundryman what he is buying when taking the ingots made on one hearth in a large quantity, while in buying a carload made up in small lots a 10 per cent. variation might result over the entire car. Such a variation would mean a possible loss in making one customer's castings or the shipment of poorer material on another order, to the customer's loss. An analysis of a carload is best made by selecting six or more ingots at random, drilling, and mixing thoroughly, and analysing the mixture, according to approved methods.

However, it is evident that the use of ingot of either method of manufacture is preferable to the purchase and use of promiscuous scrap. There is no way in which the foundryman can ascertain the exact quality of a barrel of scrap except by melting the whole lot, and analysing the contents of each crucible. The small maker cannot do this economically. This is what the ingot maker does, taking his analysis before tapping, in order to correct the bath, if necessary, by the addition of new copper, tin, lead, or zinc. The product is then an exact one, and is uniform throughout. It is further evident that the ingot maker will purchase scrap to better advantage, since he buys direct from the source of supply, and in larger quantities than the foundryman. He is in a position to select and so maintain the original quality of his raw material, an advantage to himself and ultimately to his customer.

Since the bath is tested prior to tapping, it is evident that the metal can be brought to exact formula (within reasonable limits). A buyer may ask for any analysis he desired with a variation of 1 per cent. on copper, ½ per cent. on tin, with lead and zinc within 1 per cent. Such an ingot is close to specifications and the best product obtainable. It therefore commands the highest price.

Or ingots may be ordered to read:—

	Per cent.
Copper not less than	82
Tin not less than	4
Lead not more than	7
Zinc not more than	9
Impurities not more than (including antimony)	·75

The ingot maker furnishes an analysis with his material; the foundryman checks this analysis by selection at random from the car. The contents thus determined show the foundryman with certainty the material he is using. With this certainty he not only establishes his metals for his customer's benefit, but guards his own profits in knowing that he is not throwing away metals.

In filling an order the foundryman is anxious to satisfy

his customer's formula first, and to make a profit in so doing. The following typical ingots are obtainable: —

	No. 1	No. 2	No. 3	No. 4
Copper	79·50	82·00	85·00	82·00
Tin	10·00	8·00	5·00	4·00
Lead	9·50	7·00	5·00	7·00
Zinc	0·50	2·40	4·50	6·00
Iron, Sulphur, Antimony, Arsenic	0·50	0·60	0·50	1·00
	100·00	100·00	100·00	100·00

That is, an ingot can be furnished having 79·5 copper, 10 tin, 9½ lead, with a balance of ingredients 1 per cent. or less. From this grade the ingots range to No. 4, a low tin, red brass, very suitable for commercial red brass work. No. 1 is the most expensive ingot, not only because of the high tin, but also because of the low zinc content.

A foundryman buying in large quantities can afford to allow a strong variation in contents, since he always knows this content exactly, and applies his various lots of ingots to various orders without danger of losing money or of disappointing a customer by using the wrong metal; but, the main thing, he also buys his ingots at the best price, since he can allow the ingot maker a reasonable variation in filling orders. This enables the ingot maker to fill orders with less expense and delay. The purchase of ingots to analysis means a full return to the foundryman; he can demand a full guarantee that the metal is like the sample or test ingots.

The melting loss in using brass ingots will be less than that existing with the use of scrap. The exposed surface per unit content is less in the first place, and there will be less surface oxidation. In the second place the foundryman will not have to melt unnecessary dirt or dross or to melt material in which the zinc, for instance, is high, and it will therefore be necessary for him to add unusual amounts of other metals to bring the pot to the right analysis. Since he knows exactly what each pot contains at the start, the enriching or cutting down is absolutely under his control. Or if the ingot is approximately correct for the casting desired, a small amount of one or more new metals in addition is always sufficient for the purpose. This means quick heats, low melting ratios, freedom from gas, and a low loss in melting.

The use of brass ingots means a low handling cost; carrying from car to store-room and the placing of a tabulator card on the pile covers the handling. There is no sorting to do; no rejection of junk, iron, zinc, babbitt, solder, and the various impurities sometimes found in a barrel of so-called clean brass or bronze. The saving here is obvious.

It is not intended here to present scrap ingots as a substitute for new metals. It is true, however, that brass ingots properly made can be used with economy and without detrimental effects in all commercial castings containing copper, tin, lead, and zinc. They can be purchased and used to advantage in castings, even where zinc is limited to ½ per cent., and they can be used obviously in any casting where scrap is allowable. They are, of course, unsuitable for a pure mixture of copper and tin, since lead and zinc are always present, and should not be used where the buyer specifies all new metals and pays accordingly. The best foundries to-day are buying these ingots, mixing with scrap copper, and with new material as well, when necessary, and are turning out excellent castings. By buying on analysis in their laboratories and so obtaining uniformity, full value and known contents, such foundries have every advantage over the jobbing foundry buying scrap from various sources. The big foundry, even with its high fixed charges, by use of such ingots, can underbid even the one-man plant, on the basis of delivering metals for value received; or, in other words, insisting with the customer that he knows what he is buying and paying for. In many cases brass and bronze specifications are extremely lax. The foundryman in competition will find it to his advantage to establish a customer's analysis for him and to maintain the grade at all times. These ingots, properly made, will be of the greatest assistance in this kind of work.—"The Brass World."

MISCELLANEA.

Lectures at the Institution of Civil Engineers.—By request of the Council, Captain H. Riall Sankey, R.E., M.Inst.C.E., will deliver two lectures at the Institution on "Steam Turbines: Some Practical Applications of Theory," on Friday evenings, February 2nd and 9th, at 8 o'clock. The Vernon Harcourt lectures will be delivered at the Institution on Friday evenings, February 16th and 23rd, at 8 o'clock, by Mr. W. T. Douglass, M.Inst.C.E., his subject being, "Works for the Prevention of Coast Erosion." The two courses of lectures above named are intended in the first place for the instruction of students of the Institution, but they are open also to members, and all classes of the Institution are cordially invited to attend them.

The Institution of Locomotive Engineers.—The annual general meeting of this institution was held in London on Saturday, January 13th. Prof. Elliott was elected president for the year 1912, the retiring president being Mr. John H. Adams. Mr. Alfred Trevithick was elected a vice-president of the institution. The following gentlemen were re-elected as vice-presidents: Messrs. E. L. Ahrons, L. B. Billinton, A. Rosling Bennett, B. K. Field, W. Beckit-Burnie, D.Sc., and R Goose. Also as chairman of the council, Mr. C. A. Suffield; vice-chairman, H. W. Garratt, and the following as members of the council: Messrs. H. F. Anelay, S. P. Smith, W. J. Bennett, H. P. Bray, J. Speakman, D. Sheppy, G. W. C. Jackson, H. J. Malden, W. McKie, and H. W. Dearberg. Mr. G. F. Burtt was reappointed secretary and treasurer, and to him all communications should be addressed to 46, Malling Street, Lewes.

A Diesel Locomotive.—Some interesting particulars are given in "The Times" engineering supplement of the locomotive driven by a Diesel engine which has been constructed at Messrs. Sulzer's works at Winterthur, and which has now begun its preliminary trials. This locomotive is the outcome of many years of collaboration between Dr. Diesel and the Swiss firm, while the truck has been built by the well-known Borsig Company. The present intention is to run the locomotive on the Prussian State Railways if its operation is found to be satisfactory. The motor is of the 4-cylinder type working on the single acting 2-cycle principle and capable of developing normally about 1,000 b.h.p., though it is anticipated that this will be considerably exceeded. The engine drives a loose shaft to which the two driving wheels are coupled, the locomotive having two 2-axle bogies. In order to produce a high starting torque and to develop greater power when ascending inclines an arrangement has been devised by which an auxiliary supply of fuel and air is provided for the cylinders. The weight of the locomotive on the rails in running order is between 80 and 90 tons, and the length over the buffers is about 55ft. Thus the motor is exceptionally light for the power developed.

Electrical Steering Gears.—At a recent meeting of the Glasgow University Physical Society, a paper on "Electrical Steering" was contributed by Mr. B. P. Haigh, of the Engineering Department of the University. Before entering on a description of electrical steering gears, the lecturer dealt with the conditions which such gears must satisfy. Besides possessing adequate power to put the helm hard over in a case of emergency in a minimum of time, they must be very sensitive, especially in fast fine-lined vessels. To enable a vessel to keep a good course the helm must not only respond to small motions of the hand wheel, but must do so without undue time-lag, and in this latter respect electrical steering promised an advance over ordinary steam gears. Probably no machinery required to be more free from risk of breakdown than steering gears, but it should be noted that steering mishaps were not necessarily due to defects in the steering gear. The lecturer explained the liability to suction that existed when two vessels run on parallel courses in narrow channels, and suggested that the recent collision between H.M.S. "Hawke" and s.s. "Olympic" might be due to the slip of the port propeller of the "Hawke" in the wake of the "Olympic." Mr. Haigh proceeded to describe with the aid of drawings and lantern slides a number of electrically-driven steering gears. The advantages of electrical steering gear were many, but one which would appeal to everyone was the absence of steam pipes and steering chains led aft through the passenger accommodation of the vessel.

PRACTICAL METALLOGRAPHY.

A MEETING of the West of Scotland Iron and Steel Institute was held on the 26th ult. in the rooms of the Institution of Engineers and Shipbuilders, Glasgow, the president, Mr. Walter Dixon, in the chair, when Dr. J. E. Stead, of Middlesbrough, delivered a lecture on "Practical Metallography," illustrated by lantern slides. The lecturer described the conditions most favourable to the application of this practical test, which was coming to be regarded as a most useful guide to the practical metal maker and metal worker. It was explained how valuable metallography was as a scientific research, but its use as an adjunct to practical work needed some considerable degree of experience in interpreting the results, which, however, did not detract from its immense practical value. A large part of the lecture was descriptive of how closely and accurately the microstructure revealed the previous treatment of the metal, both physically and thermally. The lecturer also pointed out what valuable information could be got from a careful inspection of the fracture of metals, especially those which had failed in service, and also from an examination of the microstructure visible through an ordinary pocket lens. The simplicity of the outfit necessary was amply demonstrated, and the preliminary operation of fine polishing was described as eminently suitable for carrying out by ladies. Some of the simplest instruments used had been designed by Dr. Stead, who exhibited a portable form of his workshop microscope which had lately been brought into service in many workshops and foundries. Some of the ambiguities which had arisen in the nomenclature of steel metallography were explained by Dr. Stead, and he advocated the use of an etching agent for tempered steels which he had found invaluable for a practical determination of the temperature to which the annealing after quenching had been carried. It consisted of a 1 per cent. solution of nitric acid in isoamyl-alcohol. Some of Dr. Stead's latest researches had shown the great advance possible in knowledge of the effects of crushing strains upon metal as investigated microscopically, and he strongly recommended it as a guide to practice in steel foundries, steel case-hardening shops, and also the rapid estimation of the arrangement of sulphur, phosphorus, and combined carbon in pig iron as used in iron foundries.

The Junior Institution of Engineers.—A party of members of this institution, through the kind permission of Mr. G. E. Pingree, managing director, paid a visit recently to the works of the Western Electric Company at North Woolwich, and spent a most interesting and profitable time in being shown over the various departments. The magnitude of the works impressed the visitors, who were lucky in seeing the various processes and machinery in operation, and their thanks were voiced by Mr. Walter T. Dunn, chairman of the institution, to which Mr. G. H. Nash and Mr. Chas. Rice replied, and the visit came to a conclusion. On February 12th the institution is holding a combined meeting with the Architectural Association to hear and discuss a paper by Mr. Paul Waterhouse, M.A., F.R.I.B.A., on "Bridges," and on February 17th the institution's annual dinner is to be held.

Fatal Accident through Bursting of Hydraulic Cylinder.—An inquest was held at Wednesbury Town Hall on the 24th ult respecting the death of a press worker, who was killed at the Monway Works of the Wednesbury Patent Shaft and Axletree Company on the previous Monday. The evidence showed that the deceased was working a pressing machine, when a loud report was heard, and a sheet of water was seen to envelop him. He was afterwards found dead, a [illegible] of the machine having struck his neck and broken the spinal column. An investigation showed that the hydraulic cylinder which worked the machine had broken. This cylinder had previously been repaired, and a band put round it, but it was pointed out by the manager of the company in evidence that when tested it was found to be quite safe, and that the reason it failed was that there was an internal crack. This would not have been noticeable from the outside, even if there had not been a band on the cylinder. A verdict of "Accidental death" was returned.

INDUSTRIAL AND TRADE NOTES.

Exhaust Turbine for Manchester.—The Manchester Corporation have recently placed an order with Messrs. J. Howden & Co., Ltd., Glasgow, for an 8,000 b.h.p. turbine, to work with exhaust steam supplied from four compound reciprocating engines.

New Steelworks for Swansea.—It is reported that Messrs. Baldwins, Ltd., are about to erect large new steelworks adjacent to King's Docks, Swansea, where they have already a tinplate works of 12 mills. It is proposed that the plant shall be made capable of producing 5,000 tons weekly. The cost of the new works will be between £100,000 and £150,000. It is also intended to erect new blastfurnaces.

Advance in English Tube Prices.—Following the success of the efforts to unite Scotch iron and steel tubemakers into one undertaking, the English tubemakers who are centred in Staffordshire and the Midlands have advanced prices 10 to 15 per cent. The advance is accomplished by a reduction in gross discounts. The new discounts become: Gas tubes, 77½ to 75 per cent.; steam, 72½ to 70; and boiler, 65. Raw material has advanced 10s. per ton since the beginning of December, being now £7. 2s. 6d. to £7. 5s.

Coal Wages Conference.—A five days' sitting of the representatives of the coalowners and miners in the federated mining areas in England and North Wales was held in London last week. As a result the following official statement was made to the representatives of the Press: "The Joint Committee of owners and workmen's representatives in the federated area have had several meetings, and have exchanged views upon the demand of the miners with reference to abnormal places and a minimum wage. A report will be submitted to the coalowners and miners in the different districts within the federated area." The conference adjourned until the 5th inst.

The Motor-car Trade.—According to "The Motor," the production of British made pleasure cars and chassis is generally estimated at 22,000 for the year 1911. Of these, 5,272 were exported, leaving 16,800 for sale at home; whilst, of the cars imported, 11,909 were retained, thus putting nearly 29,000 new cars into use during the year. The figures given by our contemporary show a steady, yet rapid, growth of the import and export trade in cars and parts, for we are now importing and keeping over £5,300,000 worth of cars, chassis, and parts from foreign makers. Our export trade in foreign cars and parts amounted to £678,186, and of British made cars and parts to £3,185,717.

Minerals in Egypt.—The Financial Adviser to the Egyptian Government states in his Note on the Budget for 1912 that the extraction of phosphate rock on the Red Sea Coast has been carried on with encouraging results, and regular commercial production on an increased scale is anticipated during 1912. Prospecting for manganese has taken place in Sinai, and reports of extensive deposits of good grade have been received. Prospecting for petroleum also has been active on the Red Sea Coast, and steady progress has been made, although no sensational discoveries have occurred. A company is now undertaking the thorough testing and opening up of the Jemsa area. Petroleum has been regularly produced in small quantities for consumption as fuel in prospecting operations throughout the year. Storage and shipping facilities are now being provided in anticipation of the beginning of operations on a commercial scale.

Trade Unions in the British Isles.—The portion of the report of the Chief Registrar of Friendly Societies dealing with trade unions, for the year ended December 31st, 1910, has been issued as a White Paper. Every trade union availing itself of the advantages conferred by registration under the Trade Union Acts is required to furnish annually to the Registrar of Trade Unions a general statement in the form prescribed by the Chief Registrar of Friendly Societies. From these it appears that at the close of the year 1910 there remained upon the register 669 trade unions; of these, 638 furnished returns. The total membership for Great Britain and Ireland of the 638 unions was 2,017,65[illegible]; their income amounted to £3,137,115, and their expenditure to £3,[illegible], while the balance of funds at end of year amounted to £5,[illegible]. The figures for 1910, compared with those for the previous year, show an increase in membership of 59,752, or 3·052 per cent., an increase in income of £141,911, and a decrease in expenditure of £21,013. During the year 1910 income exceeded expenditure by £50,330, the balance of funds at the close of the year amounting to nearly six millions sterling. The average gross income per member was £1. 11s. 7d., and the amount of funds per member £2. 18s. [illegible] In 1909, 651 unions made returns, the number of members being 1,572,861, the total income £2,[illegible], the total expenditure £1,[illegible], and the balance of funds £4,137,860.

Some Large Diesel Engines.—The largest Diesel engine so far constructed is of 2,000-2,400 b.h.p., manufactured by Messrs. Sulzer Bros., of Winterthur, and it is now stated that an order has

been placed with the same firm for four 1,000 b.h.p. engines for electric driving in Chile. These will be of the 6-cylinder type, working on the 2-cycle principle, and their design will be practically the same as that of a marine engine of the same power without the reversing gear. Crossheads will be employed, and it is intended that the engines shall be rendered as simple as possible, following on the general lines of the large 2-cycle engines already constructed. The field for internal combustion engines in South America seems to be very large, owing to the high price of coal prevailing in most parts. In our issue of January 5th we illustrated a large gas-engine plant (two engines of 100 h.p. each) operated by producer gas, which were being constructed by Messrs. Mather & Platt, of Manchester.

Anglo-Canadian Trade.—A meeting of representative men in London connected with Canadian affairs has decided to form in the United Kingdom a Canadian Chamber of Commerce, "having amongst its objects the encouragement and promotion of Anglo-Canadian trade and commerce, the safeguarding of Canadian credit, the development of Canadian industries by British capital, and the furtherance of Canadian interests in the United Kingdom." The Hon. J. H. Turner (Agent-General for British Columbia) was appointed chairman, and Mr. B. H. Turner vice-chairman. The council will be composed as follows: Mr. Hugh A. Allan (Allan Royal Mail Line), Mr. A. M. Grenfell, Mr. G. McL. Brown (European manager, Canadian Pacific Railway), Mr. E. W. Hamber (manager, Dominion Bank), Mr. W. M. Botsford (manager, Royal Bank of Canada), Mr. F. W. Aslie (manager, Union Bank of Canada), Mr. B. H. Morgan (General Electric Company, Ltd.), the Hon. J. H. Turner, Dr. P. Pelletier (Agent-General for Quebec), and the Hon. John Howard (Agent-General for Nova Scotia).

The South African Steel Company.—The Union Steel Corporation (of South Africa), Ltd., has been formed with a capital of £250,000. The company is establishing iron and steel works and rolling mills in the Transvaal with a view to manufacturing drill and bar steel, iron and steel forgings, and castings, &c., for which there has been, for many years, a large and increasing demand in South Africa. An agreement has been entered into with the Government of the Union of South Africa for the purchase of scrap for 16 years at £1 per ton, and certain important concessions have been secured. The prospectus estimates, on an annual output of only 5,000 tons, net profits of £25,000. The estimated capacity of the proposed works is 10,000 tons per annum. The Government of South Africa has a right to nominate one director on the Board.

Census of Production.—The Board of Trade have, in conformity with the provisions of section 1 of the Census of Production Act, 1906, appointed the following gentlemen as members of the general advisory committee in connection with the second census of production: Sir Hugh Bell, Sir Charles Macara, Sir P. Ratcliffe Ellis, Mr. J. H. C. Crockett, Mr. B. B. Harmer, Mr. W. H. Mitchell, J.P., Mr. Alexander Siemens, and Mr. J. W. White. Mr. G. A. G. Stanley will act as secretary to the committee. An order of the Board recently laid before Parliament prescribed that the second census should be taken in the year 1913, so that the particulars which will be required will relate to the year 1912. The functions of the general advisory committee are to advise the Board in the preparation of the forms and instructions necessary for the taking of the census, and in making any rules under the Act. It is intended to proceed at once with the preparation of the schedules on which returns are to be made, and the draft schedules will be communicated to trade associations, chambers of commerce, &c., so that those interested may have as early an opportunity as possible of acquainting themselves with the nature of the information which they will be required to prepare.

Scottish Ironworkers.—The ballot of the ironmoulders of Scotland on the question of a strike to enforce a general increase of wages has resulted as follows: For a strike, 6,704; against, 1,185. Most of the men are members of the Associated Society of Iron moulders, who are engaged in heavy casting. Recently the employers offered an advance of ½d. per hour in the case of time-workers and of 2½ per cent. in the case of piece workers. The other ironmoulders, who do light casting, are connected with the Central Society, and to these the employers have refused an advance of wages on the ground that the state of trade does not justify it. The two unions have, however, resolved to take joint action in support of the demands of the Central Society, which is the smaller body. The unions have a combined membership of about 13,000, but other classes of workers, including fitters, pattern-makers, and labourers, will also be involved, and in the event of a stoppage it is estimated that about 20,000 men will be directly or indirectly affected.

Employment and Wages in 1911.—The labour department of the Board of Trade, in its annual report on employment, wages, &c., in 1911, states that employment in 1911 was good in most of the principal industries, in spite of many important disputes in the transport trades. The shipbuilding industry, which was adversely affected by the boilermakers' dispute in the latter portion of 1910, showed a marked recovery early in 1911, and employment was very good throughout the year. The mean percentage of trade union members unemployed in this industry during 1911 was 1·3, compared with 13·2 in the previous year and 22·1 in 1909, a year not seriously affected by industrial disturbance. The percentage unemployed for 1911 was the lowest recorded since 1901, when it amounted to 3·7. In the coal mining industry employment continued fairly good throughout the year, and the average weekly number of days worked by the pits (5·25) was slightly in excess of the mean of the preceding ten years. Employment in the pig iron industry continued fair for the first four months of the year; during the next six months there was a decline, but there was some slight recovery at the end of the year. The iron and steel trade showed an improvement on the previous year. In December, 1911, the volume of employment was nearly 10 per cent. greater than in December, 1910. The tinplate and steel sheet industry continued exceptionally busy. Employment in the engineering trades was good, better than in 1910, and very much better than in 1909 and 1908. The mean percentage unemployed was 3·2, compared with 5·8 in 1910, 11·6 in 1909, and 10·3 in 1908. The average for the ten years 1901-1910 was 6·0 per cent. Returns relating to about 800,000 members of trade unions show that the mean of the percentage of members returned as unemployed at the end of each month of 1911 was 3·0, as compared with 4·7 in 1910, 7·7 in 1909, and 7·8 in 1908. The slight upward movement in wages which began in 1910 was maintained on the whole during 1911, but did not become at any time very marked. The second half of the year was, however, considerably better than the first half, the net increase up to June 30th being £4,647, as compared with £21,280 from July to December.

TRAMWAYS AND LIGHT RAILWAYS.

THE annual return of the Railway Department of the Board of Trade, recently issued, gives some interesting figures relating to the growth in capital and traffic of the tramways and light railways of the United Kingdom for the year 1910-11. Since 1878 the route lengths of line open for traffic in the United Kingdom has increased from 269 miles to 2,597 miles, the capital expenditure from £4,207,350 to £75,672,826, the number of passengers carried from 146,000,000 to 2,907,000,000, and the net receipts from £230,956 to £5,276,060. Out of a total of 1,744 miles of line owned by local authorities, 1,530 miles were worked by those authorities, or by other local authorities leasing from them, and the remaining 214 miles by leasing companies. Last year the route mileage open of electric lines was 2,467 miles out of 2,597, the remainder being 5 per cent. of the total length of line. Of the 296 undertakings, 174 belonged to local authorities, and 122 to companies or other parties. The net receipts of local authorities who work tramway undertakings belonging to them or leased from other local authorities amounted to £3,849,380 for the year, and they applied £1,178,795 towards reduction of tramway debt and £370,435 in relief of rates, carrying £888,639 to reserve and renewal funds. The figures of five local authorities and seven companies show an excess of working expenditure over gross receipts. With regard to the appropriations for interest or dividend, &c., the return shows that in 28 cases it was necessary to seek aid from rates to meet some part of the charges for the year (including interest and redemption of debt). The total amount thus obtained was £68,055. Although there is a small increase in the rate of capital expenditure per mile of route open, an increase in the number of passengers carried per route mile and per car mile, coupled with a decrease in ratio of working expenditure to gross receipts, improves net receipts to such an extent as to afford a better percentage on capital outlay than was shown in 1909-10.

The Institution of Civil Engineers: Students' Meeting.—At the students' meeting recently held at the Institution, Mr. G. Ingram, Stud.Inst.C.E., read a paper on "The Turbo-Blower and Turbo-Compressor." The author outlined the development and theory underlying their design, and discussed at some length the most suitable means of driving these machines as used for blast furnaces and mines. The paper was illustrated by numerous slide diagrams, showing details of construction and results of tests.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1910.

Apparatus for indicating the angular movement of shafts. Calten. 28180.
Railway sleepers of reinforced concrete. Gebhardt. 28358.
Method of working internal combustion engines. Schneebeli. 28582.

1911.

Process for covering iron and steel articles with a rust proof coating. Bauer. 241.
Liquid piston explosion engines for raising liquids. Siemens Bros. Dynamo Works, Ltd., and Vernon. 311.
Railway signalling appliances. Jacques. 618
Furnaces. Sackett. 671.
Draw bar springs for railway vehicles. Spencer. 907.
Apparatus for compressing air and other gases. Hessling. 909.
Valve mechanism of internal combustion engines. Till. 919.
Driving belts. Rogers. 1090.
Mode of and means for tightening and slackening driving bands, belts, or ropes. Joshua Buckton & Co., and Wicksteed. 1586.
Carburetters for internal combustion engines. Hamill. 2051.
Change speed spur and clutch gearing. Cavill. 2356.
Combined feed water heater and grease skimmer. Clausen. 2388.
Manufacture of springs. Hurdley. 3491.
Stems of mechanically operated valves of fluid pressure engines. Harrison & Melmore. 4579.
Bushing extractor for rock drills. Marks. 4601.
Centrifugal fans. C. Whittaker & Co., and Tattersall. 5097.
Continuous wire drawing machines. Rooke. 5779.
Heat actuated gas pumps. Anderson. 6063.
Appliances for the automatic generation and storage of carburetted air gas. Smith. 6132.
Toothed sprocket and ratchet wheels. Broadfield. 6189.
Radiators for heating buildings. Bourdon. 6791.
Chain gearing. Coventry Chain Company (1907), and Hill. 7525.
Means for producing an explosive mixture for carburetted air for use in internal combustion engines. Marsden. 7622.
Carburetters for internal combustion engines. Hardy. 8259.
Vaporisers for internal combustion engines. Roberts. 8801.
Water tubes and flues of steam generators. Thornton. 9340.
Air compressors. Marcon. 9469.
Alloys for use in making dynamos. Rubel. 12483.
Feed devices for steam generators. Exshaw. 12745.
Shaft hangers. Hook. 13418.
Elastic fluid turbines. Rearick. 14046.
Steam traps. Reid. 14142.
Reversing mechanism for internal combustion engines. Knudsen. 14946.
Piston rod packing. Mason. 15028.
Starting mechanism for internal combustion engines. Boult. 15471.
Regulators for fluid compressors. Newton. 16551.
Automatic emergency brakes. Choumbrot. 17301.
Rock drills. Newton. 17415.
Stay bolts. Setton Jones (Clark). 18540.
Wave motors. Wall. 19115.
Wave actuated air compressors. Wall. 19128.
Pressed steel pulleys. Justice. 19329.
Roller bearings. Perkins. 19756.
Radiators for heating buildings. Frank. 20241.
Driving and reversing gear. Couper & Lindsay. 20[illegible].
Blow out devices for steam boilers. Brooks. 20[illegible]18.
Lubricators for internal combustion engines. Moore and Ambrose Shardlow & Co. 21756.
Inter locking apparatus for the operating levers of railway signalling appliances. Hodgson, and Saxby & Farmer, Ltd. 21875.
Steam traps. Reid. 22593.
Variable speed gearing. Moore. 23219.
Miners' safety lamps. Hailwood. 2[illegible].
Safety appliance for pit and mine cages, hoists, and lifts. Golding and Edwards. 26886.

ELECTRICAL, 1910.

Printing telegraphs. Soldatencow. 11659.

1911.

Electric wiring of buildings. Milne. 318.
Electric metallurgical furnaces. Stobie. 6[illegible]1.
Electrical apparatus adapted for use in mines. Sandycroft Foundry Company and Dutton. [illegible]80.
Machine for automatically winding and insulating electric coils. Easthope & Easthope. 715.
Means of control for petrol electric vehicles. Stevens. 933.
Electric controllers or switches. Jackson & Pearson. 1658.
Means for charging storage batteries. Perry. 1886.
Combined magneto ignition gear for internal combustion engines and wireless telegraphy apparatus. Sueter, Boothby, and Paterson. 3334.
Sparking plugs for electrical ignition purposes. Jones. 5790.
Switches and interrupters for electric circuits. Schultz. 7097.
Sparking plugs for internal combustion engines. Player & Hill. 7810.
Electric motor starting switches. Johnson. 8515.
High frequency transformer. Goldschmidt. 11162.
Telephonic exchange switchboards and arrangements. Graham. 13887.
Telephone exchange systems. Western Electric Company. 16075.
Time switches. Zenner. 17718.
Incandescence bodies for electric glow lamps. Hurwitz. 20223.
Incandescent electric lamps. Schwab. 20380.
Plug and socket connections used on electric lighting or power circuits. Lundberg, Lundberg, & Lundberg. 21678.
Plug and socket connections for electrical apparatus. Naamlooze Vennootschap Fabriek van Instrumenten en Electrische Apparaten "Inventa." 23622.
Three contact plugs for telephone switchboards. Siemens Bros. and Co., and Grinsted. 23910.
Electromagnets. Quastenberg. 24146.

METAL QUOTATIONS.

TUESDAY, JANUARY 30TH.

Aluminium ingot	63/-	per cwt.
,, wire, according to sizes, &c. ......from	102/-	,,
,, sheets ,, ,, ... ,,	120/-	,,
Antimony .... £27/10/- to	£28/-/-	per ton
Brass, rolled	7[illegible]d.	per lb.
,, tubes (brazed)	9⅞d.	,,
,, ,, (solid drawn)	8d.	,,
,, ,, wire	7¾d.	,,
Copper, Standard	£61/5/-	per ton.
Iron, Cleveland	48/9	,,
,, Scotch	54/9	,,
Lead, English	£15/17/6	,,
,, Foreign (soft)	£15/13/9	,,
Mica (in original cases), small	6d. to 2/	per lb.
,, ,, ,, medium	2/6 to 4/-	,,
,, ,, ,, large	4/6 to 8/6	,,
Quicksilver	£8/5/-	per bottle.
Silver	26 13/16d.	per oz.
Spelter	£26/2/6	per ton.
Tin, block	£195/-/-	,,
Tin plates	13/6	,,
Zinc sheets (Silesian)	£29/10/-	,,
,, (Stettin; Vieille Montagne)	£30/-/-	,,

The Uses of High-pressure Gas.—At a recent meeting of the Birmingham Scientific Society, Mr. E. W. Smith, chief chemist of the Birmingham Gas Department, delivered a lecture on "High-pressure Gas and Some of Its Industrial Applications." He explained the advantages of high-pressure gas for the purpose of brass melting and blow-pipe work, and in regard to the latter said that all the effects of the usual air-blast blow-pipe could be obtained without power, bellows, or any other form of air-pressure apparatus simply by using high pressure gas. High-pressure gas, he said, was becoming very popular with the industrial firms of Birmingham, a considerable number of whom had already placed contracts with the department for large installations for brass-melting furnaces, for use in heating soldering irons, for gold and silver melting, and other purposes. The method adopted by the department when enquiries were made was to ascertain the conditions under which the gas was required, and then to allow the firms or their representatives to make their own experiments at the Windsor Street gas works, where a special foundry had been erected. In this practical way the advantageous use of high pressure gas was demonstrated, and the success which had been achieved had more than justified the enterprise of the department.

The Mechanical Engineer.

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Edited by
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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

Institution of Mechanical Engineers and Entrance Examinations.

FROM the report to be presented to the annual meeting of the Institution of Mechanical Engineers on the 16th inst., it appears that the Council propose to take the step foreshadowed in the President's address, and to impose in future an examination test upon applicants seeking admission to the Institution. The suggestion will, we are sure, meet with general approval. Such a test has for a good many years been applied by the Institution of Civil Engineers, and in view of the growing exactitude of the fields of engineering more particularly dealt with by the Mechanicals, and the high standard of scientific attainments required for success, some strictly impartial means of denoting their possession than those previously existing has been deemed necessary. Such a course has been decided upon by the Institution of Electrical Engineers, and there is no reason whatever why the Institution of Mechanical Engineers should in any way lag behind. We should be the last to worship an examination as an infallible measure of a man's capacity, especially in mechanical engineering, where so much is determined by experience of actual work done, and should be sorry if such a test excluded from the Institution men who through no fault of their own were deprived of the educational advantages which are the common lot of the young men of to-day, but who, nevertheless, have proved their ability by long years of experience in responsible positions. We are glad, therefore, that in the arrangements proposed a certain flexibility of entrance for such men will be preserved. An examination test will, undoubtedly, confer an advantage upon the younger men who have availed themselves of present day opportunities, and enable them by an impartial test to demonstrate their fitness for more serious responsibilities. The report gives an outline of the draft scheme of examinations suggested, and, as far as we can judge, we do not think much exception can be taken to it. It is comprehensive, and appears to cover practically every field within which the

candidates may from local circumstances have been bounded in his acquirement of technical knowledge, while full credit is awarded for engineering Scholarship degrees in recognised universities or colleges. Experience, doubtless, may show the need for modification here and there, but taking it as a whole the Council's proposals will, we think, meet with general approval.

The Proposed Association of Consulting Engineers.

SOME of our readers will be aware that during the past 18 months an attempt has been made to form an Association of Consulting Engineers. The attempt has not been particularly successful, and we should imagine after the circular that has just been issued by the Institution of Civil Engineers to its members, very little more will be heard of it. As we commented at length on the aims of the Association when it was first promulgated (see pages 85 and 213, Vol. XXVI.) it is not necessary to recapitulate our objections. To many no doubt it must have seemed curious that the Institution of Civil Engineers, which is supposed to specially watch over the interests of its members and to regulate their etiquette and behaviour, should have preserved silence in the presence of what to many seemed an arrogation of its functions. It is evident, however, from the circular that the Institution has not been so quiescent in the matter as some have imagined, as will be evident from the following letter addressed to the proposed Association by the Council on October 28th last, and which it now makes public in view of the numerous enquiries it has received respecting the attitude of the Institution towards the Association in question. As the letter sums up the pros and cons of the case, we reproduce it in extenso:—

PROPOSED ASSOCIATION OF CONSULTING ENGINEERS.

Referring to the communications received from you on behalf of the proposed Association of Consulting Engineers, and to the views expressed by members of the deputation which was received by the council, I am desired to say that the council have considered very carefully the proposals of the Association and the representations submitted by the deputation. The council are in cordial sympathy with the objects of the deputation in so far as they are directed to the maintenance of a high professional tone among engineers, and to the prevention of abuses which operate to the disadvantage of engineers occupied in private practice. The definition of a "consulting engineer" obviously presents no small difficulty, and apparently no complete conditions have been laid down, the fulfilment of which would entitle an individual to claim the distinctive title of consulting engineer which members of the Association propose to adopt. The council hold the view that no body or organisation can be in a position to give a better and more satisfactory professional qualification than the Institution itself, and it is obvious that when possessed of such a qualification, any member of the Institution who duly adheres to its rules of professional conduct should be able to exercise freely any professional engineering functions. The council also observe that the proposals of the Association involve the omission from the category of consulting engineers of persons who occupy at the time official positions, although they may be at the same time frequently called upon to act in a consultative capacity in engineering matters of no less importance than those dealt with by engineers who do not hold such posts. It is thought that any step tending to exclude from advisory and consultative work engineers who hold official positions in the various branches of the profession, and whose experience may specially qualify them to give advice on matters with which they are conversant, would be an injustice to them and a serious loss to the public interest. The council feel obliged to express the view that, under the conditions put before them, it would be undesirable for the Institution to lend its official support to the proposed organisation.

We are glad that the communication has been made public, as it removes any doubt and uncertainty as to the Institution's attitude, and confirms not only what we have said but what we think is the feeling of the great majority of its members.

Circulating Hot-water Boilers and Frost.

NOTWITHSTANDING periodical warnings, a keen frost seldom comes without bringing in its train the usual outbreak of explosions from boilers employed for the circulation of hot water for domestic purposes in dwellings, or for heating and ventilating public buildings, and the recent spell has been marked by quite a crop of this class of failure, attended in several instances with fatal consequences. As a protection against them some rely not so much on a positive means of relief, such as is afforded by a safety valve, as a sharp watch on the outlet taps to make sure the circulating pipes are free before lighting a fire. This is all right, to a certain extent, but a brief flow of water from the taps in the circulating pipes in the ordinary domestic apparatus is, in many cases, not an infallible test that no danger exists, for it may be simply the result of excessive presure in part of the system, especially where hot-water storage cylinders are fixed. For this reason, the taps, both in the "flow" and "return" pipes, should be tested, and if they do not both discharge freely, there may be serious risk if a fire is lighted. In heating systems where test taps are often not fitted, such a test as we have described cannot be made, and serious danger then may exist if the apparatus is not fitted with a safety valve; and having regard to the simple and inexpensive character of such a fitting, no heating apparatus should be allowed to work without one. Moreover, this fitting should be fixed either directly on the boiler or so close to it that there is no possibility of the connection being plugged with ice when the boiler contains hot water, and on no account should it be possible to close this connection with a tap or valve. A safety valve properly attached will, of course, absolutely prevent any possibility of explosion, but cannot prevent the water in the pipes from freezing, and then there is a risk of the pipes being burst by the expansion of the ice. To avoid the inconvenience often caused by this in places of worship or other buildings which remain unoccupied for days in succession, it is a good policy to keep the apparatus going continuously, if only gently, so long as severe cold continues, instead of lighting the fire only on the day of occupation.

British Standard Heads for Small Screws.—We have received a copy of the report on British Standard Heads for Small Screws Report No. 57. The report contains the recommendations of the committee for the dimensions of countersunk, instrument, round, cheese, and filister heads for B.A. screws of sizes 0 to 14, and for the saw-cuts in the same.

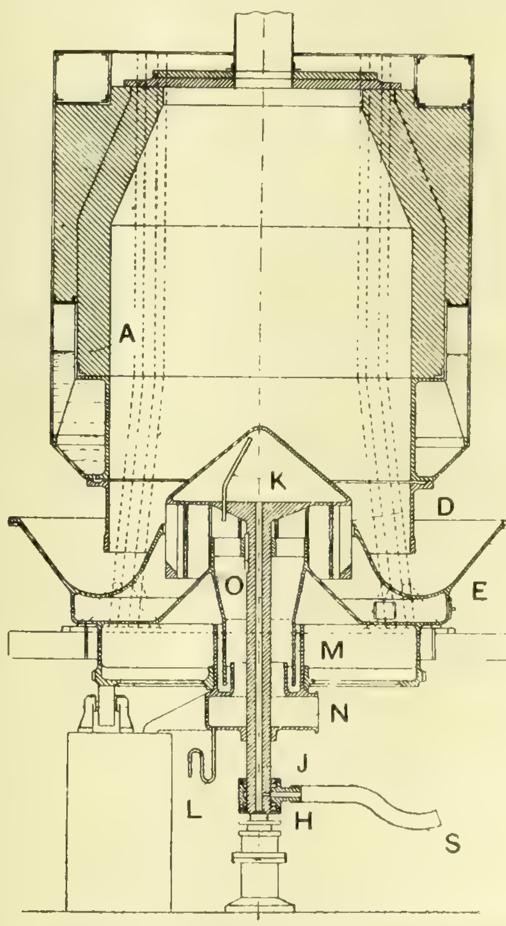
The Society of Engineers.—The first ordinary meeting of the present session was held on Monday, the 5th inst., at the Institution of Electrical Engineers, Victoria Embankment, W.C. The chair was first occupied by the retiring president, Mr. F. G. Bloyd, who presented the following premiums awarded for papers published in the Journal during 1911:—The President's gold medal to Mr. W. R. Baldwin-Wiseman for his paper on "The Administrative Aspect of Water Conservancy"; the Clarke Premium to Mr. T. J. Gueritte for his paper on "The Mechanical Installation and Upkeep of Permanent Way on Railways"; the Bessemer Premium to Mr. R. W. A. Brewer for his paper on "Two-Stroke Cycle Engines"; a Society's Premium to Mr. E. Kilburn Scott for his paper on "Nitrogen Products made with the aid of Electric Power"; a Society's Premium to Mr. F. G. Woollard for his paper, entitled "Some Notes on Drawing Office Organisation." Mr. Bloyd then vacated the chair in favour of Mr. John Kennedy, the president for 1912, who was received with acclamation.

THE SAFEGUARDING OF PERMANENT-WAY MEN ON RAILWAYS.

MR. H. A. YORKE, in his report to the Railway Department of the Board of Trade on a fatality which occurred at Camlachie, on the North British Railway, on December 11th last, when a train ran into a squad of platelayers during a fog, killing four of them and injuring a fifth, makes strong comments on the neglect of precautions too often shown when men are working under such conditions. The accident was primarily due to the inadequate and negligent manner in which the look-out man performed his duties. His behaviour may have been due either to stupidity or ignorance, or to that apathy which seems to overtake men regularly employed in dangerous occupations, and which leads them to take little or no heed of the risks to which they and their fellow men are exposed. But though this man's action was the direct cause of the disaster, Mr. Yorke does not think that he should be called upon to bear the whole responsibility. Railway companies are, he says, disposed to assume that, having left it to the foreman or ganger to appoint a look-out man, no matter how stupid or unintelligent he may be, their responsibility ceases, and that nothing more can be done, and submits that the known carelessness of the men renders it all the more necessary to spare no effort in securing in every case the services of a trustworthy person for the important position of look-out. This man in the present case had a rule book in his possession, but as he is unable to read, he might just as well have been without it. He was given no instructions by his foreman where to stand, or what he was to do in case of fog. The report points out that the "look-out" ought to have been provided with a whistle, horn, or other means of giving alarm, instead of having to depend entirely upon shouting. In 1907 the Board of Trade wrote to all the railway companies in the United Kingdom, suggesting that a whistle of a distinctive type should be supplied to every platelayer employed upon the permanent way. Forty-four of the companies, including some of the most important railways in the country, agreed to act upon this recommendation; 13 other companies said that they would supply whistles to their gangers, foremen, assistant gangers, or leading men, and to the look-out men, but not to the whole permanent way staff; while 47 companies, including the North British, have hitherto refused to give whistles to any of the men, even to the look-out men. Attention is also drawn to Rule No. 273 (d) in the Railway Clearing House Rule Book, viz.: "The men must also desist from work in cases of fog or falling snow when the foreman, ganger, or leading man considers that they would not have sufficient warning of the approach of a train, provided that such discontinuance of work does not endanger the safety of the trains," and adds that in the present instance the men should have been withdrawn from work as soon as the fog descended and rendered it impossible for the look-out to see the signal. Mr. Yorke remarks that the interests of platelayers do not seem to be sufficiently safeguarded. Their employment is one of the most dangerous in railway service. The annual number of accidents to permanent way men, exclusive of point oilers and labourers employed on miscellaneous duties, far exceeds that of any other class of railway men, while the percentage of fatalities to the number of men employed is less only than that of two other classes, the figures for the last five years giving an average of 86 killed and 143 injured. A great deal, he continues, is heard from time to time of the dangers to which other classes of railway servants are exposed, and he admits that a considerable number of the accidents appear to be due to the men's "own want of caution," but urges this only proves that the men are so helpless, and in some cases reckless, that it is all the more necessary to protect them, and not turn them on to a railway like a flock of sheep without a shepherd to guide them. The protection of the men, he remarks finally, resolves itself largely into a question of organisation, supervision, and, above all, of careful selection and instruction of the men employed to act as look-out men, the responsibility for which should rest upon the officers of the engineering department.

GAS PRODUCER WITH RISING AND FALLING GRATE.

IN this design of producer, the invention of Emile Dor-Delattre, Dorplein-Budel, Holland, the rising and falling grate is carried by a plunger, the grate being arranged in the shaft within the mass of coal at a higher level than the ashes and slag, and by it the coal can be wholly or partially raised without altering the size of the annular outlet for the cinders and ashes, which can be readily removed during the working of the producer. Owing to the arrangement of the trough into which the ashes are admitted through a large opening of constant size, it is not necessary to provide any supplementary mechanism for their discharge. Referring to the illustration, the shaft A of the producer is closed, at its lower end, by a rotatable base C in the form of a circular trough filled with water up to a certain height and forming an hydraulic joint. This trough is arranged to receive the slag and ashes which fall through the annular passage formed between the interior of the shaft and a vertical grate D. The rotating base C comprises, moreover, under the trough C, a chamber E adapted to receive the fine ashes which pass through the grate D; cleaning holes are provided in the chamber E. The grate D is arranged vertically in the central part of the trough C and is in one piece with a conical head



GAS PRODUCER WITH RISING, FALLING, AND REVOLVING GRATE.

kept cool by a current of water. The whole arrangement comprising the grate D and the conical head is carried by a column J connected to the piston H of a hydraulic press, which admits of raising the grate D and its head vertically. The lowering of the conical head and the grate D is effected by the weight of the parts. The admission of the cooling water to the conical head is effected by the hollow column J, supplied from a pipe S. The water passes away through the pipe K and siphon L, whilst the hydraulic joint M is also supplied by the water issuing from the overflow pipe K. Air is blown under the grate D from the pipe N.

When the only movement to be obtained is that of raising and lowering the grate D, the trough C remains stationary, and it is only necessary to admit water under pressure beneath the piston H of the hydraulic press. During the lifting this piston H raises the hollow column J and consequently the grate D and conical head. The speed of lifting, its extent and frequency can be easily controlled by regulating the admission of water to the hydraulic press by means of a suitable valve. This raising and lowering of the grate D and of the conical head puts the coal continually in motion and stirs it up over the whole surface. The vertical movement of the grate D can be

accompanied by the rotation of the trough C which greatly facilitates the clearing of the ashes. This double movement causes, moreover, a better agitation of the coal. The rotation of the trough C, which is always very slow, is obtained either by means of pawl and ratchet mechanism or by worm gearing. These two movements are quite independent of one another. The grate D, whilst having a rising and falling movement, also turns with the trough C. This latter, as it rotates, drives the hollow column J by means of a fixed key O. The two movements described are only employed when using coal which is readily convertible into coke, with the object of preventing the formation of fissures during the vertical displacements of the grate.

GREAT EASTERN RAILWAY SIX-COUPLED EXPRESS PASSENGER ENGINE, NO. 1,500.

THROUGH the courtesy of Mr. S. Dewar Holden, the Locomotive Superintendent of the Great Eastern Railway, we are able to give the leading particulars, along with a photo view, of the first of a class of 4—6—0 locomotives designed by him for working the more exacting of the company's heavy main line passenger trains. The chief dimensions are as follows:—

Boiler

Fitted with Schmidt superheater (21 elements).
Barrel, telescopic ....length, 12ft. 6in.
Length between tube plates ....12ft. 10in.
Maximum diameter, inside ....5ft. 0in.
Maximum diameter, outside ....5ft. 1⅛in.
Firebox casing, length ....8ft. 6in.
Firebox casing, width at top ....5ft. 3⅜in.
Firebox casing, width at bottom ....4ft. 0½in.
Ordinary tubes, 191, outside diameter ....1¾in.
Large tubes, 21, outside diameter ....5¼in.
Superheater element tubes, outside diameter ....1⅜in.
Working pressure per square inch ....180lbs.

Heating Surface—

1¾in. tubes ....1,123·0 sq. ft.
5¼in. tubes ....366·1 sq. ft.
Superheater element tubes ....286·4 sq. ft.
Firebox ....143·5 sq. ft.

Total ....1,919 sq. ft.

Grate area ....26·5 sq. ft.
Cylinders, two high-pressure, diameter ....20in.
Cylinders, two high-pressure, stroke ....28in.
Diameter of coupled wheels ....6ft. 6in.
Diameter of bogie wheels ....3ft. 3in.
Diameter of tender wheels ....4ft. 1in.

Wheelbase—

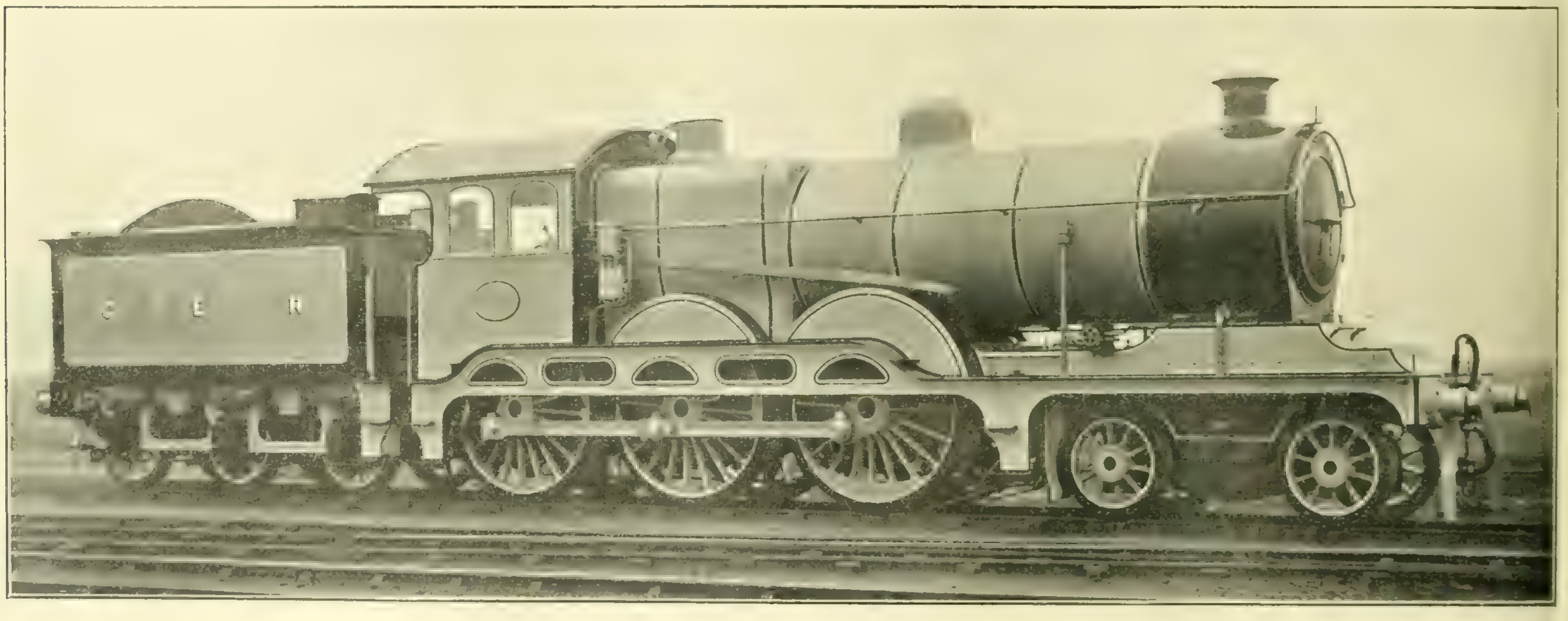
Bogie centres ....6ft. 6in.
Centre of bogie to driving ....11ft. 3in.
Driving to intermediate ....7ft. 0in.
Intermediate to trailing ....7ft. 0in.
Coupled ....14ft. 0in.
Total of engine ....28ft. 6in.
Tender, leading to centre wheel ....6ft. 0in.
Tender, centre to trailing wheel ....6ft. 0in.
Total of tender ....12ft. 0in.
Total of engine and tender ....48ft. 3in.

Length over buffers ....57ft. 7in.

Weight in working order—

On bogie wheels ....20 tons.
On driving wheels ....16 tons.
On intermediate wheels ....14 tons.
On trailing wheels ....14 tons.
On coupled wheels ....44 tons.
Total of engine ....64 tons.
Tender, on leading wheels ....12 tons, 2 cwts., 3 qrs.
Tender, on centre wheels ....13 tons, 3 cwts., 1 qr.
Tender, on trailing wheels ....13 tons, 19 cwts.
Total of tender ....39 tons, 5 cwts.
Total of engine and tender ....103 tons, 5 cwts.

Capacity of tender, coal ....4 tons.
Capacity of tender, water ....3,700 galls.
Adhesive power (508lbs. per ton) ....22,352lbs.
Tractive power (mean effective pressure taken at 82 per cent. of boiler pressure) ....21,194lbs.



GREAT EASTERN RAILWAY SIX-COUPLED EXPRESS PASSENGER ENGINE, NO. 1500

Four 3in. safety valves are fitted to the boiler. The firebox is of the Belpaire type; the front half is inclined above the intermediate axle and the back half is horizontal. The cylinders are placed horizontally between the frames, and the piston valves are fitted with their centres vertically above the cylinder centres. These piston valves are 10in. diam., with inside admission, 1¼in. lap and $\frac{3}{16}$in. exhaust negative lap, and are operated by a Stephenson link motion through the medium of a rocking shaft. The connecting rod is 7ft. 3in. long and of I section. A Wakefield 8-feed mechanical lubricator, driven off the right-hand valve-spindle crosshead, affords forced lubrication to cylinders, valves, and piston tail rods. The tender is of the standard 6-wheeled type, fitted with air scoop for water pick-up.

Association of Railway Locomotive Engineers.—Mr. Pickersgill, chief mechanical engineer of the Great North of Scotland Railway, has been elected President of the Association for 1912, and Mr. Harry S. Wainwright, chief mechanical engineer of the South-Eastern and Chatham Railway, has been elected Vice-president. Mr. Wainwright has been secretary of the association since 1898.

RECENT DEVELOPMENTS IN STEAM TURBINE PRACTICE.*

BY K. BAUMANN.

(*Continued from page 139.*)

THE CRITICAL SPEED OF TURBINE ROTORS.

IN the design of steam turbines a most important factor is the critical speed of the shaft. In this matter the disc type of turbine has a very considerable advantage over the drum, in that its critical speed can be calculated with ease and certainty. The first turbines of the Rateau and Zoelly type were made with a flexible shaft, *i.e.*, the normal speed was above the first critical speed. At one time there was even a tendency to neglect the critical speed altogether, in spite of the investigations made by

FIG. 24.

FIG. 25.

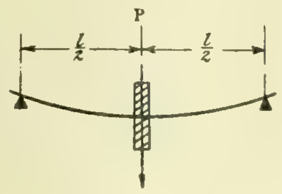


FIG. 26.

Prof. Stodola, as it was found that turbines, if properly balanced, could, under normal condition, be run very satisfactorily even at the critical speed. Unfortunately, it was soon found in commercial running, when abnormal conditions are bound occasionally to occur, that if the shaft were deflected—as, for instance, when water is carried over with the steam—it remained deflected because it was running at the critical speed.

The question of the critical speed is of the first importance when using the 3-bearing design, which is becoming more generally adopted for small turbines. It will therefore be of some interest to recall the main facts relating to critical speeds of rotors, as used for turbines, generators, blowers, compressors, and pumps. The critical speed of a shaft is usually defined as that speed at which a very small eccentric mass will cause the shaft to deflect to a very great extent. It can be demonstrated that this speed coincides with the natural frequency of vibration of the shaft, and also that it is that speed at which any accidental deflection of the shaft results in a centrifugal force due to its rotation about its position of rest, sufficiently large to maintain this deflection.† In the following investigation a shaft will be referred to as rigid if its critical speed is above the normal running speed, and as a flexible shaft if its critical speed is below the normal running speed.

1. **Critical Speed of a Weightless Shaft with One Wheel.**—When a vertical shaft loaded with one wheel of mass M is run much below the critical speed it retains its straight position (Fig. 24). On the other hand, a horizontal shaft has an initial deflection, due to the weight of mass M (Fig. 25), and if caused to rotate will still keep this configuration—*i.e.*, the deflection of the shaft, due to the weight, will remain the same, and the shaft will not straighten itself, as might be expected at first sight.

In either case, if the shaft is run much below the critical speed, and is for any reason deflected from its position of rest, the elastic forces of the shaft will restore it to its original position. The critical speed is reached when the deflection of the mass M, owing to its rotation about its position of rest, produces a centrifugal force sufficiently large to maintain this deflection. It is evident therefore, that the critical speed of a shaft is the same whether in a vertical or a horizontal position, as the additional deflection due to centrifugal force is identical in either case. In general terms, this means that the position of the shaft does not influence its critical speed.

It is clear from the above that the governing condition of the critical speed is that the centrifugal force P, which is equal to $M\,y\,\omega^2$, must be large enough to keep the shaft in the deflected position, *e.g.*, in the case of the shaft shown in Fig. 26—

$$P = y\,\frac{48\,E\,I}{l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

where—

E = modulus of elasticity.
I = transverse moment of inertia.
l = length of shaft.
y = maximum of deflection.

More generally $P = a\,y$, where

a = constant for given shaft, position of weight, and method of support.
y = deflection of the shaft measured at the point where the weight is carried.

This formula, combined with $P = M\,y\,\omega^2$, will give

$$M\,y\,\omega^2 = a\,y.$$

or—

$$M\,\omega^2 = a \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

Thus the critical speed is independent of the deflection imparted to the shaft, or, in other words, a shaft running at the critical speed is in neutral equilibrium.

Although the critical speed *has really nothing whatever to do with the deflection due to gravity*, there is a very simple relation between the critical speed and the deflection f of the shaft, due to the weight of mass M when supported horizontally. The relation is given by

$$G = M\,g = a\,f \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

Combining (17) and (18) we get

$$f\,\omega^2 = g \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

where

f = the deflection of the shaft due to the weight, and is measured at the point where the weight is carried.
ω = critical angular velocity in radians seconds.
g = constant of gravitation.

This formula applies to any weightless shaft loaded with one concentrated mass in any position and for any method of support. A few of the most important cases are illustrated in Fig. 27. It will subsequently be proved that by a very slight modification of the constant this formula can be used equally well for shafts with any distribution of load which may occur in practice.

2. **Critical Speed of Shafts with Uniformly Distributed Loads.**—For a uniform shaft with a uniformly distributed load it can again be demonstrated that the critical speed corresponds to the natural frequency of vibration. The critical speed is given

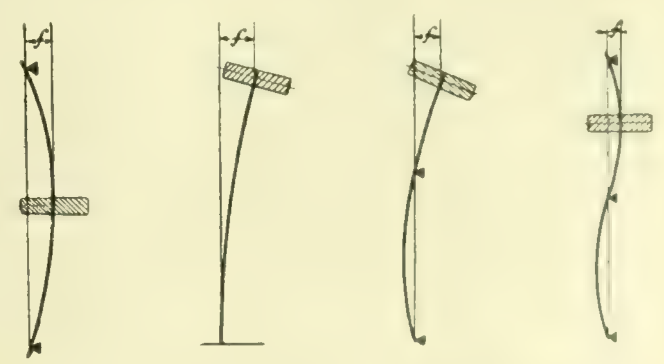


FIG. 27.—DIFFERENT CASES OF CONCENTRATED LOADING.

by the following formula for all the five different methods of support illustrated in Fig. 28:—

$$\omega = k^2\,\frac{\pi^2}{l^2}\sqrt{\frac{I\,E}{m}} \quad . \quad . \quad . \quad . \quad . \quad (20)$$

where

l = length of shaft, as shown in Fig. 28.
I = transverse moment inertia of shaft.
E = modulus of elasticity.
$m = \frac{w}{g}$ = mass per unit length.
w = weight, load per unit length.

If only one weight be used, there is but one critical speed, and as the speed is raised above this the running becomes steadier. Extensive use of this fact has been made by de Laval in his single-wheel turbine, in which, in order to reduce vibration, the running speed is seven times greater than the critical speed. If more than one weight be used the shaft will have critical speeds

* Paper read before the Manchester section of the Institution of Electrical Engineers, January 16th, 1912.

† For a more complete investigation of the phenomena of critical speed see Prof. Stodola's "Dampfturbine," 4th ed., upon which these remarks have been based.

of higher frequency, and in the case of shafts with uniformly distributed loads there are theoretically an infinite number of critical speeds, of which, however, only the first, second, and in exceptional cases the third and fourth, are of practical importance.

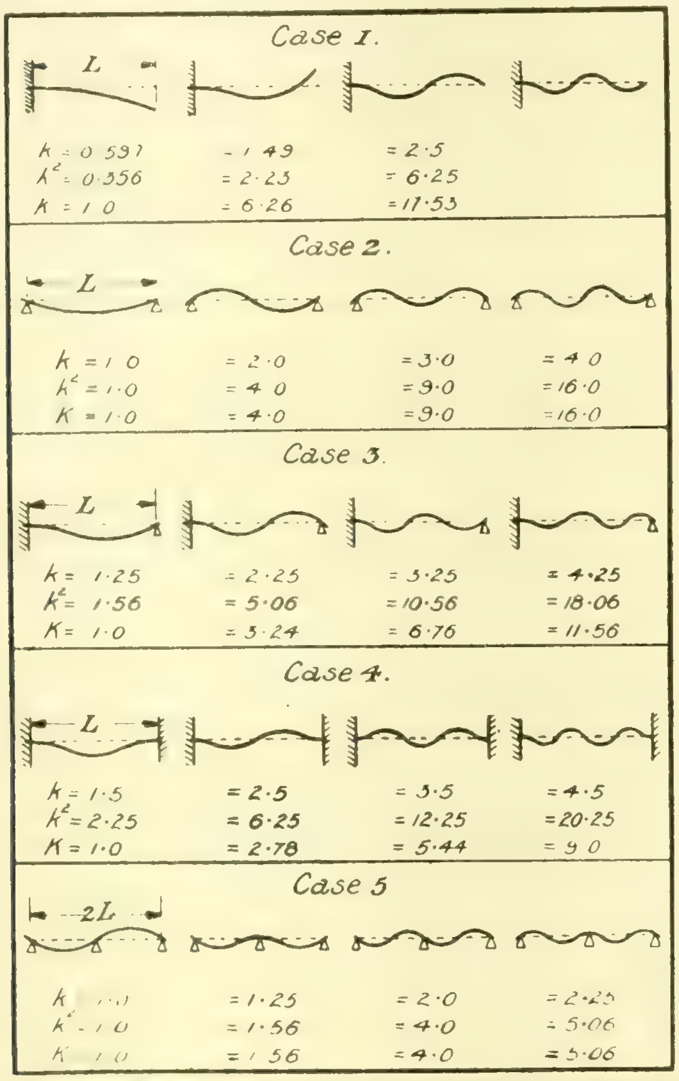


FIG. 28.—CRITICAL SPEEDS OF SHAFTS WITH UNIFORMLY DISTRIBUTED LOADS.

The constants k and k^2 for these different critical speeds are given in Fig. 28 together with the corresponding elastic curves, which are characteristic of them. With the help of this table, all important critical speeds, or natural frequencies of vibration, can be calculated for any of the conditions given. The first, or fundamental critical speeds are, of course, of the greatest importance, and for the different cases their relative values are given by the constant k^2.

Case	1	2	3	4	5
k^2 =	0·356	1·0	1·50	2·25	1

This shows, for instance, that the critical speed of the overhung shaft is about one-third of that of a shaft supported in two bearings. It is very important to know the second critical speed of shafts running above the first because it is essential that the running speed be sufficiently removed from both the first and the second in order to reduce the vibration to a small amount. Also, it is very often impossible to calculate the critical speed with absolute accuracy, and consequently it should be made a standard practice to have the running speed at least 30 per cent. above or below any critical speed. The ratios of the higher critical speeds to the fundamental are given by the value of K in Fig. 28.

For case 1 the second critical speed is 8·26 times higher than the first; for case 2, 4 times; case 3, 3·24 times; case 4, 2·78 times; and for case 5, only 1·6 times higher. In the last case, which often occurs in practice, and is known as the 3-bearing design, this figure may be further reduced by the use of smaller shaft diameters in the centre bearing, from which the practical difficulties of a 3-bearing machine, running between the first and second critical speed, are apparent. This statement is only correct when the critical speed of both the spans are about equal.

When one span is a rigid and the other a flexible shaft the combined effect raises the first critical speed of the flexible shaft to a maximum determined by the ratio of the first critical speed of case 2 to that of case 3, and the second critical speed may be sufficiently far from the first to render a 3-bearing machine, running above the first critical speed, quite practicable. It will, however, always be necessary for the designer to satisfy himself as to the approximate position of the different critical speeds. For this purpose Fig. 28 will be of considerable help.

We will now proceed to find a relation between deflection due to gravity and the first critical speed. In all five cases the maximum deflection due to a uniformly-distributed load is given by the following formula :—

$$f = c\,\frac{m}{\mathrm{I}\,\mathrm{E}}\,l^4\,g \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (21)$$

The values of the constant c are

For case	1	2	3	4	5
c =	1/8	5/384	1/185	1/384	5/384

Combining formula (20) with (21) we get—

$$f\,\omega^2 = c\,k^4\,\pi^4\,g \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

writing—

$$\gamma = c\,k^4\,\pi^4$$

we get—

$$f\,\omega^2 = \gamma\,g \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (23)$$

The value of y for the different cases being :—

Case	1	2	3	4	5
	1·55	1·27	1·35	1·29	1·27

(23) is of similar form to the formula found for the critical speed of a weightless shaft with one wheel. The additional factor y shows that the critical speed given by—

$$f\,\omega^2 = g$$

is to be multiplied by the coefficient $\sqrt{\gamma}$ in order to obtain the exact critical speed for the different cases, *i.e.*,

Case ..	1	2	3	4
By $\sqrt{\gamma}$ =	1·25	1·13	1·16	1·13

In all five cases the difference in the value of the coefficient is remarkably small, and they cover nearly all possible arrangements of shafts. Considering the actual distributions of loading are combinations of concentrated and uniformly-distributed loads, it will be an easy matter, by the aid of Fig. 28, to estimate to a very fine degree the limits of the factor $\sqrt{\gamma}$.

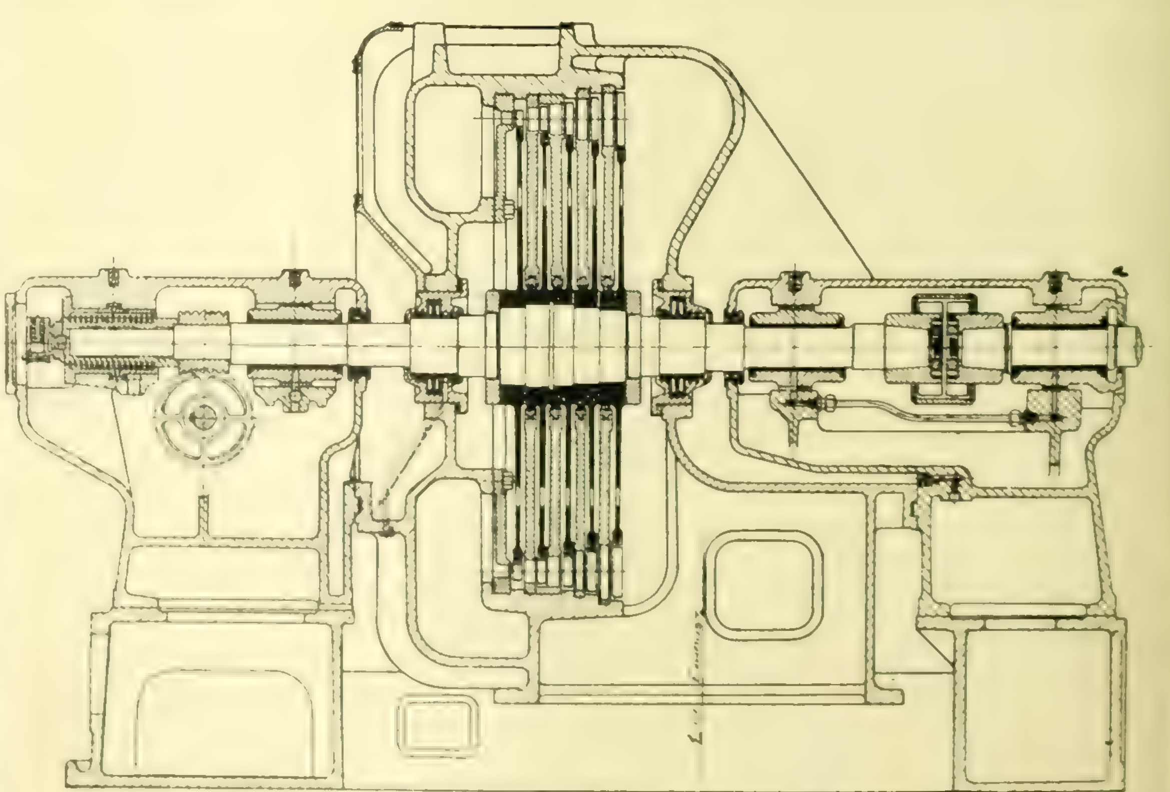


FIG. 29.—LOW-PRESSURE TURBINE. BRITISH WESTINGHOUSE COMPANY, 1910.

3. **Critical Speed and Deflections of Turbine Rotors.**—The

author has had an opportunity of verifying the relation existing between the critical speeds and deflections for shafts as used in impulse turbines, blowers, and compressors. By well-known methods the critical speed and deflection due to gravity were calculated (as accurately as possible by different engineers) with the invariable result that

$$f\,\omega^2 = (1{\cdot}07 \text{ to } 1{\cdot}08)\,g\,;$$

or in cm./sec. units with — $g = 981$ cm./sec.^{2}—

$$f\,\omega^2 = 1{,}050 \text{ to } 1{,}060.$$

With this formula it is possible to answer at once the question, What is the maximum deflection of a turbine shaft running at

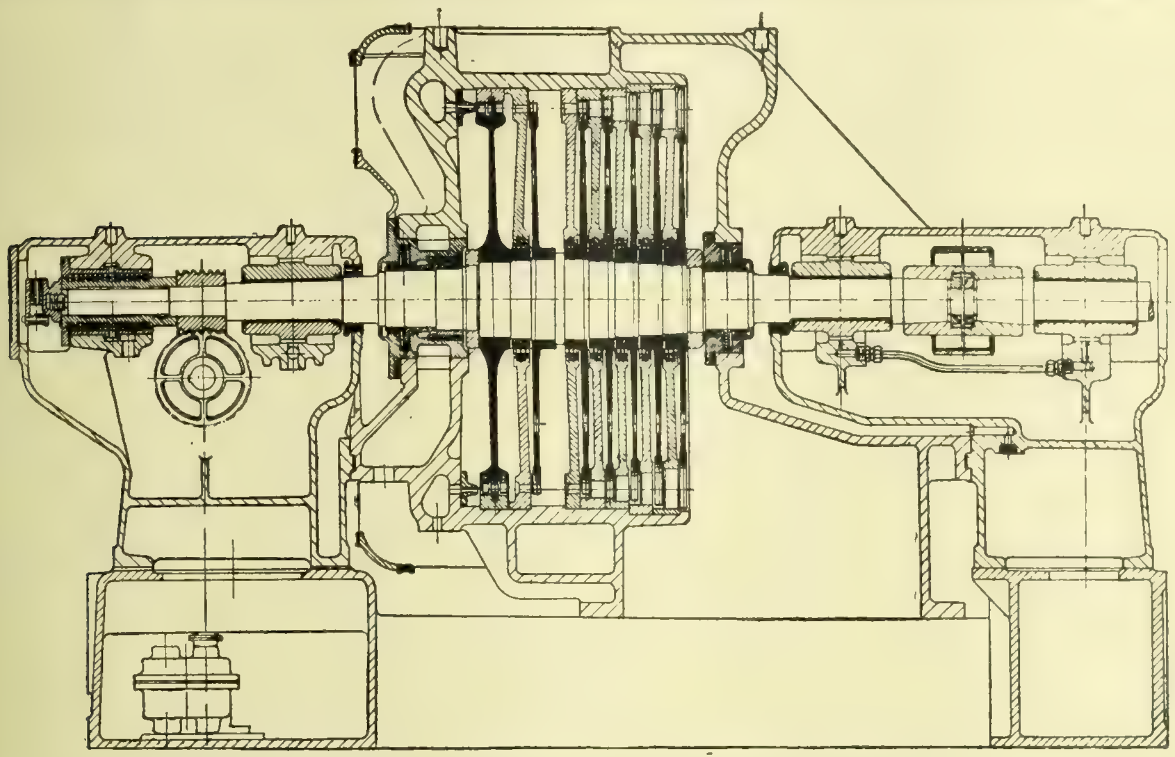


FIG. 30.—MIXED-PRESSURE TURBINE. BRITISH WESTINGHOUSE COMPANY, 1910.

3,000 revs. per minute if the critical speed is 30 per cent. above the running speed?

$n = 3{,}900$ revs. per minute.

$\omega = 410$ sec^{-1}.

$$f = \frac{1{,}060}{410^2} = 0{\cdot}0063 \text{ cm.} = 0{\cdot}063 \text{ mm.} = 2{\cdot}5 \text{ mils.}$$

For a turbine running at

1,500 revs. per minute	f	would be	0·010in.
1,000 ,,	f	,,	0·022in.
750 ,,	f	,,	0·040in.

GOVERNING OF STEAM TURBINES.

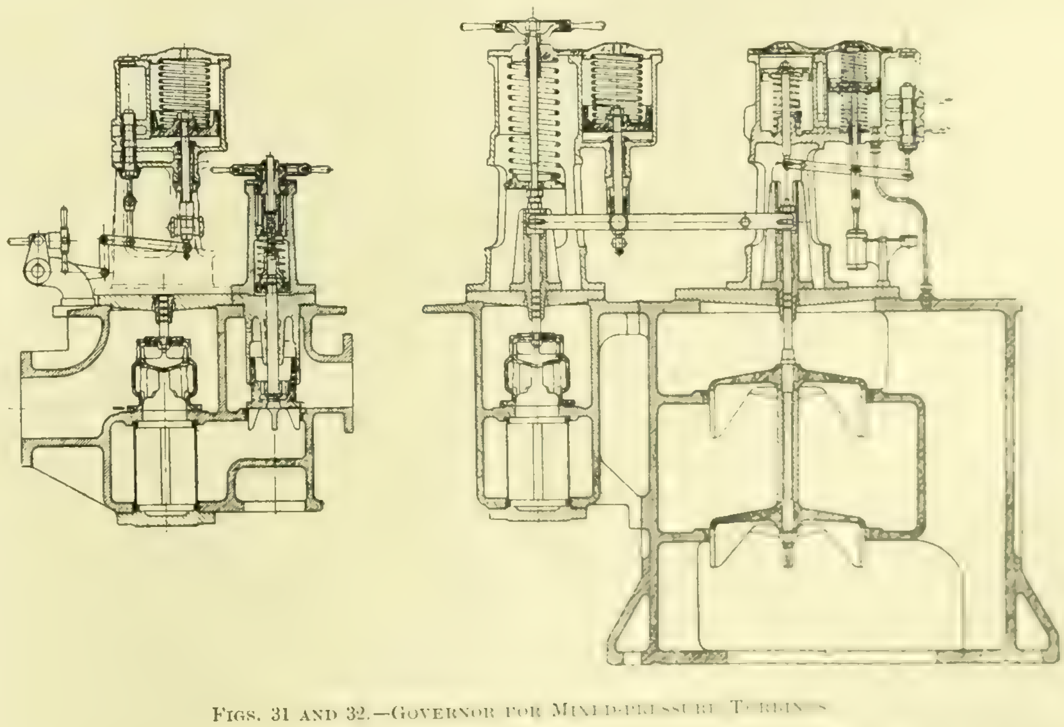
Steam turbines are generally governed by a throttle valve, which is connected to a mechanical governor, either directly or indirectly, by means of steam or oil relay. Direct governing, which has been adopted from steam-engine practice, is very satisfactory for small turbines, provided the valves are absolutely balanced; for larger turbines, steam relays with pulsating motion have been used, but now nearly all manufacturers of steam turbines use oil relays, and this is undoubtedly the most satisfactory arrangement.

In the case of combined turbines, governing by cutting-out nozzles improves the economy at partial loads. Special nozzles for cutting-out by hand were first used by the de Laval and later by the General Electric Company; the latter also introduced automatic nozzle cut-out governing, *i.e.*, an arrangement by which nozzle control valves, under the control of the speed governor, are opened in succession according to the load. Similar arrangements have been adopted by the A.E.G. in connection with their Curtis-Rateau turbines.

It has been stated that a disadvantage of the combined turbine is that it must be provided with nozzle cut-out governing at partial loads, in order to obtain satisfactory consumption at these loads. This, however, is not so, as there is, of course, no reason why ordinary throttle governing should give less satisfactory results at partial loads with combined turbines than with "pure" types of turbines. It is a fact that automatic nozzle control complicates the governing mechanism to such an extent that it should only be adopted in exceptional cases, where turbines are run for a considerable length of time at low loads and where the loads may change rapidly. In most cases ordinary throttle governing is preferable, as the small improvements obtainable with nozzle cut-out governing (2 per cent. at ¾-load, 4÷5 per cent. at ½-load) do not justify the additional complication in the governing apparatus. The practical difficulties of automatic nozzle control are due not to the necessity of arranging valves in front of the nozzles, but to the complicated gear required to operate the valves, which latter must be reasonably tight when closed. These difficulties, therefore, do not exist when hand-operated valves are used, and in most cases these meet the requirements. The problem of cut-off governing, which has been successfully solved for steam engines, is more difficult in the case of steam turbines, but it is also of less importance.

INCREASE OF THE FIELD OF APPLICATION OF TURBINES.

1. **High-pressure Turbines.**—The steam turbine is the machine for large outputs, and it has, during the first half of the last decade, superseded the steam engines for outputs above 1,000 kw. The recent improvements in steam turbines, which resulted in the adoption of the combined types, has still further reduced the minimum output at which a steam engine is more advantageous than a steam turbine. Units of 500 kw. capacity are now usually ordered as turbines, and even 250 kw. turbines are able to compete successfully with the best modern steam engines. In countries, as for instance the United States, where the cost of coal is of second importance, there is a tendency to adopt turbines for even the smallest outputs. For small units generally the pure Curtis types with only a single wheel are used. These are also used very



FIGS. 31 AND 32.—GOVERNOR FOR MIXED-PRESSURE TURBINES.

successfully for special purposes, as, for instance, the driving of condenser and high-lift pumps, which are discussed more fully in the last paragraph.

The developments which have taken place during the last five years show an improvement not only in high-pressure

condensing turbines as used for power stations, but also a tremendous increase in the application of turbines to all possible industrial purposes. This has involved the manufacture of new kinds of machines known at present as:—

Low-pressure or L.P. turbines.
Mixed-pressure or M.P. turbines.
Back-pressure or B.P. turbines.
Reducing or R. turbines.

2. **Low-pressure Turbines.**—The great importance of low-pressure turbines was first pointed out by Prof. Rateau, who invented the Rateau steam accumulator, which is really a necessary accessory for low-pressure installations. The first plant including low-pressure turbines and steam accumulator in conjunction with winding engines was installed by Prof. Rateau in 1903 for the Mines de Bruay.

The Rateau accumulator allows low-pressure steam at a constant or approximately constant rate to be taken from a machine which is working intermittently. If the available low-pressure steam quantity is always sufficient for the output required, the installation of a low-pressure turbine is quite satisfactory, and if for short periods no low-pressure steam is available, high-pressure steam must be reduced into the low-pressure steam main. If, however, this occurs for long periods, or if the low-pressure steam quantity is not sufficient to produce the power required from the turbine, the losses due to throttling high-pressure steam to below atmospheric pressure are too large. In such cases, which represent the normal condition, the installation of a mixed-pressure turbine is necessary.

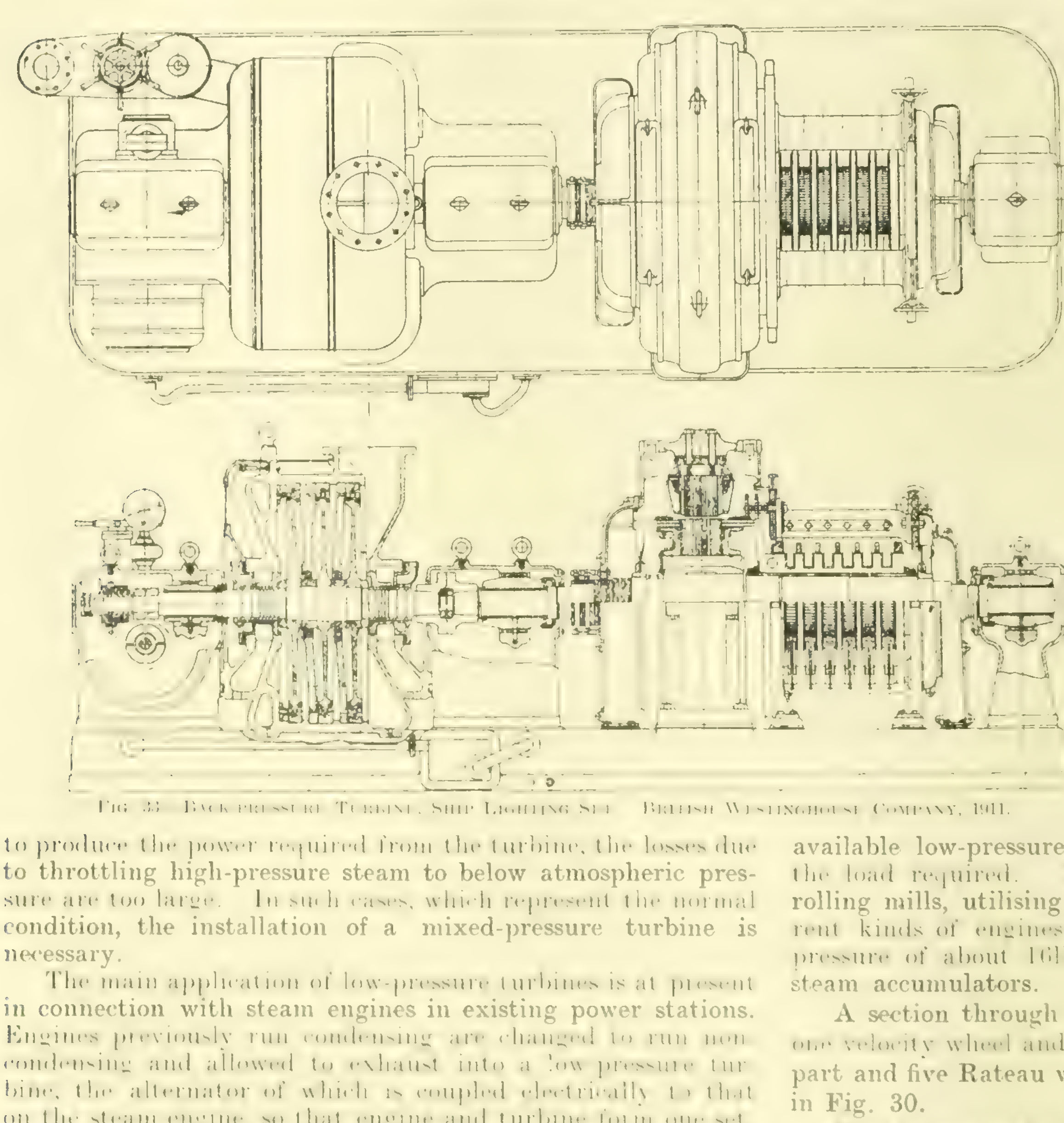


Fig. 33.—Back-pressure Turbine, Ship Lighting Set.—British Westinghouse Company, 1911.

The main application of low-pressure turbines is at present in connection with steam engines in existing power stations. Engines previously run condensing are changed to run non-condensing and allowed to exhaust into a low-pressure turbine, the alternator of which is coupled electrically to that on the steam engine, so that engine and turbine form one set.

This arrangement is very economical, providing the normal output of the combined set is increased at least 50 per cent. above that of the engine alone. Usually the combined set is arranged so that the normal full load of the engine alone when exhausting against a back pressure of about 16lbs. per square inch absolute is kept the same as before, the low-pressure turbine utilising the exhaust steam coming from the engine. It is advisable to pass the exhaust steam from the engine through an oil separator which acts also as a water separator. The additional output which can be obtained from the low-pressure turbine depends mainly on the vacuum. The improvement in economy is much larger in cases where river or sea water is available for cooling water than in cases where cooling towers are necessary. At partial loads the back pressure on the steam engine drops below atmospheric pressure; it is therefore essential to steam-seal the glands on the low-pressure cylinders of the steam engine in order to reduce air leakage to an absolute minimum and to secure the highest possible vacuum.

The following figures are based on the average conditions which usually occur in these combined plants in the case of compound engines. The steam consumption of the engine running non-condensing will be about 35 per cent. (30 per cent. to 40 per cent.) greater than when running condensing. The exhaust steam from the engines will give an additional output in a low-pressure turbine of:—

61 per cent. of the output of the engine at 27in. vacuum,
70 „ „ „ „ „ 28in. „
81 „ „ „ „ „ 29in. „

and the steam or coal consumption would be:

For 27in. vacuum: $\frac{1\cdot35}{1\cdot61} = 84$ per cent. of the original steam consumption,
„ 28in. „ $\frac{1\cdot35}{1\cdot70} = 80$ „ „ „
„ 29in. „ $\frac{1\cdot35}{1\cdot81} = 75$ „ „ „

As the turbine is electrically coupled to the engine, no special governing of the turbine is required. For starting and paralleling generally, high-pressure steam is required, which is either regulated by hand or by a mechanical governor. It is not necessary to provide a reducing valve, as the steam pressure in the low-pressure turbine will anyhow not be higher than atmospheric pressure, due to the very large areas through the blading of the turbine. A section of a low-pressure turbine is illustrated in Fig. 29, from which it will be seen that it is simply a high-pressure turbine with the first wheels taken off. The section of this turbine shows five wheels with full admission, and the capacity is 1,000 kw. at 2,700 revs. per minute.

3. **Mixed-pressure Turbines.**—Mixed pressure turbines are high-pressure turbines with an additional inlet for low-pressure steam, or low-pressure turbines with additional high-pressure stages to utilise high-pressure steam in case the available low-pressure steam quantity is not sufficient for the load required. They are generally used in collieries, rolling mills, utilising low-pressure steam coming from different kinds of engines, which are exhausting against a back pressure of about 16lbs. per square inch absolute through steam accumulators.

A section through a mixed-pressure turbine consisting of one velocity wheel and one Rateau wheel in the high pressure part and five Rateau wheels in the low-pressure part is shown in Fig. 30.

Mixed pressure turbines are not generally connected electrically with the steam engines from which the supply of low pressure steam is obtained, and must therefore be separately governed by a speed governor. In order to obtain satisfactory running in parallel with other engines, it is essential that the load of the turbo set be independent of the steam conditions, which means that the speed of the turbine must be only dependent upon the load of the alternator, and independent of the low pressure steam quantity available. The change in speed, when changing from high-pressure steam to low pressure steam, or vice versâ, must therefore be as small as possible. These conditions were first realised by Prof. Rateau, who invented a governor fulfilling these conditions (see English Patent No. 3,822, 1905), and which

is now applied by nearly all the manufacturers of mixed-pressure turbines.

Figs. 31 and 32 show a sectional diagram of the mixed-pressure governor made by the British Westinghouse Company in accordance with Prof. Rateau's patents.

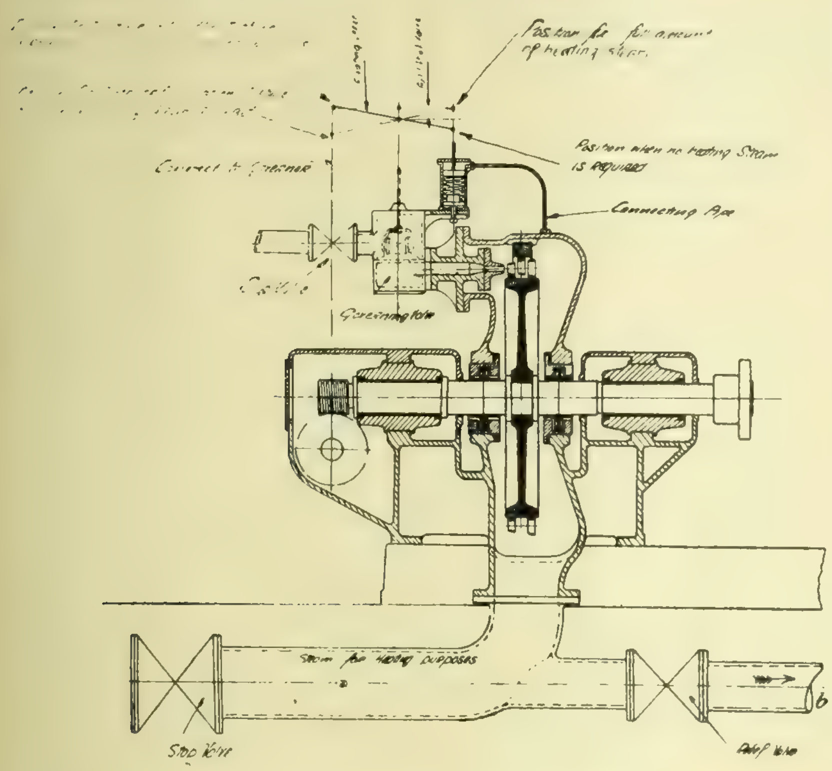


FIG. 34.—BACK-PRESSURE TURBINE GOVERNOR.

Although it is only five years since the first mixed-pressure turbine was installed in this country for the Gloucester Railway Wagon and Carriage Company by the British Westinghouse Company, its development has been very rapid during the last two years. The present importance of the mixed-pressure turbines for this country is best illustrated by the fact that nearly 40 per cent. of the turbines ordered are of the mixed-pressure type. It is interesting to compare the two main turbine types, the drum types and disc types, when designed as low-pressure or mixed-pressure turbines. The only factor we need to consider is the maximum output which can be obtained from the low-pressure part of these turbines. The steam consumption of low-pressure turbines is about double that of high-pressure turbines, which means that a low-pressure turbine has to deal with twice the steam quantity of a high-pressure turbine of the same output, or the maximum output of a low-pressure turbine is only half that of a high-pressure turbine, assuming the outlet velocity of the last rows of blades is the same for both high-pressure and low-pressure turbines. As, however, the available heat drop of a low-pressure turbine is only about half that of a high-pressure turbine, the leaving losses when expressed in per cent. of the heat drop appear twice as high. It is therefore of great importance to keep these leaving losses as low as possible. Diagram Fig. 23 can be used for the approximate calculation of maximum outputs of the low-pressure and mixed-pressure turbines, when taking the maximum outputs to be half and the leaving losses to be double those indicated.

It shows, for instance, that for impulse turbines running at 3,000 revs. per minute and a leaving loss of 5 per cent. the maximum output is only 2,300 kw. at 27½in. vacuum,
or— 1,900 kw. at 28in. vacuum,
or— 1,600 kw. at 28½in. vacuum,
whereas for drum turbines the leaving losses for the same outputs would be 20 per cent., which in most cases would be far too high, so that a double-flow turbine would be necessary. From this it is clear that in the case of low-pressure turbines the maximum outputs obtainable depend more on the turbine than the alternator, which is, of course, the reverse of what we found in the case of high-pressure turbines.

4. **Back-pressure Turbines.**—Back-pressure turbines exhaust against a back pressure which is above atmospheric pressure. Turbines run non-condensing and exhausting into free atmosphere are also included in this class.

The exhaust steam is generally used for heating purposes, as, for instance, in ships for heating the feed water, or in mills for heating water in open pans, or in salt works for evaporating brine. Fig. 33 represents a low-speed lighting set 400 kw. running at 1,500 revs. per minute driving a direct-current generator, and exhausting against 20lbs. per square inch absolute back pressure. The exhaust steam is used for heating the feed water. The small output at a very low speed and the light weight required made it necessary to use velocity wheels.

The governing of these turbines may differ according to the conditions prevailing. When all the steam is required for heating purposes, independent of the load, an ordinary speed governor is used, opening or closing a high-pressure throttle valve according to the load required. When, on the other hand, the turbine is required to work in parallel with other engines, and is intended to utilise only that amount of steam required for heating purposes, it need not be provided with a speed governor at all, the steam being controlled by the pressure in the heating steam pipe. If more heating steam is required the pressure in the heating steam main decreases, and this change of pressure can be used to open the governor valve in a similar manner to that used for reducing valves. Fig. 34 shows an arrangement where either of the two methods can be used, governing by mechanical governor or by the pressure in the heating main.

Neither of the two methods are quite satisfactory in all cases. If, in the first case, more load is required than that obtainable from the heating steam available, steam must be passed through the turbine and blown into atmosphere. This represents a great loss, as this steam could be utilised in a low-pressure turbine. The second method is absolutely satisfactory in this respect, but it is necessary that it be run in parallel with other engines, the load of which is changed according to the heating steam quantity required

An absolutely satisfactory arrangement can be obtained by the use of the :—

5. **Reducing Turbines.**—In case the load of the turbine is more than that obtainable from the heating steam quantity required, the surplus steam is by-passed to low-pressure wheels which are fixed on the same shaft and placed in the same cylinder. The sectional blading arrangement and the governing arrangement of a reducing turbine are shown in

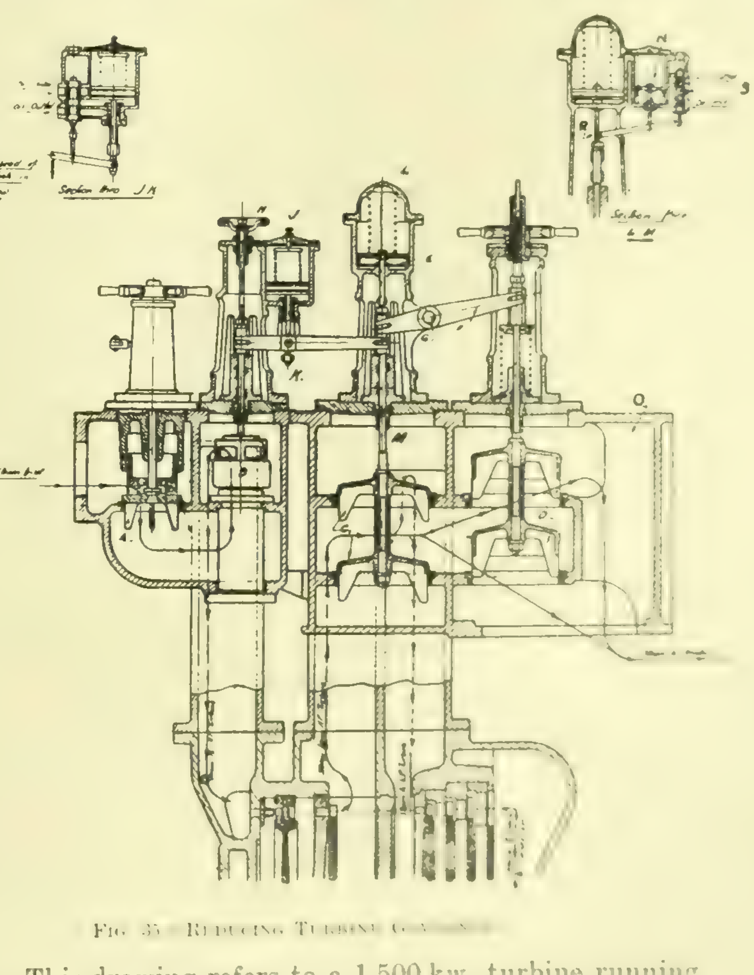


FIG. 35.—REDUCING TURBINE GOVERNOR.

Fig. 35. This drawing refers to a 1,500 kw. turbine running at 3,000 revs. per minute, and supplying normally 47,000lbs. of steam per hour at 16lbs. per square inch absolute back pressure for salt works.

Governing arrangements for reducing turbines have already been patented in this country in 1892 by T. Mu[illegible]

(Patent No. 14,013/1892). Patents on the same subject have been taken out in Germany by E. Mennig and G. D. Picard (No. 18,932/1903), and P. Beck (No. 139,013/1902). The governing arrangement for the turbine shown is similar to the mixed-pressure governor described above. The heating steam main is in communication with the under side of the spring-balanced piston N, which operates the low-pressure valve M by relay valve S and power piston R, admitting steam to the low-pressure turbine. In addition, both high-pressure and low-pressure valves are always under the control of the speed governor through the horizontal lever T, relay valve U, and power piston V.

When the turbine is running at a certain load and the heating steam quantity decreases, the pressure rise in the heating steam main will cause piston R to rise, and consequently the low-pressure valve to open, and simultaneously the high-pressure valve to close. More power will be developed on the low-pressure side, and less on the high-pressure side. The load is kept constant without appreciably affecting the position of piston V, and consequently the speed of the turbine.

On the other hand, when the output increases the decrease in speed causes the piston V to rise. The high-pressure valve will first be opened, and afterwards the low-pressure valve, on account of increasing back pressure. Thus both high-pressure and low-pressure valves are automatically adjusted for the larger load without any change in the heating steam quantity. Variation in the outputs, or in the heating steam quantity of the opposite nature to those considered above, result in a reverse series of operations.

In order to obtain automatically overloads with small quantities of heating steam, it is necessary to increase the pressure in front of the low-pressure wheels, so that a correspondingly increased steam quantity is passed through the low-pressure turbine. This is done automatically by lever F, which is operated by the low-pressure valve as soon as the latter is full open. The same arrangement may, under certain circumstances, be used for full load, the principle being to throttle always the smaller quantities, either the low-pressure steam or the heating steam, in order to secure the highest possible economy at all loads.

(*To be continued.*)

The Institution of Naval Architects.—The annual meetings of the Institution of Naval Architects will be held in the hall of the Royal Society of Arts, John Street, Adelphi, London, on March 27th and the two following days. The Marquis of Bristol is announced to preside. The annual dinner will take place in the Connaught Rooms on March 27th. The council of the Institute intimate that they "will be willing to present a gold medal to any person, not being a member or associate member of council, who shall at the forthcoming meetings read a paper which in the judgment of the council shall be deemed to be of exceptional merit. The council will also be willing to present a premium of books or instruments to the reader of any paper, not being a member or associate member of council, whose paper shall in the judgment of the council merit this distinction."

Fatal Spurwheel Accident.—An inquest was held a few days ago at Birmingham touching the death of a millwright's labourer, who was killed as the result of an accident at the works of Messrs. Guest, Keen, & Nettlefold, at Smethwick. Evidence showed that the accident was caused by the breaking of a cogwheel in the shafting tunnel. The wheel, which was 5ft. diam., was examined every week, and had been in the same position for 11 years. During the morning of the accident the cogwheels were at work, and were making 136 revs. a minute. Shortly after 11 o'clock a crunching noise was heard in one of the tunnels, and the machinery was stopped, when it was found that the wooden box over the wheel had been knocked off, and the deceased was lying unconscious near by. One-third of the rim of the wheel had been torn away, and two teeth of the remaining part had been knocked off. An examination of the wheel showed a blowhole, which extended for about 8in. It would not be visible from outside, and had existed from the time the wheel was originally cast. The weight of the broken portion of the wheel was from 8 cwt. to 10 cwt. A verdict of "Accidental death" was returned.

BOOK REVIEWS.

Machine Tools Commonly Employed in Engineering Workshops. By James Weir French, B.Sc. Two Vols. 13½in. by 10in. Vol. 1, 170 pages; Vol. 2, 212 pages. London: The Gresham Publishing Company. Price 42s.

The most striking features of these two imposing volumes are the wealth of beautiful half-tone illustrations on highly-glazed art paper and the almost complete absence of sectional illustrations or scale drawings, though as some atonement for the absence of the latter a number of cut-out and superimposed coloured model views are given. But however interesting these may be to some, they are a poor substitute for good sectional views. The description of the photo-picture views of the various tools described, though clear, is woefully disappointing to anyone who seeks definite information on machine tool design or performance. Such information as is given is expressed in the general phraseology customary in makers' catalogues, and would appear to be mainly derived from them. As a choice selection of extracts of this kind the book may not be without interest to a certain class of readers, but the tool draughtsman, the engineer, or the student who desires to know something about the root principles of machine tool design and operations will, we fear, regard it as disappointing and expensive.

* * *

Technical Arithmetic and Geometry for Use in Technical Institutes and Workshops. By C. T. Mills, M.I.Mech.E., Principal Borough Technical Institute. London: Methuen & Co., Ltd. 7½in. by 5in. 300 pages. Second Edition. Price 3s. 6d.

Technical students nowadays cannot complain of any lack of good elementary literature on almost any subject, and the number of books dealing with the principles of mensuration and arithmetic must be legion. The reason for this profusion is doubtless the lamentably low standard of mathematical knowledge possessed by the average lad when he leaves the elementary school and the pressing need of it presented to teachers of technical subjects. The book under notice is a sincere attempt to make good a deficiency which ought not to exist when a lad enters a technical class. Its chief merit is that the practical examples by which the teaching is expounded are not dissociated from mathematical principles or allowed to degenerate, as is sometimes the case in books of this class, into mere rule of thumb. Geometric illustrations are freely given, so that the student can realise graphically the nature of the operations he performs by means of figures. We think, however, that the author, in his efforts to make things clear, occasionally drags out his descriptions to unnecessary lengths.

* * *

Annual Report of the Smithsonian Institution for the Year ending June 30th, 1910. Government Printing Office, Washington.

The collection of scientific papers comprised within these reports always possess a special interest, owing to the wide range of selection exercised, and the present volume is more than usually so. The papers collated deal with such widely divergent subjects as "Progress in Aviation," "Reclamation of Arid Lands," "Electric Power from the Mississippi River," "Industrial Safety Appliances," "Astrophysics," "Life Outside of Organism," "Significance of Pulse Rate," &c., and there is scarcely one in which any intelligent reader would not find of interest.

* * *

The Journal of the Institute of Metals. (Vol. VI.) Edited by G. Shaw Scott, M.Sc. The Institute of Metals, Caxton House, Westminster, S.W.; 21s. net.

The major portion of the journal consists of a series of papers of scientific interest which were read at the annual autumn meeting of the Institute of Metals, held in Newcastle-on-Tyne in September, and covers 322 pages. Valuable though these papers were when they were originally presented, their utility is now increased, as a result of written communications which have been received since the papers

were read, from men eminent in the scientific and metal-working worlds. The papers which are thus reproduced in the journal include the following: (1) "The Corrosion of Brass, with Special Reference to Condenser Tubes," by P. T. Bruhl, M.Sc.; (2) "Further Note on the Nature of Solid Solutions," by C. A. Edwards, M.Sc.; (3) "The Electrical Conductivity and Constitution of Alloys," by Dr. W. M. Guertler; (4) "Volume Changes in the Alloys of Copper with Tin," by J. L. Haughton, M.Sc., and Prof. T. Turner, M.Sc.; (5) "Non-ferrous Metals in Railway Work," by George Hughes; (6) "The Failure of a Brazed Joint," by Prof. H. Louis, M.A., D.Sc., Assoc.R.S.M.; (7) "The Mechanical Properties of Hard-drawn Copper," by D. R. Pye, B.A.; (8) "The Alloys of Aluminium and Zinc," by Dr. W. Rosenhain, B.A., and S. L. Archbutt. In addition to the above, the volume contains a verbatim report of a lecture by Dr. G. T. Beilby, F.R.S., on "The Hard and Soft States in Metals." There is also a useful series of abstracts of papers relating to the non-ferrous metals and the industries connected therewith, dealing with such subjects as electro-metallurgy; the properties of metals and alloys; metallography; furnace and foundry methods; analysis, testing, and pyrometry; statistics; and bibliography.

VAPORISERS FOR INTERNAL-COMBUSTION ENGINES.

HERETOFORE, in order to provide for using hydrocarbon or oil fuel of different qualities, vaporisers have been constructed with a plain or unjacketed part, which becomes highly heated during the working of the engine, and with a water-jacketed part which is retained in a relatively cool condition, such water-jacketed part being usually arranged at the end of the vaporiser nearer to the cylinder, and the unjacketed part at the end most remote from the cylinder, although this arrangement has been sometimes reversed. Vaporisers have also been constructed with two water-jacketed parts arranged at the ends of the vaporiser and with an unjacketed intermediate part between the jacketed portions, the water-jacketed parts being supplied with cool water from a common main or so arranged that the flow of water through them can be regulated. In practice, however, this method of regulation has not been found to provide a sufficient varying range of temperature to enable hydrocarbon or oil fuel of widely-differing qualities to be used.

To enable the temperature of the vaporiser to be regulated with greater accuracy, the arrangements illustrated have been designed and patented by D. Roberts, Spittlegate Iron Works, Grantham. In the illustrations, Fig. 1 is a sectional elevation, and Fig. 2 is an end view of the vaporiser provided with water-jacketed portions at the ends and an intermediate unjacketed portion. Fig. 3 is a view illustrating a modification in the arrangement of the water discharge pipe as applied to a vaporiser having the outer end only jacketed. A indicates the vaporiser having the contracted neck B which engages with the cylinder, and C D are the water-jacketed chambers formed around the inner and outer ends respectively of the vaporiser, with an intervening unjacketed space, the chambers C D being connected at the top by a passage E and having connected to them at the lower part the inlet pipe F for the cooling water. G is the pipe through which the water is discharged from the jacket, and the height of the open end of which within the jacket is adapted to be varied in order to regulate the water level. As shown in Figs. 1 and 2, this pipe G has a horizontal portion which extends through a stuffing-box on the jacket, one end of the horizontal portion projecting through the stuffing-box and being provided with a handle H by means of which the pipe can be rotated in the stuffing-box to vary the position of the open end of the pipe in the chamber, for instance, by placing the pipe in the position indicated by the dotted line J in Fig. 2, which corresponds with the lowest level of the water in the jacket, or, in the position indicated by the dotted line K, which is the position corresponding with the highest water level in the jacket. The placing of the pipe in any intermediate position correspondingly varies the water level. The stuffing-box is provided with an annular chamber to which a pipe M is connected, and in the horizontal portion of the pipe G a series of holes N is formed, so that the water, which flows through the pipe G, can escape therefrom into the pipe M in any position of the pipe G. A water gauge is fitted for indicating the level of the water.

In the operation of the apparatus the cooling water will enter the water-jacketed chambers C D through the pipe F and escape through the pipe G, the level of the water in the jacketed chambers corresponding with the position of the open end of the pipe G. In moving the pipe from a position in which the jacket is practically full to any lower position, the imprisoned air within the jacket, or the steam generated from the cooling water, will quickly force out the water above the level of the mouth of the discharge pipe G.

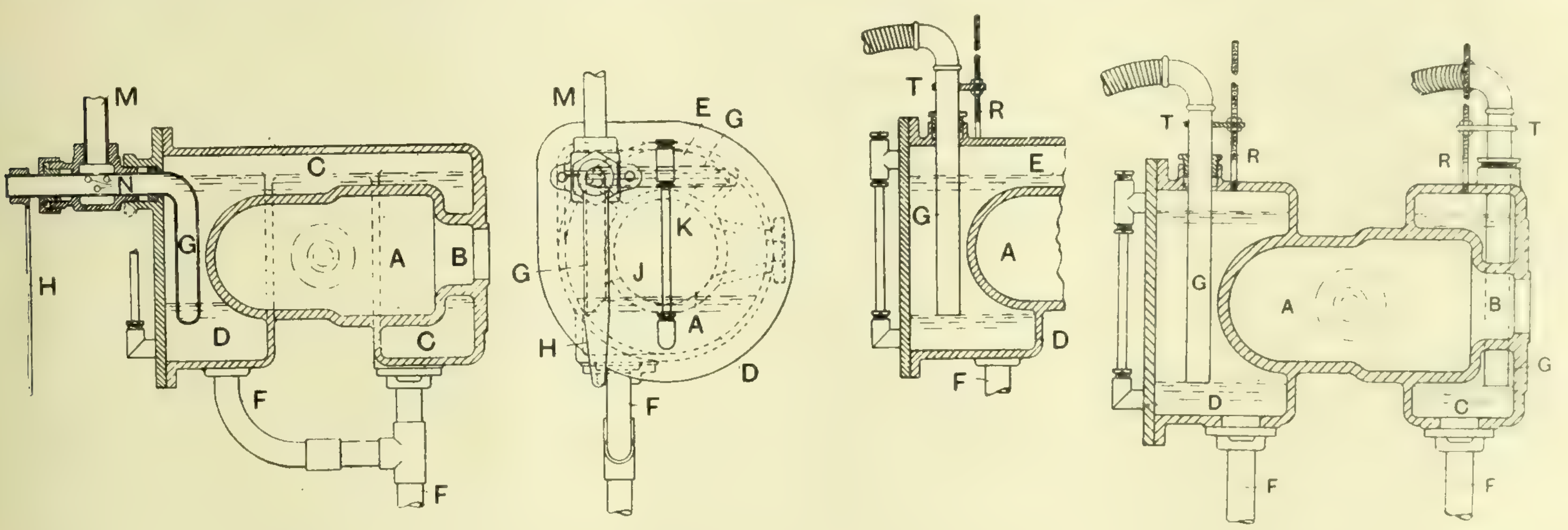


FIG. 1. FIG. 2. FIG. 3. FIG 4.

VAPORISERS FOR INTERNAL-COMBUSTION ENGINES.

In the arrangement shown in Fig. 3 the discharge pipe G instead of being adapted to be rotated, as in the arrangement last described, is designed to be raised and lowered through a stuffing-box, the pipe being connected to the outlet by a flexible pipe. Instead of connecting the discharge pipe G to a flexible pipe as just described, it may be arranged so that as it is raised and lowered it telescopes into the outlet pipe. The raising and lowering of the pipe P is effected through the medium of a screw R having upon it nuts arranged in connection with an arm T connected to the pipe G.

In Fig. 4 is shown a vaporiser with two independent water-jacketed chambers each of which is provided with a water-level regulating device of the kind shown in Fig. 3.

New Type of Submarines.—There was launched on Monday last from the naval construction yard of Messrs. Vickers the first submarine of an entirely new class for the British Admiralty. She is known as E 2, No. 1 being still on the stocks. She is almost three times as large as those of the A class, and of much greater beam. She will be driven by a heavy oil engine, and will be an all-round improvement on anything yet turned out. She will carry quick-firing guns. Messrs. Vickers have, we learn, just received an order to build three super E class for the British Navy.

HEAVY-OIL ENGINES FOR MARINE PROPULSION.*

BY G. C. DAVISON.

WITHIN the past few years there have been various types of engines developed for the purpose of using crude oil, or fuel oil. These engines may be divided into two general classes—those working on the constant volume, or Otto cycle, and those working on the constant pressure, or Diesel cycle. The Otto cycle is too well known to require a description here, since it is the cycle used in all gasolene and gas engines. Its use is practically limited to volatile fuels and gases. Kerosene and the heavy hydrocarbons have been used to a limited extent in engines of the Otto principle by vaporising the fuel oil by means of heat. But up to the present, little practical success has rewarded the efforts made in this line.

The Diesel engine, on the other hand, has been a success from the first as a heavy-oil engine. Its use was at first limited to stationary engines. Success has been so marked that the increase in the output of these engines has been remarkable since its first development. Only in the last few years has it been considered as a marine engine, but it has shown itself so well adapted to marine propulsion that its use afloat has rapidly grown, so that at the present time it is estimated that over 250 sea-going vessels of from a few hundred to several thousand tons each are now equipped, or being equipped, with these engines.

The Diesel cycle may be briefly described as follows: (1) On the admission stroke pure air is drawn into the cylinder. (2) On the compression stroke the pure air is compressed to a pressure of about 500lbs. per square inch. Due to such a high degree of compression the air is heated to about 1,000° Fah. (3) At about the beginning of the return or expansion stroke the liquid fuel is sprayed through a specially designed valve into the hot compressed air. Due both to the high pressure and the high temperature, the small particles of fuel are burned almost instantly, thereby increasing the temperature and maintaining the pressure about constant during the first part of the stroke. Fuel is sprayed in until enough has been supplied to enter into combustion with the oxygen of the air. When this point is reached, usually at about one-tenth the stroke, the fuel valve is closed, and during the remainder of the stroke the hot products of combustion expand, doing work. (4) On the next stroke the products of combustion are expelled.

The cycle above described is the usual 4-stroke cycle, and is the one on which the engine was first developed, and hundreds of thousands of horse-power are in use to-day. It has certain advantages as well as disadvantages. The Diesel cycle is also used on the 2-stroke principle, as is the case with engines of the Otto cycle, but here again the Diesel cycle has a great advantage. During the process of scavenging at the end of the expansion stroke the Otto cycle, employing a mixture of air and fuel, loses a part of the unconsumed fuel through the exhaust ports. The Diesel type of engine, on the other hand, is scavenged by a charge of pure air, and, therefore, no fuel is wasted in this way. The fuel does not enter the cylinder until after the end of the compression stroke, and every particle of fuel injected is burned in the cylinder.

From the foregoing it will be seen that the main points of difference between the Otto and Diesel cycle may be summarised as follows:—

Fuel.—The Diesel engine may employ practically any form of combustible liquid, while the Otto cycle must use a gas or vapour.

Compression.—Theoretically, the higher the compression the greater the efficiency. There are certain practical limits to this, and the Diesel engine is enabled to attain this limit, since only pure air is compressed. In the Otto cycle the compression is limited by the danger of premature explosion due to raising the temperature of the mixture by compression.

Explosion.—Since the fuel is sprayed into the Diesel engine at a rate just sufficient to maintain a constant pressure, there is no explosion, and, consequently, no sudden shocks, nor instantaneous changes of temperature. This is conducive to smooth running and long life of working parts. The Otto cycle, on the other hand, is based on an explosive action.

From the foregoing it is seen why the Diesel type of engine has shown itself so well adapted to the use of heavy oils. Mechanically there are other advantages peculiar to the Diesel type, such, for example, as absence of an igniting device, absence of a carburetter, or vaporising device, all of which are delicate affairs, and give the greater part of the trouble experienced with explosive engines.

A complete Diesel engine requires certain auxiliaries. These are the air compressor, the fuel pumps, a lubricating pump, and a water circulating pump. The last two mentioned auxiliaries are also found on all engines of the Otto cycle. The air compressor is usually built in two stages, though some designers prefer three. Two stages seem ample, as the maximum air pressure used for spraying the oil into the cylinders is seldom in excess of 1,000lbs. per square inch. In engines of a few hundred horse-power it is customary to use only one compressor, on the same bedplate with the engine, and driven from a crank on the main shaft. There are no novel features in connection with the design of these compressors. The fuel pumps are always attached to and driven by the main engine. It is the usual practice to supply a separate pump for each cylinder, but it is possible to operate two or more cylinders from one pump.

The governing of the engine is accomplished by controlling the amount of fuel delivered by the fuel pumps to the spray valves. In this way the fuel is practically measured out for each stroke by the pump, and very accurate control is possible. There is no throttle valve employed on these engines. The amount of air taken in and compressed on each stroke is the same. At half load, for example, only about half the amount of fuel is delivered. This fuel burning in an excess of oxygen is completely consumed, and imparts all its heat to the contents of the cylinder. Hence, the engine is efficient at reduced loads, and is as flexible as any type of internal-combustion engine. Governing of these engines is merely a question of flywheel and number of cylinders. A recent test of a 2-cylinder stationary engine, having a coefficient of fluctuation of one-ninetieth, showed a variation in speed of 2 per cent. from full load to no load.

The relative advantages of 4-cycle and 2-cycle marine engines may be summed up as follows:—

Economy.—The 4-cycle has about 8 to 10 per cent. less fuel consumption than the 2-cycle. Taking an average case, a 4-cycle engine would use only 0·46lb. per horse-power hour, while a corresponding size 2-cycle engine would consume 0·50lb. of fuel per horse-power hour. This is the principal advantage of the 4-cycle over the 2-cycle, but advocates of the latter type believe this difference in fuel consumption will soon be reduced.

Heat Conditions.—The 4-cycle engine has the advantage as regards the cooling of pistons and cylinders, but loses some advantage by having an exhaust valve in the head exposed to hot exhaust gases.

Turning Moment.—The 2-cycle is much superior, requiring a very much smaller flywheel. Six-cylinder high-speed engines require no flywheel.

Reversibility.—The 2-cycle is again superior. First, because the same valve gear may be used both in the ahead and astern directions, thereby simplifying the construction: second, because for a given engine twice the number of cylinders may be brought into action: and, third, because of less inertia, due to reduction in weight of flywheel, the engine will respond quicker.

Weight.—The 2-cycle naturally has an advantage.

Space.—Again, the 2-cycle has the advantage, due to its nature.

It seems to be the general opinion of authorities on the subject that, for marine purposes, the 2-cycle is superior to the 4-cycle engine. For marine purposes, the superior economy of the 4-cycle engine has to be balanced against the even turning moment, the simplicity, the reversibility, the lightness, and the compactness of the 2-cycle engine. If, as

* Abstract of paper read before the Society of Naval Architects and Marine Engineers, New York.

many engineers confidently expect, the economy of the 2-cycle can be made the same as the 4-cycle, there will be no room for argument.

Considering the present development of the two types, the question, as applied to stationary engines, assumes an entirely different aspect. Here we are not greatly concerned with questions of weight, space, and reversibility. This gives the 4-cycle engine, due to its superior efficiency, the leading place. Consequently, practically all stationary oil engines at present are of the 4-cycle type. It remains to be seen whether they will maintain this position. If the economy of the 2-cycle engine is improved, as many expect, the question for land installations will then hinge upon the cost of manufacture. When this time arrives it is probable that the 2-cycle engine will become the favourite for land as well as sea.

Going further into the development of oil engines, we come to double-acting types. There are now in successful operation, horizontal 4-cycle double-acting tandem engines developing 500 h.p. per cylinder. Their use is at present limited to land installations.

The vertical 2-cycle double-acting engine for marine purposes is the latest development. Several engines have recently been completed and tested. The smallest of these develops 300 h.p. per cylinder, and the largest 2,000 h.p. per cylinder.

A natural advantage of the double-acting engine is that it permits a reduction in weight per horse-power. An alternative advantage is that for a given weight per horse-power it permits of a reduction in piston speed, and, consequently, of a slower number of revolutions and of a larger and more efficient propeller. As it happens, the first large marine double-acting engines have taken advantage of the latter in preference to the former feature. When applied to large ocean-going steamers, where the question of weight and space is not of paramount importance as compared to reliability, the builders of these recent engines appear to have been wise. Even with the comparative low piston speed and massive parts, there is a saving in weight and space as compared with the usual steam plant for the same class of vessel. It is interesting here to note that the owners of two of these large vessels have had occasion to complain of the small space occupied by the engine, slow and strong as it is, because of the rules for measurement for tonnage and consequent dues. This, of course, is only a passing phase of the problem, and is only another instance of the case where engineering developments are ahead of the laws and customs.

In general, the mechanical problems which have been met and solved in Diesel engines are of the same nature as those encountered in large gas engines. In fact, the firms which have done most to develop the oil engine have had a wide experience with gas engines, and utilised much of the knowledge thereby acquired in their oil engine construction. The problem of dealing with heat in cylinders and pistons is dealt with as in gas engines. In large marine engines the latest tendency is to cool the pistons by means of circulating oil in their heads. The heated oil on leaving the pistons is passed through a cooler, consisting of a nest of tubes around which cooling water is circulated. The reason for using oil as a cooling medium instead of water is that slight leakages in the flexible connections is not objectionable, and would not interfere with the lubrication of working parts. Oil, however, is not as good a conductor as water, and also has a much smaller specific heat.

Materials.—In the earlier types of Diesel engine the columns, bedplates, cylinders, and water jackets were made of massive cast iron. This ensured ample strength and durability, but made the engines very heavy, some of them weighing as much as 400lbs. per horse-power. As these earlier engines were used on land only there was, and is, no objection to their heavy construction. When the attention of marine engineers was directed toward heavy-oil engines, radical changes in construction were at once inaugurated to adapt them for use on board ship. As a result, a number of firms have produced engines which are amply strong, and yet lighter in weight than the lightest steam plants afloat. The lightest engine which has been built weighs only 20lbs. per horse-power. In this engine the bedplate and housing were aluminium, the crank shaft and connecting rods of special high-grade steel, the water jackets of copper, and the cylinders and pistons of cast iron.

Certain 4-cycle marine engines have been constructed up to 1,000 h.p., and weighing from 40lbs. to 60lbs. per horse-power. In these engines cast steel bedplates and cast or built-up steel housings have been used. In these, cylinders and pistons are the only cast-iron parts. These engines have demonstrated that they are amply strong and durable.

Many 2-cycle marine engines, ranging from 150 h.p. to 2,500 h.p., have been built, in which the weight is not more than 40lbs. per horse-power. In these, high-grade bronze castings are employed for bedplates and housings.

Piston Speeds.—The lowest speeds used are about 600ft. per minute in very heavy slow-running engines. The highest speed in the lightest types is 1,100ft. per minute. For ordinary work it is perfectly safe to use a piston speed of 1,000ft. per minute, as has been found to be the case in steam and gas engines.

Lubrication.—In practically all marine oil engines some form of forced lubrication is used. Babbitted bearings are used throughout. Little or no trouble has been found with bearings. Due to the high pressures used, the bearings are somewhat larger than in steam engines of the same power.

Piston Packing.—The same form of ordinary split rings are used as in ordinary gas-engine practice. On account of the higher pressure a greater number of rings are employed in oil engines.

Stuffing Boxes.—For double-acting engines of this type a special form of metallic packing for stuffing-boxes has to be provided. The usual forms of metallic packing used in modern steam engines are inadmissible, both on account of the high pressure and temperature. This problem has, however, already been successfully solved.

To sum up, the only problems which have had to be solved are those due to the high pressure and temperature in the cylinders. All these problems have been successfully solved, so that there are now fully a score of different designs in successful operation. From this it should not be assumed that these practical problems are easily and cheaply solved. Their solution represents years of expensive experimental work on the part of manufacturers, who naturally retain for their own use the practical knowledge thus derived. Ordinary steam-engine and gas-engine practice cannot be followed without some modification.

Tests.—Many tests have been made with various types of these engines, and have been given in the technical press of the world. The most important results are in connection with fuel consumption. These show an extreme range from 0·4lb. to 0·6lb. fuel per horse-power hour. Some of these tests have extended over several weeks of continuous running on the test stand. The results of recent voyages of ships fitted with these engines have demonstrated the remarkable fuel economy obtainable.

It has been estimated that over 250 vessels in the world are to-day fitted with oil engines. Submarine torpedo boats form a large part of this number. These vessels usually have from 600 h.p. to 2,000 h.p. France is now constructing submarines having two oil engines of 2,500 h.p. each. Russia has had gunboats of 600 h.p. each for several years. Italy is building a torpedo-boat destroyer equipped entirely with oil engines. England has ordered a destroyer having an oil engine for cruising purposes and steam turbines for high speed. Germany is reported to have an engine of 12,000 h.p. for use on one of her latest battle-ships for cruising purposes. Austria has a cruiser with two 900 h.p. 2-cycle engines. The foregoing does not pretend to be a complete list of what foreign navies have already done in connection with these engines.

In the merchant marine the following instances may be mentioned. In Russia a number of tank steamers have been running on the Black Sea for the past few years, using oil engines of about 600 h.p. In France the Barque Quevilly, fitted with two 300 h.p. Nuremburg engines, has crossed the Atlantic three times and her engines have been pronounced a great success. The owners of this vessel are now building another ship to be fitted with still larger engines. Other vessels with oil engines are in daily use in that country. In Germany the firm of Blohm & Voss has already finished a 7,000-ton ship, to be equipped with two engines of 1,000 h.p.

each. These are the first double-acting 2-cycle oil engines ever built, having been designed by the Nuremburg branch of the Maschinenfabrik Augsburg-Nürnberg A G. One of these engines was built by Messrs. Blohm & Voss, the other at Nuremburg. These engines are heavy and strongly built and run at a slow speed—125 revs. per minute. These engines have but three working cylinders. On account of the success obtained with these engines, Messrs. Blohm & Voss are now building a cargo vessel of 11,000 tons. The engines for this ship are of 1,500 h.p. each, and work on them is well under way. In England and Holland, a number of large vessels propelled by oil engines have already been built and others are building, but space will not permit of a further discussion of this phase of the subject. Considering the short time in which this development has taken place it appears truly remarkable.

In view of the rapid progress, and the world-wide interest in this new engine, some of its leading advantages are here reviewed, and will fully explain why it is considered such an important matter.

Economy of Fuel.—Under ordinary conditions a vessel propelled by steam will consume about 2lbs. of coal per horse-power hour. In daily practice, due to unfavourable conditions, such as bad firing, inferior qualities of coal, leaky valves and pistons, &c., the consumption frequently exceeds 3lbs. of coal per horse-power-hour. The oil engine consumes about ½lb. of fuel per horse-power hour. The variation from this amount is slight. For large engines under certain conditions the consumption would be slightly less. Generally speaking, as extreme limits, the oil consumption may be said to vary from 0·4lb. to 0·6lb. per horse-power hour. Therefore, for a given weight of fuel a ship propelled by oil engines would have from four to six times the radius of action of a similar ship propelled by steam. From a military point of view this advantage alone is so overwhelming as to force all navies to eventually adopt oil fuel for the fighting ships of the future. Aside from the military advantage of increased cruising radius there is a decided commercial advantage resulting from fuel economy. The extent of this advantage is a mere matter of arithmetic, depending on the relative cost of oil and coal in the port from which the vessel operates.

Attendance. The economy in the cost of fuel is but one item in the total saving due to the use of oil engines. In general terms it may be stated that the cost of attendance of a heavy oil engine is about half that of a steam plant of the same power. The expenses due to water tenders, firemen, and coal passers is entirely eliminated. Due to the absence of these persons on board a ship there is an incidental saving of space in the living quarters, which would prove of considerable value in any vessel, and especially in a naval ship.

Weight.—As regards the item of weight of plant, exclusive of fuel, the advantages are all in favour of oil engines. Comparing light-class installations, the steam plant will weigh about 60lbs. per horse-power, while the oil engine will weigh less than 40lbs per horse power. Taking heavier installations, as in a merchant vessel, the difference is still more striking, the oil engine weighing from one-half to one fourth of the steam plant of the same power.

Space. As regards space occupied, the oil engine will require less than half that occupied by a steam plant. This applies to both heavy and light types of oil engines when compared with heavy and light types respectively of steam installations.

Endurance. To maintain full speed for considerable lengths of time on naval vessels propelled by steam involves such strenuous work on the part of the fireroom force that as a matter of fact very highly powered vessels, such as destroyers, seldom if ever have been able to make a run at full speed corresponding in length with the total fuel supply. With oil engines, however, there being no fireroom force, this drawback does not exist. The engines are designed with a view to continuous running, and aside from the extra vigilance which any engineer would naturally give his engine when running at full speed, no extra strain or hardship is inflicted upon the personnel.

Repairs.—The yearly average cost of repairs are much less for an oil-engine plant than for a steam-engine plant. This follows from the fact that not only are the boilers and their auxiliaries eliminated, but also important auxiliaries such as condensers and air pumps disappear with the adoption of oil engines. The latter have only three small auxiliary pumps, usually driven by the engine. These are the water-circulating pump, the lubricating pump, and the fuel pump. On account of the consequent simplicity of the oil-engine plant, regarded as a whole, with the consequent reduction in the number of parts, it is easy to see why there should be such a great reduction in the cost of repairs.

Reliability.—In an oil engine, each cylinder is in many respects an independent unit. Not being dependent upon so many external units, such as boilers, feed pumps, condensers, air pumps, lines of steam piping, the probabilities of any accident external to the engine, causing the plant to stop, are very remote in comparison with the steam plant. In the event of an accident to one cylinder, such as a fracture, such cylinder could be run idle while the other cylinders would independently develop their power.

Absence of Smoke.—This is a purely military advantage, much sought after but not heretofore obtained with coal. With oil engines there is a complete absence of smoke.

Funnels.—In a war vessel it has been found that unprotected funnels are a great menace in action. With the oil engines, the need for a funnel disappears.

Cleanliness.—Having no coal smoke nor cinders, a vessel using oil engines would be as easy to keep clean as one of the old sailing ships.

Readiness for Action.—With modern water-tube boilers and turbines it is still necessary to spend about an hour getting up steam, warming the engines, &c., before the vessel is ready to move. With oil engines none of these preparations are necessary. The engine is ready to run at a few seconds' notice.

Time for Loading Fuel.—To coal a war vessel quickly is of such paramount importance that it is now the custom to make an evolution of this event, the services of every officer and man of the crew being required. But in spite of this, coaling is still a matter of one or more days. With oil fuel it ceases to be a matter of manual labour, but is dependent solely on the equipment used—on the pumps and sizes of piping used, and with any vessel could be easily reduced to a matter of an hour.

It will not be long before high-powered vessels equipped with internal-combustion engines will become familiar objects. According to accounts, Italy has recently ordered a destroyer equipped with internal-combustion engines, while England has ordered one to be built by Thornycroft, in which there will be an internal-combustion engine on the middle shaft for cruising purposes, while the outer shafts are driven by steam turbines.

Metallography in the Foundry—At a meeting of the Glasgow branch of the Foremen's Mutual Benefit Society, a lecture was delivered by Mr. H. S. Primrose, metallurgist to Messrs. G. & J. Weir, Ltd., Cathcart, on the subject of "Practical Metallography." The value of this to the practical man was demonstrated by a number of lantern slides showing photo-micrographs of various kinds of metal, and illustrating the effect of different methods of casting and subsequent heat treatment. The causes of failure in iron castings were discussed, and the non-ferrous alloys used in brass foundries were shown to depend more upon their structural condition, as revealed by the microscope, than their actual chemical composition. The methods of remedying some of the founder's troubles were indicated as being to a large extent dependent upon a proper microscopical investigation of the metal.

Danger of Mine Explosions.—In a recent lecture on "Firedamp and Coal Dust," Mr. G. H. Winstanley, M.Sc., of Sheffield, said that the atmosphere in a colliery, charged with 6 per cent. of firedamp, was explosive, and the greatest explosive violence was experienced at 10 per cent. When the percentage exceeded 16, however, the mixture was not explosive, because there was insufficient oxygen to promote combustion. To-day, however, firedamp was not relatively a more serious element of danger than coal dust, because the ventilation in all properly-equipped collieries made it the simplest possible operation to render inflammable gas harmless by taking care that its molecules or particles were so separated that one could not ignite the other. He was in the neighbourhood of Hulton three weeks before the terrible explosion which resulted in the loss of 344 lives, 13 months ago, and it was a pathetic coincidence that he then used similar arguments by way of warning that he was now using.

THE INFLUENCE OF TIN AND LEAD ON THE MICRO-STRUCTURE OF BRASS.*

BY F. JOHNSON, M.SC.

WITH a view to elucidating the exact relations which exist between tin and lead when occurring together in brass, the author recently made a series of experiments, which are herein described.

The statement made by Prof. Louis in a paper on the "Failure of a Brazed Joint," read by him at the 1911 autumn meeting of this Institute, was challenged by the author in his contribution to the discussion. The statement, which referred to the reticulated structure caused by the presence of lead and tin in a brazed joint, was as follows: "I have therefore no doubt but that this appearance was caused by an alloy consisting essentially of lead and tin, much more fusible than brass, which solidifies about the crystals of brass; the planes thus formed constitute planes of weakness, liable to yield under strain, and thus allowing liquids to penetrate into the mass of the metal." Experimental alloys were made by Prof. Louis, with the object of imitating the composition and structure of the braze.

Since those alloys were not analysed, however, it cannot be said that they exactly corresponded to the braze in composition, but it is quite probable that, owing to the inevitable loss of some zinc when making brass alloys, the analyses would approximate fairly closely, for the ratio of zinc to copper used in preparing the experimental alloys was higher (viz., 33·3 to 66·6) than that in the braze (31·3 to 66·6). The structure of the braze was imitated, however, with a definite degree of success, the "reticulations" being faithfully reproduced.

The Influence of Tin.—So far as the author has been able to judge from his experience with commercial brass alloys, it has seemed to him that tin could exist in solid solution in brasses consisting wholly of the α phase, after the processes of cold-drawing and annealing, to the extent of at least 1 per cent.; also to the same extent at least in alloys consisting of the α and β phases, in the cast or rolled condition. In order to confirm this, the author made alloys of the following composition:—

	I. Grammes.	II. (Naval Brass.) Grammes.
Copper	70	62·0
Zinc	29·25	37·0
Tin	0·75	1·0

Electrolytically-deposited copper, the purest stick zinc, and Straits tin were used.

The copper was melted under a layer of charcoal in a covered clay crucible, the zinc and tin added, the mixture well stirred with a charred stick, and allowed to cool under charcoal in the crucible.

Microscopical Examination.—When quite cold, microsections were sawn from each alloy, ground on an emery wheel, polished on graded emery papers, and finally with globe polish on chamois leather. The surface was etched with a dilute solution of ammonium persulphate. In alloy I. (see Fig. 1) there were numerous areas similar in structure and colour to the δ constituent ($SnCu_4$) appearing in gun-metal (*e.g.*, 88 per cent. copper, 12 per cent. tin). An excellent illustration of this constituent is shown in Law's "Alloys," photomicrograph No. 11.*

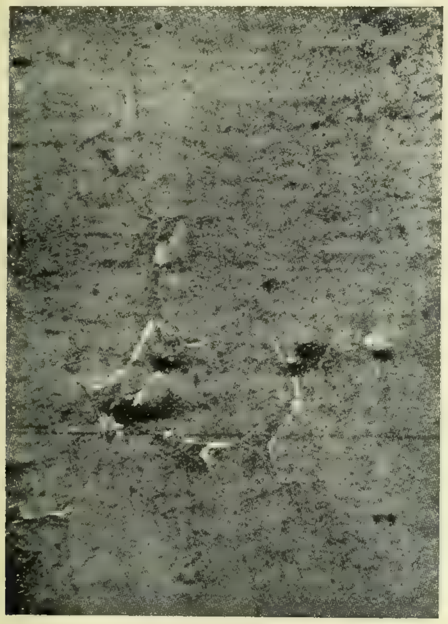


FIG. 1.—ALLOY I.
70/30 brass, containing 0·75 tin. Showing insolubility of $SnCu_4$ in the α phase. Magnified 180 diameters. Vertical illumination. Etched.

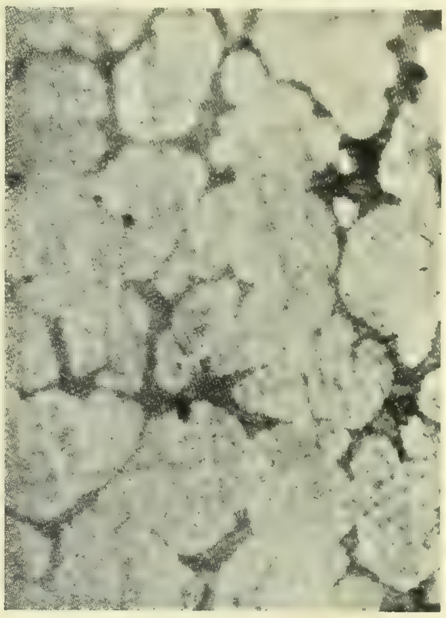


FIG. 2.—ALLOY II.
Naval brass, slowly cooled, showing solubility of $SnCu_4$ in the β phase. Magnified 180 diameters. Vertical illumination. Etched.

FIG. 4.—ALLOY III.
Pure brass, slowly cooled, 2 copper to 1 zinc. Shows areas of β. Magnified 180 diameters. Vertical illumination. Etched.

Alloy II. (naval brass) showed none of these areas, the typical structure caused by the presence of the α and β phases together being revealed. As will be seen from Fig. 2, there are just traces of thin pale blue films of $SnCu_4$ separating the two phases; there are two small patches also visible in one of the β areas, sufficient time apparently not having been allowed for its complete solution. These passed entirely into solution after annealing at 800° C. The results of these experiments point to the very slight solubility of tin

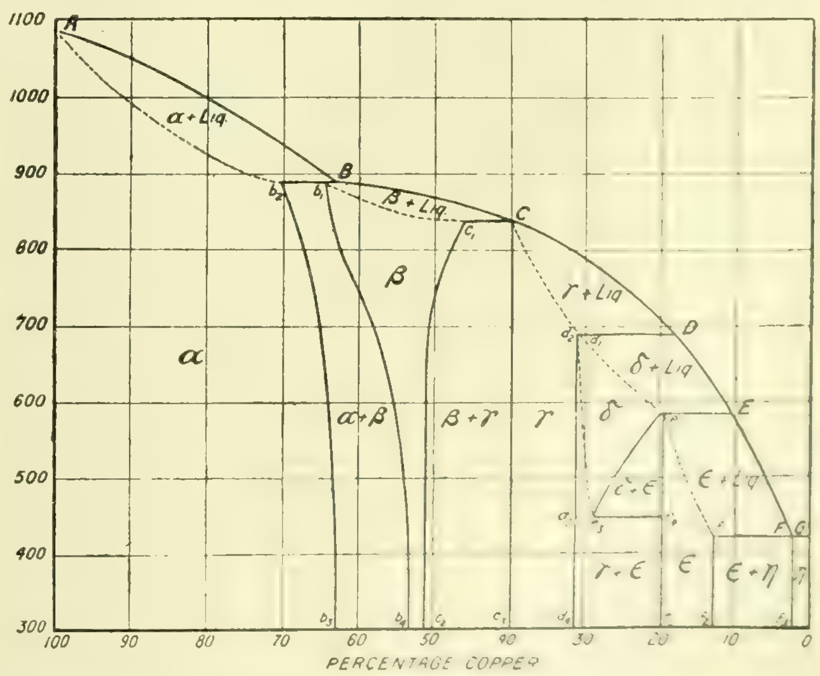


FIG. 3.—SHEPHERD'S DIAGRAM

* Paper read before the Institute of Metals, January, 1912.

* The author regards only the white material as $SnCu_4$, it having been thrown out from what was a solid solution of $SnCu_4$ in the α phase at high temperatures. This solid solution appears as a pale-bronze structureless constituent in alloy I. quenched at 700° C.

in the α phase as cast, and to its almost complete solubility in the β phase.

In order to test the effect of mechanical work and annealing on the solubility in the α phase, a piece of alloy I. was rolled cold from $\frac{1}{2}$in. to $\frac{3}{16}$in. thickness, and annealed for half an hour at 800° C., and cooled slowly. After polishing and etching, it was seen that very little of the $SnCu_4$ constituent was visible, most of it having passed by diffusion into the α crystals. In commercial alloys of 70/29/1 composition, it is quite probable that practically all of the tin is thus made to pass into solution by annealing subsequent to rolling or drawing. The author would strongly advocate thorough annealing at a red heat of these alloys at every stage, in order to procure homogeneity of composition, as well as maximum softness for subsequent mechanical "work."

FIG. 5.—ALLOY IV.
Showing effect of quenching at 800° C., brass containing the tin bearing β phase. Magnified 180 diameters. Etched.

FIG. 6.—ALLOY IV.
Same as Alloy III., but containing tin. Shows separation of $SnCu_4$ constituent from the β phase. Magnified 180 diameters. Vertical illumination. Etched.

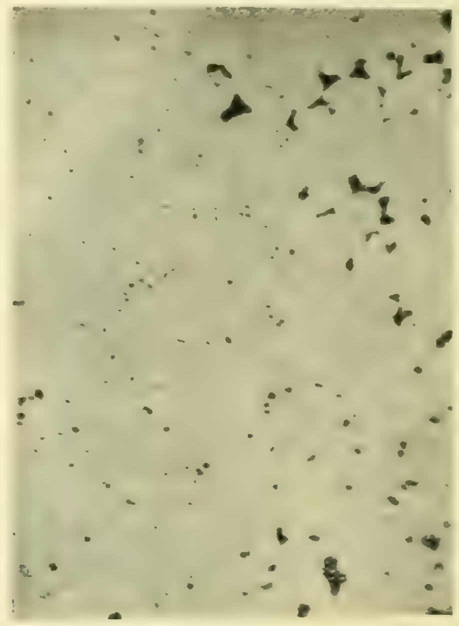


FIG. 7.—ALLOY V.
Showing existence of lead (black spots) independently of the $SnCu_4$ areas in brass. Magnified 40 diameters. Unetched.

Influence of Lead.—Several workers have shown that it exists in the free state in brass, polished sections of the latter showing black spots and intercrystalline areas. Bengough and Hudson* have very clearly pointed out the nature of its occurrence in 70/30 brass in the following words: "The presence of lead is indicated in more or less rounded particles scattered through the crystals." Law,† amongst others, has shown that lead exists in a similar condition in bronze. The blackness of these areas is probably due to the excessive softness of the particles of lead, which are rubbed away to a greater extent during the polishing than the harder crystals of brass, thus leaving microscopical pits, from which the light from the illuminator of the microscope is not suitably reflected.

Influence of Lead and Tin together.—In order to clear up the point as to the nature of the "reticulations" which Prof. Louis believes to be "an alloy consisting essentially of lead and tin," alloys were prepared corresponding to Prof. Louis's alloys A, B, and D. They were prepared in exactly the same way as alloys I. and II., and were constituted as follows:—

III. (Pure Brass.)		IV.		V.	
	Grammes		Grammes		Grammes
Copper ..	66·66	Copper ..	66·66	Copper .	66·66
Zinc	33·33	Zinc	33·33	Zinc ..	33·33
		Tin	0·75	Tin	0·75
				Lead .	0·5

It is not clear from Prof. Louis's description whether he added the impurities in the above way, or whether he substituted them for equivalent weights of copper or zinc. The difference would be of little importance if he did take the latter course, so that the above alloys III., IV., and V. may be taken to correspond respectively to Prof. Louis's alloys A, B, and D.

It will be noticed that the ratio of copper to zinc (2:1) is constant throughout. According to Shepherd's diagram, Fig. 3, this alloy (No. III.) should, under sufficiently slow cooling, consist entirely of the α phase. In ordinarily cooling such an alloy, however, and even with the retarded rate of cooling adopted by the author, a true state of equilibrium is not attained, and some of the β phase remains undissolved (see Fig. 4). This phase, although stable at a high temperature, is unstable at normal temperature. It will be noticed that the patches of β are, like the α phase, structureless.

In alloy IV. similar patches of β occur, but they are no longer structureless. The pale blue compound $SnCu_4$ is clearly seen in bunches of grains, and as a film of beautifully uniform thickness enveloping this constituent. The author assumed this to be the result of decomposition of a solid solution of $SnCu_4$ in the β phase, having proved its comparative insolubility under similar conditions in the α phase (Fig. 1), and its solubility in the β phase (Fig. 2).

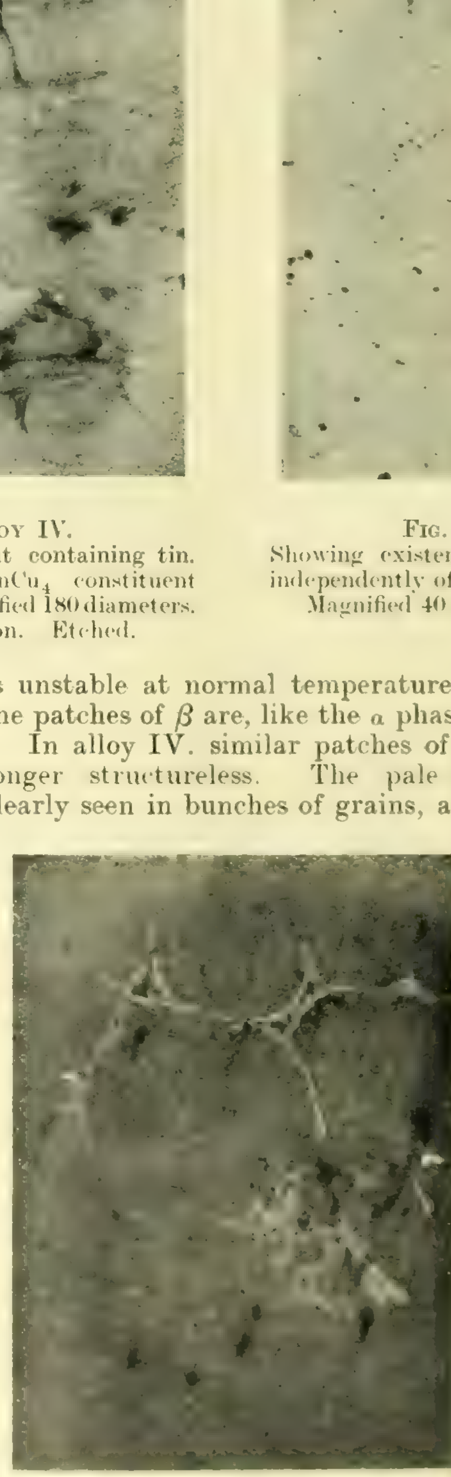


FIG. 8.—ALLOY V.
Same as Fig. 7, under higher magnification. Magnified 180 diameters. Vertical illumination. Etched.

If this assumption were correct, a specimen of the alloy quenched at 800° C. should show no free $SnCu_4$, on account of the greater volume of β which exists at that temperature. Fig. 5 shows this to be the case. The specimen was kept at 850° C. for half an hour, and then quenched from about 800° C. in cold water.

The duplex character of the β constituent in this case can possibly be explained by one of two theories; either: (1) It represents a stage in the transition of β to α where the two phases exist in intimate mixture. In such a case the tin is in solid solution in the β particles. Or, (2) it represents an intimate mixture of two constituents, one corresponding to the β constituent of the brasses, and the other corresponding

* "The Heat Treatment of Brass." Bengough and Hudson "Journal of the Institute of Metals," No. 2, Vol. IV.

† "Alloys," page [illegible]

to the β constituent of the bronzes,* the latter having possibly existed in solid solution in the former at a higher temperature, though this is doubtful. It is shown in the photomicrograph at the stage above that at which it will deposit $SnCu_4$ on slow cooling.

Since a piece of the pure brass alloy (III.) showed no such duplex structure when submitted to the same treatment, the author is inclined to favour the second theory. Whatever the theory may be, the separation of $SnCu_4$ as "reticulations" can be safely ascribed to insufficiency of the β constituent to hold it in solid solution.

Incidentally, it will be noticed that the β constituent occupies a greater area in the quenched than in the slowly cooled specimen (compare Fig. 5 and Fig. 6). This is only what one would expect from a study of Shepherd's diagram.

Fig. 7 shows the appearance of alloy V. under low power. The presence of free lead as globules and intercrystalline areas is shown by the black spots; these are not present in alloys III. and IV., which contain no lead. The "reticulations" which appear as faint light-coloured meshes (specimen unetched) are due to $SnCu_4$-bearing β areas, and these have exactly the same structure as that shown in Fig. 6 when viewed under high power. Fig. 8 shows this alloy under higher power and after etching. The black particles of lead are seen clearly, having a separate identity from the "reticulations."

Conclusions.—(1) Tin is only slightly soluble in the α phase of the degree of concentration existing in 70/30 alloys as cast. Rolling and annealing help it to pass into solution. (2) Tin is readily soluble in the β phase (limit undetermined) as contained in alloys of naval brass and Muntz metal type, even in the cast condition. (3) The "reticulations" caused by the presence of tin in a brass in which the ratio of copper to zinc is 2 : 1 have no structural relations with any lead which may be present, the latter existing in the "free" state. This is probably true of all α brasses. (4) The "reticulations" are due to the deposition of $SnCu_4$ from the β constituent, which is insufficient in quantity to retain it in solid solution.

Finally, the author would point out how the foregoing experiments explain why it is advisable in works practice: (*a*) Thoroughly to anneal castings of the 70/29/1 and the 62/37/1 (naval brass) compositions before subjecting them to mechanical treatment, in order that the brittle tin compound may pass into solution; (*b*) to allow material made of naval brass to cool slowly after annealing for the same reason.

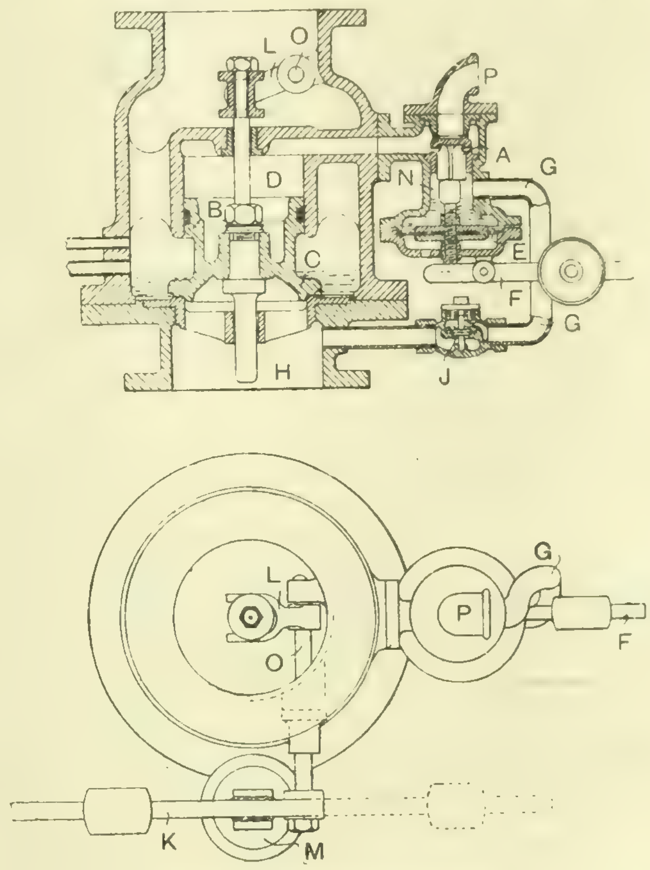
* The author only wishes to imply that the similarity exists so far as the allotropic change is concerned, not as regards composition. The composition is probably that of the pale-bronze constituent mentioned in a previous footnote, which would naturally deposit $SnCu_4$ on slowly cooling, just as it did in the case of alloy I.

The Iron and Steel Institute.—The annual general meeting will be held at the Institution of Civil Engineers, London, on Thursday and Friday, May 9th and 10th, 1912. The president-elect (Mr. Arthur Cooper) will be inducted into the chair and will deliver his presidential address. The Bessemer Medal for 1912 will be presented to Mr. John Henry Darby, Member of Council, and a selection of papers will be read and discussed. The annual dinner will be held at the Connaught Rooms, Great Queen Street, W.C., on Thursday, May 9th.

Light Alloys of Aluminium and Cobalt.—A study of the mechanical properties of light aluminium alloys containing cobalt, by H. Schirmeister, shows that the greater strength is given by those containing from 9 to 12 per cent. of cobalt; the tensile strength is, however, little more than that of pure aluminium. The structure is coarsely crystalline. The addition of from 0·8 to 1·2 per cent. of tungsten renders the structure fine, and increases the strength to two or three times that of cast aluminium. Such alloys have a specific gravity 2·8-2·9; they work and polish well, and are very stable in air. Molybdenum has the same effect. The further addition of tungsten is disadvantageous. The alloys should not be prepared directly from their constituents, but by means of rich intermediate alloys of tungsten and cobalt, best prepared by Goldschmidt's process. Clay crucibles must be used, carbon and sulphur being completely excluded.—"Journal of the Institute of Metals."

AULD & GRAHAM'S RELIEF VALVE.

THE relief valve shown in the accompanying illustrations, the joint invention of John Auld, Whitevale Foundry, Rochester Street, Glasgow, and John Graham, has been designed more particularly for regulating the pressure of steam supplied to turbines or for similar purposes. The main valve C is connected to a balancing piston B working within a cylinder D which may be placed either above, as shown, or below the main valve C. An auxiliary duplex valve A is fitted beside the main valve C outside its casing and is connected by its spindle to diaphragm E, which is fitted with stiffening metal plates above and below. The lower end of the auxiliary duplex valve spindle is acted on by a weighted lever F. This auxiliary valve has two working faces for which two seats are provided. One valve face and seat close a passage leading from the space within the cylinder D above the balancing



AULD & GRAHAM'S RELIEF VALVE.

piston B of the main valve C to the atmosphere by the duct P, while the other face being simultaneously lifted off its seat opens a passage G from the main valve steam inlet H to cylinder D, the duplex valve A being so arranged that when it opens one passage it closes the other. A non-return air valve J is fitted in the duct G from the steam inlet to the cylinder D above the balancing piston B to prevent air passing should a vacuum be formed below the main valve C. This non-return valve J may be fitted with a water seal as also may the main valve C, both having water supply and overflow pipes. The main valve C is counterweighted by a weighted lever K connected to the main valve spindle by spindle O fitted at its inner end with a forked lever L engaging with the valve spindle. A dashpot M, of ordinary construction, filled with oil, has its piston rod jointed to the weighted lever K to prevent main valve C hammering or chattering on its seat. A projecting lip may be formed round the outer or, as shown, the inner circumference of the main valve face for the same purpose.

In operation the steam enters the main valve casing by the inlet branch H and also passes by the passage G in which is fitted the non-return valve J, through this valve and into the chamber N above the diaphragm E of auxiliary valve A. So long as the pressure does not exceed that for which the auxiliary valve is loaded, the passage through the auxiliary valve allowing the steam to flow to upper side of main valve piston B remains open, while the other face of the valve A closes the passage from upper side of main valve piston B to the atmosphere. On the pressure rising above that arranged for, the action of the auxiliary valve faces and seats

is reversed by the steam pressure acting on the diaphragm E and the space above the main valve piston B is closed to the steam and opened to the atmosphere through the duct P. The steam escaping thus from the upper side of the main valve piston B to the atmosphere relieves the pressure over piston B and main valve C and allows it to open for the passage of the surplus or over-pressure steam. When the pressure falls to that arranged for, the operation is reversed and the main valve C again held down on its seat.

EXPLOSION OF A TURBINE CONDENSER.

WE reproduce herewith two photo views from our contemporary "Power," showing the destructive effects caused by the bursting of the condenser of a turbine, which led us to make some observations in our last issue (see page 122) on the importance of testing this part of a steam turbine equipment to prove its sufficiency to resist any accidental access of pressure in the event of failure of the air-pump mechanism, a contingency which in the case of turbines might afford little or no evidence of its existence to those in charge until it was too late, owing to the absence of visibly moving parts, and the greater ease with which, under certain circumstances, the acceleration of pressure in the condenser might take place.

The turbine and condenser in question, our contemporary states, formed part of the municipal lighting plant at Fort Wayne, Ind., which consisted of two 500 kw. vertical Curtis turbines and a new 1,500 kw. turbine of the same type, the latter having been recently installed, and the condensing apparatus for the new unit consisted of a large surface condenser having 2,200 ⅝in. by 16ft. tubes through which the cooling water circulates. This water was obtained from a reservoir adjacent to the plant, and is forced through the condenser by a 12in. volute centrifugal pump driven by a small vertical engine, and the vacuum was maintained by an 8in. and 10in. by 12in. air pump, both air and circulating

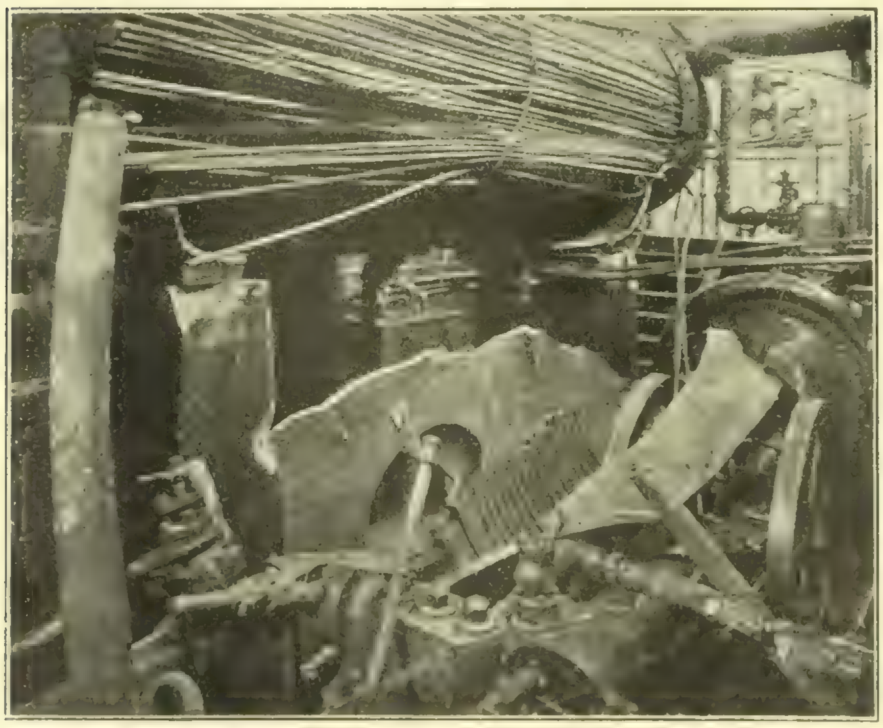


FIG. 1.—RESULT OF CONDENSER EXPLOSION.

pumps being located in a pit below the condenser opposite the turbine exhaust steam outlet.

"Early in the evening of Sunday, November 12th, the new 1,500 kw. unit was running alone, being but partially loaded. Some difficulty was experienced in maintaining a good vacuum. The engineer in charge went into the pump pit to locate the trouble. Shortly, a tremendous explosion took place at that point, and the engine room filled with steam. The switchboard attendant shut off the turbine and went into the pit to find the engineer. He had been instantly killed, and lay under a section of the condenser shell. The attendant then started up one of the 500 kw. units, and again took up the load just 12 minutes after the explosion. The cast iron shell of the condenser was broken into several sections, the top half and that portion opposite the turbine outlet being forced off into the pit and against the station wall. In falling, the parts struck the circulating pump, the air pump, and the adjacent piping. The housing of the circulating pump was broken off just below the flange, but it was not otherwise injured. The valve mechanism of the air pump was shattered. All steam piping and fittings for the air pump were demolished. Many of the condenser tubes were bent or dented, but the turbine itself was not damaged in any way.

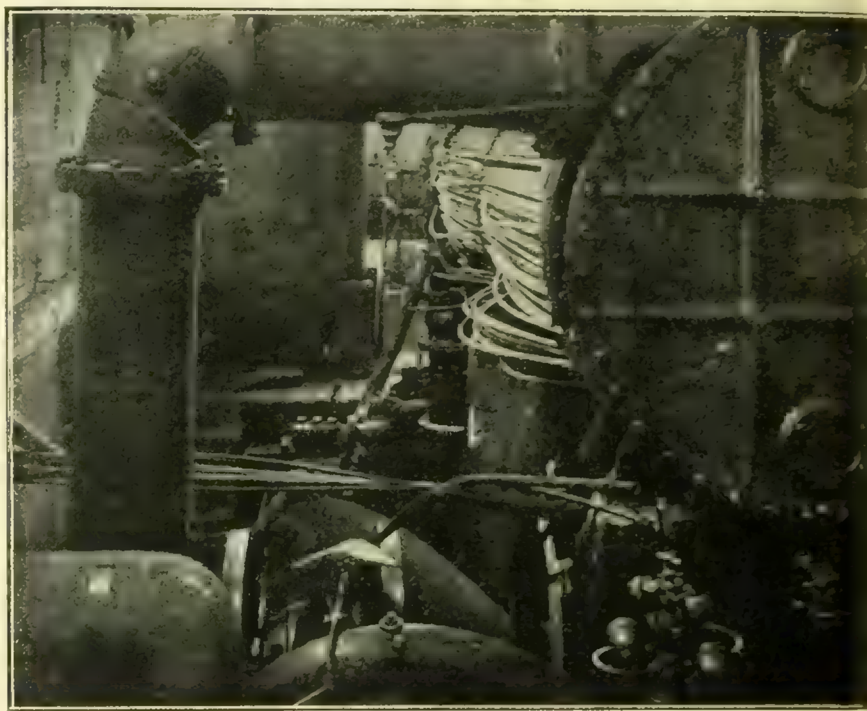


FIG. 2.—END VIEW OF CONDENSER, SHOWING FRACTURE IN CIRCULATING PIPE.

"The cause of the accident is not definitely known, but it is evident the condenser received steam under considerable pressure, though whether this was due to some fault in the air pump or to failure elsewhere cannot be determined from the evidence and information obtainable after the accident. The turbine was supplied with a relief valve from which the atmospheric exhaust pipe led downward, through a butterfly valve, and horizontally out of the station. It is possible that the relief valve failed to operate or that the escaping steam temporarily closed the butterfly valve."

International Association for Testing Materials.—The President of the United States has consented to act as patron to the Sixth Congress of the International Association for Testing Materials, which will open in the Engineering Societies' Building in New York City on Tuesday morning, September 3rd, 1912, and continue in session, if necessary, during the balance of the week. There will also be inspections of various works, &c. Following upon this there will be arrangements made for a week's excursion over the Lehigh Valley Railroad, with a visit to the Bethlehem Steel Company's works and some of the cement plants in that district. The route will then proceed to Niagara Falls and Buffalo, where the Lackawanna Iron and Steel Company's works are situated; then to Pittsburg, where many iron and steel plants of various kinds are situated, and also those of the Westinghouse Electric and Manufacturing Company; finally to Washington to visit the Government departments, including the Bureau of Standards, Testing Bureau of the Army and Navy, Smithsonian Institute, &c. A reception will be given by the patron, his Excellency President Taft. Return to New York Saturday, September 14th, where the party will break up. A detailed programme with a final enquiry sheet on the participation of members will be soon issued. The issue of Congress papers will begin in March. Those gentlemen intending to lay a report before Congress and not yet having sent in the same direct or through their council members to M. E. Reitler, Secretary of the Association, at Nordbahnstrasse 50, Vienna, II-2, are requested to do so as soon as possible. All communications respecting this notice should be directed to Mr. G. C. Lloyd, International Testing Association, 28, Victoria Street, S.W.

THE EVOLUTION AND PRESENT DEVELOPMENT OF THE TURBINE PUMP.*

BY DR. EDWARD HOPKINSON AND MR. ALAN E. L. CHORLTON.

(*Concluded from page 144.*)

INSTALLATIONS.

Bore-hole Pump. 1897.—This pump installation is particularly interesting on account of its novelty. The pump consists of six chambers in series and is arranged to work suspended in a bore-hole at a depth of 100ft. below the surface; it has a capacity of 850 galls. per minute, with a lift of 170ft. and runs at 1,900 revs. per minute. The general arrangement of the rising main by which the pump is suspended is shown in Fig 17. The pump and main rest on a crutch pipe at the bottom of the bore-hole. The pump is specially designed to fit the bore-hole lining tube, and its overall diameter is necessarily reduced. It is driven by a vertical shaft passing down the centre of the rising main and supported at each pipe joint by suitable stay bearings. At the surface this shaft is arranged with double-bevel gears and pulleys driven from a steam engine.

An interesting feature of this installation is shown in the illustration immediately below the pump, consisting of an expanding plug which effectively stops out all objectionable surface water, allowing the supply desired to come in through the suction pipe suspended below. This pump has given continuous service for over 14 years, during which time it has

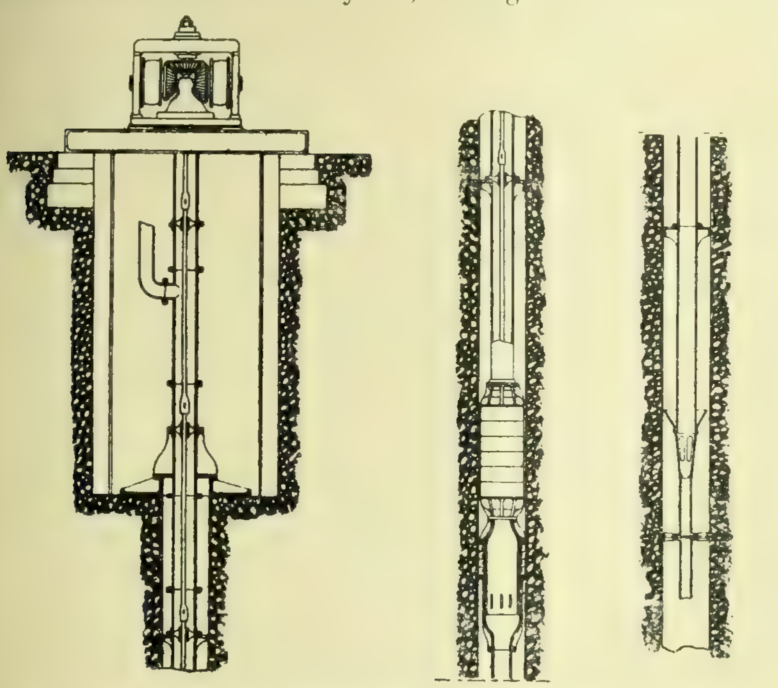


FIG. 17.—ARRANGEMENT OF MATHER-REYNOLDS' PUMP IN BORE HOLE, 1897.

received no repairs. In fact it has only once been brought to the surface during this period, when a portion of the shaft in the bore-hole was found to be corroded and required renewal.

Mine Pumps: Sulzer Installation of 1898.—The authors believe this to be the first installation of centrifugal turbine pumps of large capacity for mine drainage. It consisted of three multiple pumps arranged in stages, the pump of each stage delivering direct through the rising main to the stage above. The pumps were motor-driven, and each set was erected in a chamber off-set from the mine shaft, measuring 26ft. by 11ft. 6in. by 11ft. 6in., thus demonstrating the great convenience afforded by this type of pump for underground work. The capacity of the installation was 1,000 galls. per minute against a total head of 1,500ft.

Engineering Laboratory Plant. 1900.—This plant, constructed for the Engineering Laboratory of the University of Cambridge, consisted of a pump at one end, a similar turbine at the other end, and an electric motor between them. It forms an interesting combination designed for the purpose of carrying out a variety of tests. It could be worked either as a motor-driven pump, or a turbine-driven dynamo, or as a combination, the motor making up the loss of power in the water passing the turbine and pump, thus giving an hydraulic Hopkinson test. For this last purpose the magnets of the motor were slung on ball-bearings and provided with arrangements for measuring the torque.

Newcastle Electric Power Station. 1901. The combination above described was made use of later for actual installation, amongst others at the Newcastle Electric Power Station, for circulating the condensing water. The pump raised and forced water from the river to the condenser in the electric generating station in the town, the return flow to the river passing through and driving the turbine, the loss being made up by the electric motor in between.†

Mine-drainage Pump. 1911.—Fig. 18 and photo, Fig. 19, show a section through a series turbine pump lately constructed for mine drainage. It is interesting, as it is probably the mine pump with the largest capacity yet constructed. This pump is capable of delivering 2,500 galls. per minute to a height of 2,000ft. when running at a speed of

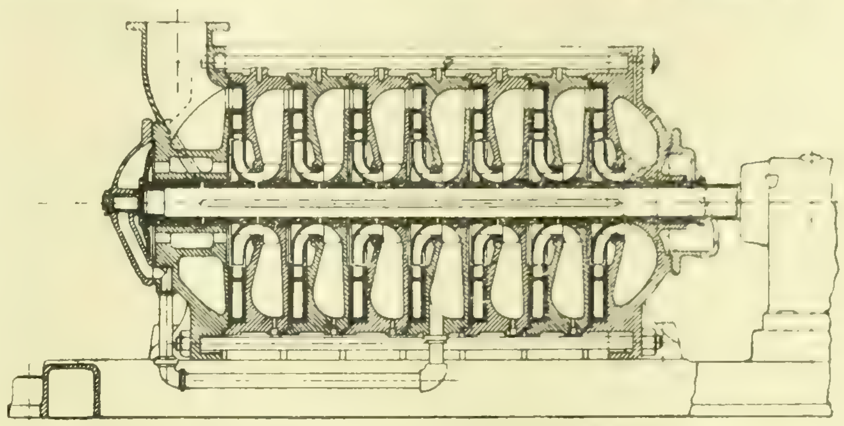


FIG. 18.—MINE-DRAINAGE PUMP, 1911 (MATHER & PLATT)

1,450 revs. per minute, and absorbs over 1,900 h.p. at the spindle. It is operated by a 3-phase motor of 2,500 volts, direct coupled through a flexible coupling of the pin and rubber-bush type. The pump has seven impellers arranged in series working in chambers, following each other in the same manner as those pumps already described, and not as is sometimes done for such high heads by arranging the impellers back to back, with the intention thus to balance the end-pressure. The series impellers are constructed of phosphor-bronze, and are mounted on a shaft of extra large diameter, to prevent sag in the middle and allow of fine clearance in the neck rings at the eyes of the impellers, thus reducing leakage. The guide vanes into which the impellers discharge are large castings of special bronze, double-sided and cast in one piece, thus securing increased rigidity.

The intermediate chambers have the return passages from

FIG. 19.—MINE DRAINAGE PUMP, 1911

the periphery to the suction of the next impeller cast in. They are of cast iron, and have feet cast on, which, resting on the planed surface of the bedplate, support and keep the whole pump in true alignment, a precaution more necessary when the length of the pump is as great as in this case. The construction also facilitates the stripping and rebuilding of large pumps. There is only one exterior bearing, in the form of a separate pedestal standing on and bolted to the main bedplate at the suction end. The reason for this bearing being separate and of such a solid form and not overhung from the pump-casing, as in the more standard form of smaller pumps, is due to the large power transmitted through the pump shaft at a high speed. There is a water-logging passage to the shaft at the suction stuffing box to prevent air leakage.

At the delivery end of the pump there is an internal [illegible]

* Paper read before the Institution of Mechanical Engineers, January 19th, 1912.

† Paper by C. Hopkinson, Proceedings Inst. Mech. E. [illegible] "[illegible] for Condensing Water."

matically grease-lubricated bearing and a differential end balance plate readily accessible for examination and adjustment, a great advantage with dirty waters. This construction obviates the disadvantages of a gland at the delivery end, subject to the full head pressure, with its attendant leakage and cutting of shaft. The lubrication of the internal bearings is effected by a piston worked by the head pressure pumped against.

Boiler Feed Pump. 1909. Figs. 20 and 21 show an electrically-driven boiler feed pump, consisting of two 6-chamber pumps in series, of the split-body type, allowing of the whole of the inside impellers, shaft, and guides being taken out together when the top half-cover is removed. This is a much simpler and quicker operation than taking adrift a standard type, but it is a more expensive form of construction.

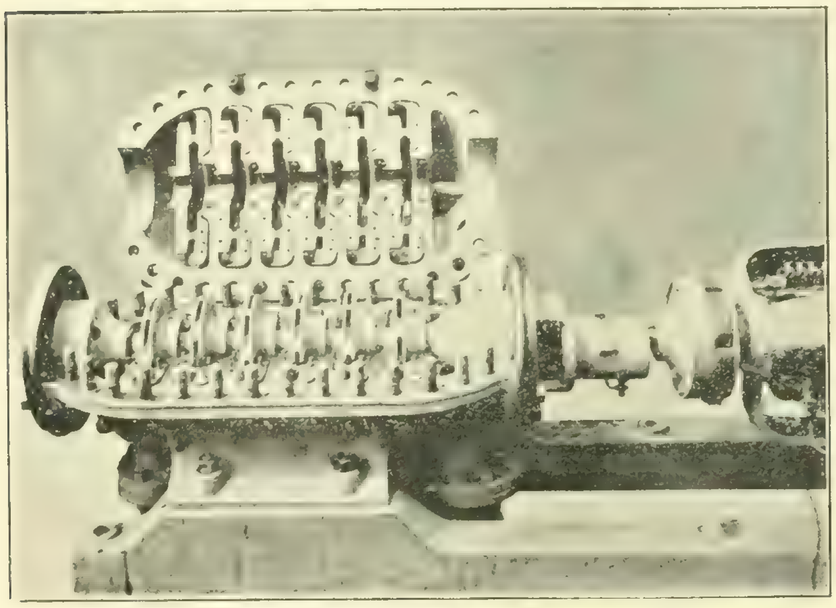


Fig. 20. Electrically-driven Boiler Feed Pump, 1909. Capacity 140 Galls. per Minute. Delivery Pressure 260lbs. per Square Inch, at 1,270 Revs. per Minute.

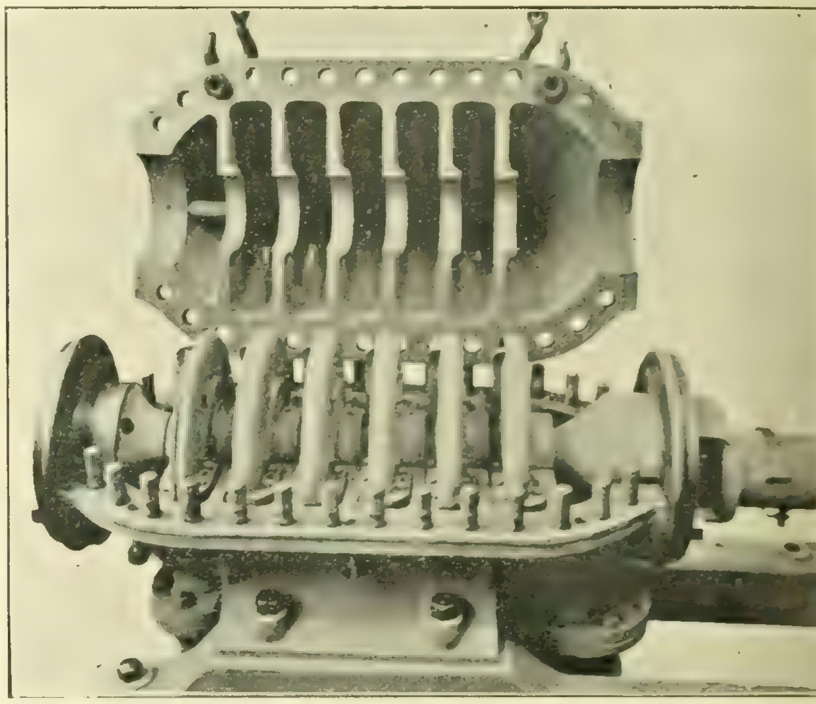


Fig. 21. Electrically-driven Boiler Feed Pump, 1909. Capacity 140 Galls. per Minute. Delivery Pressure 260lbs. per Square Inch, at 1,270 Revs. per Minute.

The difficulty in such a design is to deal with the 260lbs. per square inch internal water pressure on the split joint. Reference to the illustration will show how this is accomplished. It will be seen that the impellers are surrounded by guide plates, put on in halves and bolted together, and the whole is then placed in a casing divided in the middle horizontal plane. The casing is provided with as many dividing ribs as there are impellers. Turned bosses on the guide discs rest in suitably machined seats in the dividing ribs. The top cover is bolted on to secure them in their places, and they are prevented from rotating by pins. The main joint against heavy pressures is thus a plain one and of great rigidity, and can easily be maintained tight. The capacity of the pumps shown in Figs. 20 and 21 is 140 galls. per minute, 260lbs. per square inch delivery pressure at 1,270 revs. per minute.

Fire Pumps. An interesting application of the turbine pump for fire prevention purposes, as fitted to petrol automobile fire engines, is shown in Fig. 22. The capacity varies usually from 350 galls. to 1,000 galls. per minute, against a head of 250ft. to 300ft. The pump has a single chamber, and is designed to fit on the back part of the chassis of an automobile, and to be driven by an extended shaft from the engine. The regularity of the flow of water delivered renders the holding of the hose jets much easier, and the action of the turbine pump allows the shutting off of any particular jet, or of all the jets, without any tendency to burst the hose pipes, as may be the case with a reciprocating pump. Further, the pump is much lighter than a corresponding pump of reciprocating type, and takes up considerably less space. The difficulties incident to starting with a heavy suction can be met by the provision of a small auxiliary pump which exhausts the suction pipe, thus causing the water to fill the turbine pump. As soon as the turbine pump has developed its head pressure, the auxiliary pump can be put out of action, and the turbine pump will continue to work with suction lifts up to at least 80 per cent. of the height of the barometric water column.

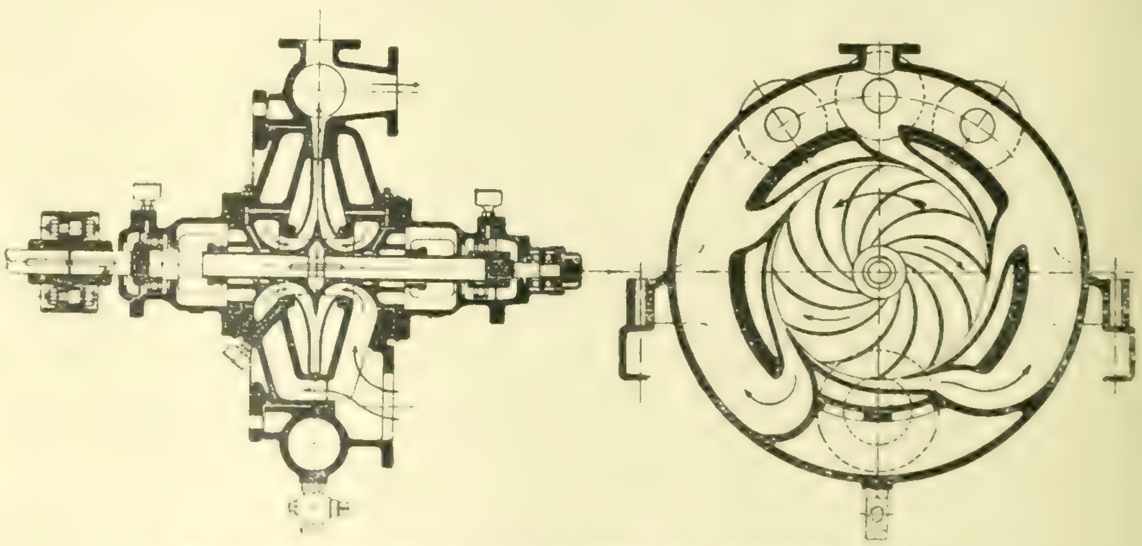


Fig. 22. Single-chamber High-lift Turbine Pump (Mather & Platt).

Waterworks Pump Driven Direct by a Steam Turbine. 1908.—This pump, like the mine-drainage pump already described, is of very large capacity, but differs from it in running at a high speed, being driven direct by a steam turbine. The plant is installed at the St. Gabriel Pumping Station of the Montreal Water and Power Company, situated on the banks of the St. Lawrence, and is capable of delivering in continuous work 10,500 galls. per minute at a head of 404ft. The turbine is of the Zoelly type, 1,350 to 1,500 revs. per minute, and is capable of normally developing 1,720 b.h.p. with steam at 165lbs. per square inch and 150° Fah. superheat. The air pump of the condenser is independently driven through reduction gear by an enclosed high-speed reciprocating engine placed at a lower level than the steam turbine pump. This auxiliary engine is of about 275 h.p. and runs at 465 revs. per minute. Direct coupled to the other end of the shaft is an auxiliary low-lift pump which draws water from the suction well and delivers it to the main pump at a small pressure, thus relieving the main pump from suction, and thereby effectively preventing any trouble in that pump from cavitation. A portion of the water from the auxiliary pump is by-passed through the condenser on its way to the main pump. It thus serves also as a circulating pump. The main pump

is of special design in that, owing to the high speed, only one impeller is needed to give the head, and two are required for the quantity. Consequently the pump is of 2-chambered parallel type. Each of the impellers has a double entrance, so that the shaft is in lateral equilibrium and no balancing device is required. A plant of this character has great advantage over a direct-acting or gear-driven reciprocating pump in the relative smallness of the space occupied and

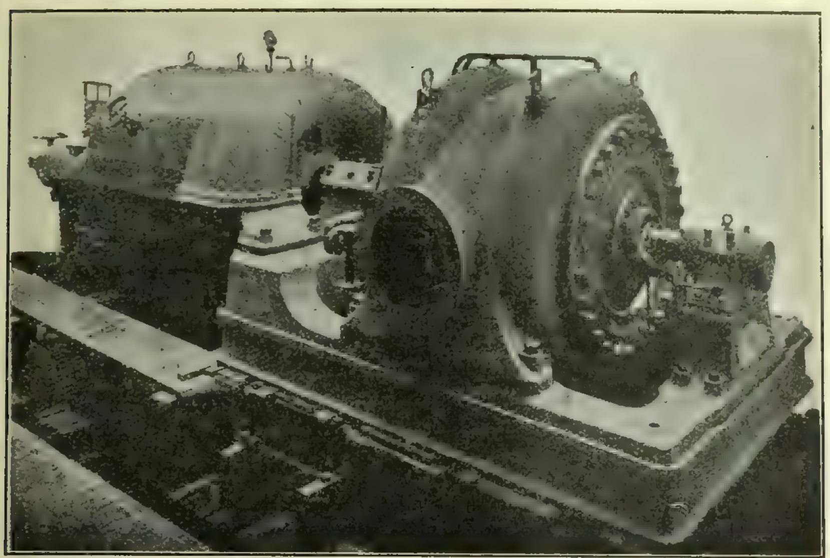


FIG 23.—WATERWORKS PUMP DRIVEN BY A STEAM TURBINE 1908

foundations required and in silency of operation. The steam turbine and pump are illustrated in Fig. 23. This pump and the mine-drainage pump already described, so far as the authors are aware, are the largest of their type in the world, and so give a fitting indication of the development of the Reynolds turbine pump since its inception 37 years ago, and illustrate some of its great possibilities in various duties.

FROZEN PIPES AND EXPLOSIONS OF DOMESTIC AND CIRCULATING BOILERS.

AN explosion due to the cold having frozen the water in the pipes occurred in a house in Victoria Road, Horwich, last Sunday. The occupants had just finished tea when the kitchen boiler exploded. Furniture was smashed, doors and windows blown out, and brickwork hurled through the ceiling into the room above. Mr. Holt, the tenant, and his son, who were sitting by the fireside, were thrown across the room and injured, the father severely. The same explosion did considerable damage in the next house. The range, mantelpiece, and boiler were torn from their place, and thrown across the room, while Mr. and Mrs. Hopkinson, the occupants, were both injured.

At Liverpool a lady named Miss Simm, was killed as the result of a boiler explosion at her house in Prescot Road. Miss Simm was preparing dinner in the kitchen at the time of the explosion. She was killed instantly. The force of the explosion was so great that the fireplace of the next house was blown to pieces, and considerable damage was done to the rear of the premises.

Two kitchen boiler explosions are reported from Manchester as a result of frozen pipes. One of a very serious nature occurred at a house in Granville-street, Chorlton-on-Medlock. Mrs. Turner and her daughter were seated last Sunday in the kitchen when the boiler burst, and the brickwork was blown out, completely wrecking the kitchen. Mrs. Turner received a severe shock. Her daughter escaped without injury at all. After the explosion there was a slight fire, but this was soon extinguished. The fire brigade were also called out to a house in Mabfield Road, Fallowfield, where again the kitchen boiler exploded, and some damage was done. The fire was speedily extinguished, however, and no person was injured.

At Mr. Gordon's coachworks, Bolton, on Saturday, the boiler of the heating apparatus exploded and blew out the windows of the premises, and also of an adjoining house. A youth was severely scalded about the face and hands, and another workman sustained injuries. Both were taken to the infirmary.

An explosion in the heating apparatus at the premises of Messrs. Gaunt & Son, sword manufacturers, Birmingham, caused a fire on Monday which did damage estimated at £15,000, in the course of which a man was struck by débris and killed. A number of girls working in adjoining premises were rescued with difficulty.

At Gospel Temple Congregational Church, Gowerton, South Wales, the heating boiler exploded early on Sunday morning, and owing to the absence of a fire brigade the edifice was completely destroyed. The explosion was due to the pipe being choked with ice.

FATALITY FROM AN ELECTRIC COAL CUTTER.

AN enquiry was held at the Hamilton Sheriff Court, on January 24th, into the circumstances attending the death of a miner who was killed in a colliery belonging to the Summerlee Iron and Coal Company, on December 21st last. The Home Office was represented by Mr. Robert McLaren and Mr. A. H. Steele, H.M. Inspectors of Mines.

In the course of the enquiry, the colliery fireman said that on the night of the accident he was in the humph coal seam of the colliery, and was assisting the deceased and some others to shift the position of a bar coal-cutting machine. This was being done by means of a bogie. When the machine had reached the place where it was intended to be located, it was partly lifted off the bogie. The current was then immediately switched on, the idea being that the machine by its own force would get entirely clear of the bogie and land on the pavement, as was desired. At this particular part of the workings, water was constantly dropping from the roof on to the machine, and when the latter was made entirely free from the bogie it completely "loaded up." All the men felt two distinct shocks—the second being worse than the first—and deceased was instantly killed. The witness stated that water was falling from the roof on to the plug of the machine. The plug and bat of the machine were, in his opinion, tightly screwed up.

The man who operated the coal cutter, in his evidence, was of opinion that it was the water dropping on the machine which caused it to get "loaded up." Deceased was about 2ft. from the machine when he got the fatal shock; that showed that a large portion of the pavement surrounding the coal cutter had become "live" with electricity. He gave it as his opinion that the water had conducted the current from the machine to the pavement. He was positive that he screwed up the pin at the plug properly.

The electrical engineer at the colliery said he examined the coal cutter on the day following the accident, and found everything about the machine in order. As to the cause of the fatality, witness stated that the machine was standing in water. If the deceased was in a state of perspiration he would be a good subject for receiving a shock. Continuing, he said the system at Bardykes was 3-phase, 500 volts. Double-armoured cables were laid from the generator at the surface to the face. The earthing system was through armouring to the earth-plate at the surface. In ordinary circumstances any leakage occurring in any part of the machine should go back to earth. In this case it did not do so, and he could find no explanation accounting for the cause. The only defect he had found about the earth connection was that the earth-pin was somewhat bent; that prevented it from being screwed in fully. He could not admit that there was anything wrong with the plug connection, but he believed the presence of water and the fact that the earth-pin had been bent were important factors in causing the deceased's death. He admitted that the fact that there was an earth-plate on the surface was, in the present instance, no remedy.

The manager at the colliery, in the course of his evidence, said that the presence of water would have the effect of conveying the current on to the body of the machine. The pin at the plug connection was not, in his opinion, screwed in as tightly as it might have been. At the same time, there was a good local earth at the point of the accident, and it ought to have taken the current away. The earth-wire from the machine to the surface was in order, and, even supposing the plug was not sufficiently screwed up, the leakage should have been taken off.

The jury returned a verdict of accidental death.

DEVELOPMENT OF SHIPBUILDING AND MARINE ENGINEERING.*

BY JOHN KENNEDY.

I PROPOSE, in the few remarks which I have to address to you, to confine myself more especially to those branches of engineering science with which I am personally acquainted, namely, shipbuilding and marine engineering, and also to indicate the lines upon which future development may be expected. Shipbuilding is one of the oldest of the "Arts and Crafts," and may be said to partake of the nature of both. Man had no sooner attended to his more immediate bodily wants than his inventive skill was exercised as to means of floating on the waters. The earlier Egyptian drawings show boats constructed of sawn planks, propelled both by sails and oars, and later on the Greeks and Romans improved on these early Egyptian models. A further step was reached when the Norsemen constructed their Viking warships, capable of making voyages of even 2,000 and 3,000 miles. Many, including Dr. Nansen, you will remember, are of opinion that the Norsemen discovered North America long before its re-discovery in the 15th century. The hulls of these boats that have been unearthed have extremely good lines, which are rather narrower and shallower than the proportions adopted at the present day. The size of the ships continually increased, and in the middle ages, owing to the supposed requirements of marine warfare, some most cumbersome and unseaworthy types were developed. There is no doubt that the defeat of the Spanish Armada was largely due to the superior handiness and freedom from top hamper of the English vessels. It would be tedious to trace out the various steps in the evolution of the modern ocean-going steamer. Gradually the science of shipbuilding was put upon more definite lines, until to-day we have built, or are building, steamers of, in round numbers, 45,000 tons each, whose capacities, displacement, and speed can be calculated with almost mathematical accuracy.

In designing a steamer the first step is to study the requirements of the service in which she is intended to be employed, for example, for mails and passengers only, or to carry also a limited amount of cargo, or lastly, to be merely a freight carrier, designed to work at the most economical speed. To fulfil any of the above conditions there are numerous intermediate stages, and the object of the designer is so to balance the various requirements as to provide the most suitable compromise for the particular trade. Leaving out of consideration the question of ships of war, undoubtedly the most specialised of all types, and the high-class ocean-going greyhounds, the writer's experience has been mostly in connection with the better class of cargo-carrying steamers, with limited passenger accommodation. The growing tendency among these steamers has been for them to have higher speeds, and the steadily increasing competition between the different lines forces the shipowners to build larger vessels to meet the reduction in freights. The requirements of the merchant are legion. A vessel may be designed to have a small consumption of fuel per ton-mile, but such a vessel may be quite unsuitable for certain purposes. For example, the trade may be confined chiefly to perishable cargoes, in which case speed is a more important factor than the saving of a small quantity of fuel. Again, the general internal arrangements of a ship which is built for one trade are unsuitable for, and different from, those for another. In short journeys between small harbours, ships are constructed to leave port and arrive at their destination at the respective times of high water in each place.

Steamers now are generally built in accordance with the rules of one of the Classification Societies (Lloyd's Register having by far the largest number built to their requirements) and are subject to periodical surveys, to ensure that the ships are maintained in a sound and seaworthy condition. Other Classification Societies, both in this and in foreign countries, have also done good work in advancing the safety of life and property at sea, and a healthy rivalry has sprung up which is of benefit to all. The total tonnage of the world's shipping, as recorded by Lloyd's Register, is 43,147,154 tons, of which 38,781,572 tons gross is steam, and 4,365,582 tons net is sail. The number of vessels is 30,087, of which 22,473 are steam and 7,614 sail. The writer appends a table showing the growth in the size of vessels for the last 50 years, the ships named being the largest in existence during the various periods. The "Great Eastern" was long before her time, and consequently what was really the second largest vessel in each period has been given in the list down to 1900, for it was not till 1901 that a vessel larger than the "Great Eastern" was built.

Table showing names and tonnage of the largest steamers in existence in each year since 1858:—

Years.	Name.	Tons gross.
1858	"Great Eastern"	18,915
1862 to 1873	"Scotia"	3,871
1874 to 1880	"Germanic"	5,008
	"Britannic"	5,004
1881 to 1888	"City of Rome"	8,144
1889 to 1891	"City of New York"	10,499
	"City of Paris"	10,499
1892	"Campania"	12,950
1893 to 1896	"Lucania"	12,952
1897 to 1898	"Kaiser Wilhelm der Grosse"	14,349
1899 to 1900	"Oceanic"	17,274
1901	"Celtic"	20,904
1902	"Cedric"	21,035
1903 to 1904	"Baltic"	23,876
1905	"Kaiserin Auguste Victoria"	24,581
1906 to 1910	"Mauretania"	31,938
1911	"Olympic"	45,324

In a scientific sense, the hull of a ship can be compared to a beam, which in still water is supported in two places, viz., at the water-borne sections; but at sea, in weather that frequently varies, high waves are met with, which deeply immerse the middle of the structure, or, on the other hand, leave it largely unsupported, and the object of the naval architect is to meet these varying conditions as economically as possible. For many years the main framing of steamers has been vertical, with longitudinal stiffeners fore and aft to connect the structure, but recently various longitudinal systems of framing have been introduced, which more nearly meet the conditions of the problem, and consequently enable the weight to be reduced. From Lloyd's annual report we see that 38 vessels of 175,299 tons have been built on the Isherwood system of longitudinal framing to Lloyd's Classification, while 34 others of 155,000 tons are now in course of construction. There has lately also been an unusually large demand for steamers intended to carry oil in bulk, which may be explained by the enormously increased use of all kinds of oil engines.

It is unnecessary before a meeting of professional men to enlarge on the luxurious appointments and conveniences of the modern ocean liner, but an idea, tried some 30 years ago in this country, has recently been revived by Mr. Frahm, of Blohm & Voss, to counteract the rolling of ships, and consequent ill-effects on passengers, and damage to cargo. Some seven vessels fitted with the Frahm anti-rolling tank are already in service, which with those now building will make a total of 280,000 tons. The principle of this ingenious device is the time-worn law of the swing of the pendulum under which the period is constant for any given length of arm. Bodies that can oscillate about an axis of equilibrium swing strongly when repeatedly acted upon by comparatively small impulses if the period of the impulses is synchronous with that of the oscillating body. For instance, soldiers in military formation when crossing a suspension bridge or other light structure are ordered to "break step," in case the period of their step should coincide with the period of oscillation of the bridge.

Now every ship, by reason of her lines, her metacentric height, or other features, permanent, or temporary when due to any particular loading, has a definite and natural period of oscillation or roll; and on the principle of setting a thief to catch a thief, the Frahm anti-rolling tank has been introduced. It utilises a secondary and artificial resonance in order to minimise the influence of the primary resonance between the wake and the ship. The secondary resonance is introduced by a U-shaped tank, in which the water columns can oscillate the same number of times per minute as the ship rolls per minute. As the phases of the impulses of the waves and ship, and ship and tank, lag by 90°, there results a total difference of (90° + 90°, equal to)

* Presidential address delivered before the Society of Engineers, February [illegible], 1912.

180° between the waves and tank; thus the water will act in exactly the contrary direction, and greatly minimises the effect of the waves. With such a device on board to scare away the bête-noir of ocean travellers sea sickness a shipowner should in the future be sure of a full passenger list.

Largely owing to the experiments of Froude at Devonport, and of various builders on the Clyde, the correct form of vessel for a certain speed can be ascertained with great accuracy, the power required being deduced from the performance of the model by certain well-known laws. The most recently constructed tank in this country is that at the National Physical Laboratory, the building of which was due to the public spirit of Mr. A. F. Yarrow, M.Inst.C.E., Hon.F.S.E., who gave £20,000 for the purpose. The Yarrow tank is 500ft. long, 13ft. deep, and 30ft. wide, and is the second longest, and the first as regards cross-sectional area, of those constructed.

The enormous increase in the size of steamers has compelled the various port authorities to make still larger docks, with deeper and wider entrances and approaches. One need only mention the names of certain ports in our own country, viz., London, Dover, Southampton, Bristol, Fishguard, Liverpool, Barrow, the Clyde, Rosyth, the Tyne, Grimsby, Immingham, &c., to bring to mind what is being done. The upkeep of these channels and harbours in most cases requires continuous dredging, and where protection against the sea has been provided by walls and piers, Nature has often resented interference with her old boundaries. In addition, large dry docks and floating docks are required for the upkeep of the hulls of these vessels.

In addressing a meeting of engineers, one's thoughts naturally turn to the engineering problems involved in the propulsion of modern vessels. As far back as the writer can remember the favourite engine was the old-fashioned side-lever engine, working at 10 to 15 revs. per minute, with a steam pressure of about 7lbs. per square inch above the atmosphere, driving paddle wheels with fixed floats. The first of the Cunarders was built in 1839. It was about 200ft. long and had a speed of about 8 knots. The last of this company's paddle steamers was the "Scotia," afterwards converted to a screw steamer, and employed in cable laying.

The introduction of the screw propeller, and the consequent demand for a higher number of revolutions, led to a steady increase in the boiler pressure, and established the superiority of the direct-acting inverted type of engine, which holds its own up to the present day. In the meantime, the manufacture of steel has passed from the rule-of-thumb stage, and improved material, together with superior workshop appliances, have made possible the design of boilers for pressures even greater than can be used by the engines, and so the original high-pressure engine has been compounded, tripled, and even quadrupled. Among the earliest of the inverted compound engines were those of the "Murillo" and "Velasquez," built in 1861 by John Elder, of Glasgow. These steamers were fitted with Percy Williamson's water-tube boiler. The writer was, for a considerable time, engineer of the "Velasquez," soon after she came out. The water-tube boilers, owing to being surrounded by large masses of brickwork, were, unfortunately, failures, and had to be removed at the end of the first voyage, and were replaced by the Scotch type of double-ended boiler.

During the long period in which the inverted cylinder engine has been in the field, many modifications in the various parts have been tried, but on the principle of the survival of the fittest, a standard type with unimportant variations has been evolved. The surface condenser was introduced about the middle of the last century, and this important addition allowed the steam pressures to be steadily increased, till to-day pressures of 200lbs. per square inch are common. During recent years, the design of condensers has again been much to the fore; and to meet the requirements of steam-turbine practice, the condenser is fitted with an addition known as the vacuum augmenter.

The steam turbine at present holds the field for high-speed vessels, but has so far been practically confined to fast passenger vessels and to warships. It depends essentially for its efficiency on a high number of revolutions, and high vacuum. In the case of the "Vespasian" running at moderate speed, the turbine has been geared down to permit of a suitable propeller being fitted. It is now possible to get gearing with an efficiency of 98 per cent., so that while the frictional loss is practically nil, the propeller efficiency is largely increased.

Among several of the large steamers belonging to different lines, a combination of a vertical inverted triple or quadruple expansion engine with a low-pressure turbine has given very satisfactory results. The two systems are each at their best, the engine taking steam at a high pressure, while the turbine makes use of the low pressure and high vacuum.

The steam engine, being a heat engine, depends for its maximum possible efficiency on the range of temperature available, and the obvious method is to increase the initial temperature of the working fluid. Practical considerations limit the boiler pressure, so in recent years renewed attention has been given to superheating the steam. Particularly has this been the case on the Continent, where the Schmidt system has been largely in use for locomotive and marine purposes.

In the beginning of 1910 the writer recommended his firm to adopt this system in one of their steamers, the "Luque," and the consequent economy has been rather surprising. The consumption of coal, as compared with her own previous performances, has been reduced by about 20 per cent. over a period of 12 months. During this time she has steamed 31,090 miles on a coal consumption of 2,065 tons, while her sister-ship using saturated steam made a distance of 29,697 miles on a consumption of 2,937 tons. In this case the writer was fortunate in having a man to start this new departure who, as chief engineer, took a very warm personal interest in its success. It may be of interest to give a few particulars taken on a voyage. The boiler pressure was 175lbs. per square inch, the temperature of the steam averaging 590° Fah., the temperature of the funnel gases was 480° Fah. at about one-third the height of the funnel above its base, the temperature of the feed water was 150° Fah., while the indicated horse-power was 680; these figures being the averages during the voyage. The advantage to the shipowner is increased beyond the monetary value of the coal saved, owing to the extra cargo that can be carried in its place. Encouraged by the foregoing excellent performances, the owners have fitted four more of their steamers with superheaters, and although the time is rather early to speak definitely there is every reason to expect similarly gratifying results.

The internal-combustion engine has in recent times been largely developed, and, as instanced in the case of the aeroplane motor, large powers are obtained from an engine of very small weight. In the oil engine type, using light or heavy oils, the fuel is fed direct to the engine, while in the gas engine type, some form of producer is necessary. The saving of weight in the former case is a great consideration for marine purposes, while, on the other hand, recent developments in the latter type have rendered possible the utilisation of the more common fuel, namely, bituminous coal.

The absolute requirements of a marine engine are that the engine shall be completely under control at any time and under any conditions; that is to say, that it can be instantly started, stopped, or reversed, and that the speed may be varied to any required extent between full speed ahead and full speed astern. While these conditions have, no doubt, been sufficiently met for the very small engines, as found in canal boats, fishing boats and the like, it cannot yet be said that a satisfactory solution has been found in the case of the larger types. The success of the oil engine for fishing boats is assured, for an ordinary first-class sailing boat can be supplied and fitted with an oil engine for little more than half the cost of a steam drifter. The speed obtained is very little less, while there is great economy in fuel consumption, as the oil engine only uses fuel when driving, while the steam drifter must lie under banked fires to be ready for action when required. A very strong company has been formed to apply this principle to the propulsion of barges on canals. The consumption of oil, ranging from petrol to the residuary oils, for power purposes must be enormous, and although new fields are being opened up, it is as yet uncertain whether there is sufficient available to supply the motive power for our mercantile marine, and for the many other uses developed in modern practice. Oil fuel is also largely used in our own and other navies, in the furnaces of steam-driven craft, but so far has not been extensively used in the mercantile marine, possibly owing to the difficulties of supply.

The advantages claimed by the advocates of the oil engine for marine work are: (1) Less space occupied. (2) No "stand-

by" losses. (3) Engine-room staff largely reduced. (4) Less weight of fuel carried and less weight of machinery, consequently more cargo capacity. (5) Elimination of a large number of auxiliaries required for the steam engine.

Among other systems might be mentioned the electric transmission of power from a generating station amidships to a motor aft, driving the propeller. The objection for moderate speeds has been that the weight of the motor would be considerable owing to the low number of revolutions required when direct coupled, but this might be overcome by gearing down.

Valuable research work in progress also points to a much better understanding of the correct dimensions and form of the high-speed propeller. The prime movers in this case can of course be steam or internal-combustion engines, and as the power required can be divided in any required number of units, it can be arranged that only the sets necessary for any speed are in use and working at their most efficient load. This would appear to be a valuable quality in war vessels when cruising.

It is impossible to close these remarks without reference to the Diesel oil engine, now so much in evidence as a serious rival of existing methods of propulsion. The higher the compression in the internal-combustion engine, the greater is the efficiency, but with the ordinary Otto cycle the danger of pre-ignition limits the range of compression. In the Diesel engine, the air alone is compressed and the oil fuel is sprayed directly into the cylinder at the commencement of the working stroke, and the supply continued for some time during the stroke. The compression of the air has, of course, raised its temperature, and this is carried to such a point that the temperature is sufficient to ignite the sprayed oil, which with the air forms an explosive mixture. This compression is to about 500lbs. per square inch. An air compressor worked off the engine itself is used for starting purposes, and the speed of the engine is governed by reducing or increasing the supply of fuel. The Diesel is probably the most economical engine at present known, the consumption of oil being about ½lb. per brake horse-power hour, a further advantage being its capacity to make use of the cheap residuary oils. This engine is, in common with other engines, subject to the difficulties of reversing, which is accomplished in the smaller types by mechanical gearing, although the writer understands that recent improvements are likely to overcome this difficulty. The "Vulcanno," a vessel of over 1,000 tons register, fitted with Diesel engines of the 4-stroke cycle, has already made several voyages with good results as to economy and reliability. There are at the present time building, or projected, about a dozen vessels to be fitted with oil engines, mostly of the Diesel type. These are vessels of considerable size, ranging up to as much as 8,000 tons gross register (it is also reported that a 14,000-ton vessel is being built on the Continent), and if, as there is no reason to doubt, the results prove satisfactory, there will be a considerable reduction in the cost of sea transport.

Sealing Metals.—At a recent meeting of the Physical Society a paper on "Sealing Metals" was read by Dr. P. E. Shaw. The established method of fixing quartz fibres for accurate torsion experiments is due to Prof. C. V. Boys. It involves careful cleaning, silvering, electrolytic deposit of copper, tinning, and finally soldering. This considerable trouble can be avoided by the simple means given below, while the resulting joint is in some cases stronger. Prof. Threlfall used Margot's solder (92 per cent. Sn, 8 per cent. Zn) to fasten glass, aluminium or quartz surfaces to any other. The writer finds this material acts perfectly and is very simple, the bit being of aluminium and there being no flux. Further investigation shows that there is no special merit in Margot's formula. In place of Margot's solder the following will be found to act very well: (*a*) Tin, (*b*) zinc, (*c*) various alloys of tin and zinc, (*d*) tinman's solder, (*e*) aluminium. Lead does not stick well, though it might be made to do so if oxidation were prevented. Then there is a variety of materials with melting point ranging from 180° to 660°. For all these and like materials which act in the same manner as sealing-wax the writer suggests the term sealing-metals. They have the advantages over any wax in (*a*) high melting point, (*b*) non-emission of vapour when temperature is raised. There are obvious applications other than for tension fibres where joints to withstand temperature are required.

THE INFLUENCE OF OXYGEN ON COPPER CONTAINING ARSENIC OR ANTIMONY.*

BY R. H. GREAVES, B.SC.

WHEN oxygen is introduced into pure copper it exists in the metal as cuprous oxide, Cu_2O, which forms a eutectic with the copper containing 3·45 per cent. Cu_2O, equivalent to 0·39 per cent. of oxygen. The influence of oxygen on the properties of pure copper was first investigated by Hampe, who found that—

0·45 per cent. Cu_2O† slightly decreases the tenacity, but does not affect the ductility of pure copper;
0·90 per cent. Cu_2O causes some diminution in ductility;
2·25 per cent. Cu_2O considerably lessens the tenacity, and the presence of more renders the metal first cold and then hot-short.

According to Keller, the best pure refined electrolytic copper may contain 0·6 to 0·8 per cent. Cu_2O, while a similar metal with 2 to 3 per cent. Cu_2O may still be rolled into sheets.

All samples of commercial tough-pitch copper contain oxygen in amounts varying approximately from 0·05 to 0·15 per cent. If the metal contains much more than this, or if some is removed, as in overpoled copper, its strength, ductility, and malleability are impaired. The effect of oxygen on tough-pitch copper has been dealt with recently by Mr. F. Johnson.‡ The study of tough-pitch copper, however, is complicated by the effect of a number of impurities, especially as little is known of the effect of oxygen on copper with any one of these taken alone. In this connection Hampe found by the addition of arsenate and antimonate of copper to the molten metal, that the former was distinctly more harmful and the latter less harmful than its reduction product. Thus the presence of 0·55 per cent. of arsenic in the form of arsenate was found to induce cold-shortness, while 0·5 per cent. of antimony in the form of antimonate showed no tendency to cold or hot shortness. The influence of oxygen in relation to the failure of arsenical copper has been discussed by Messrs. Bengough and Hill.§

The work described in this paper was begun in conjunction with Mr. A. H. Hiorns, as a continuation of that of Hiorns and Lamb,‖ on the effect of arsenic and antimony on copper.

PREPARATION OF THE MATERIAL.

The alloys used were prepared synthetically from pure electrolytic copper. Oxygen was introduced as cupric oxide, obtained by the ignition of recrystallised copper nitrate; arsenic or antimony was added in the form of a rich alloy with copper. In preparing the alloy of high arsenic content, copper was melted in a fireclay crucible, and metallic arsenic added. After stirring the metal was poured into a warm mould, allowed to cool slowly, and when cold was powdered in a large iron mortar. Any particles of iron which it contained were removed by means of a magnet: the powder was then carefully mixed and sampled for analysis. The antimony alloy was prepared in a similar way. These rich alloys contained

	Per cent.		Per cent.
(*a*) Copper	.. 67·0	(*b*) Copper	.. 32·84
Arsenic	.. 32·68	Antimony	.. 67·11

On account of the volatilisation of the oxides of arsenic and antimony, and the uncertain oxidising or reducing atmosphere in contact with the metal, it was difficult to obtain the definite compositions intended. Finally the method adopted was to melt about half a pound of copper under lump charcoal in a clay crucible. The charcoal was then skimmed off, the copper stirred with a charred stick, and a weighed quantity of cupric oxide tipped in. This rapidly dissolved, and after a few seconds the rich alloy was added, the metal stirred rapidly with an arc-lamp carbon, left in the furnace until dead melted, and then poured into an open mould.

Methods of Analysis.—Arsenic and antimony were determined by distillation, the former from an acid ferric chloride

* Abstract of paper read before the Institute of Metals, January, 1912.

† Cu_2O contains slightly over one-ninth of its weight of oxygen.

‡ "Metallurgical and Chemical Engineering," 1910, p. 574; 1911, p. 397; "Journal of the Institute of Metals," No. 2, 1910, pp. 163-173.

§ "Journal of the Institute of Metals," No. 1, 1910, Vol. III., pp. 47-52, and discussion.

‖ "Journal of the Society of Chemical Industry," 1909, Vol. XXVIII., pp. 451-45[illegible]

solution, the latter from a solution of zinc and copper chlorides as described by Gibb.* The distillates after neutralising were titrated in the presence of sodium bicarbonate, with a standard solution of iodine.

TABLE I.—*Copper with Oxygen and Arsenic.*

No.	Composition.		Relative Hardness.	Cold-rolling Test.	Wire-drawing Test.
	Oxygen per Cent.	Arsenic per Cent.			
A 1	0·05	0·05	8·3	β	—
2	0·07	0·08	7·7	β	—
3	0·08	0·19	8·4	α+	—
4	0·08	0·29	8·8	α	—
5	0·08	0·35	9·5	β+	—
6	0·09	0·19	8·5	α	—
7	0·10	0·12	8·4	β −	—
B 1	0·10	0·49	8·5	β	β+
2	0·16	0·22	8·9	α	α
3	0·17	0·40	9·2	α	α
4	0·29	0·04	10·9	β	γ
5	0·30	0·06	10·4	β	γ
6	0·31	0·03	10·5	δ	δ
7	0·33	0·33	8·8	β+	γ
8	0·33	0·43	8·6	β	β
9	0·35	0·19	9·5	α	γ
10	0·36	0·51	9·5	β+	γ
11	0·60	0·24	11·9	δ	δ
12	0·62	0·03	12·8	δ	δ
C 1	0·26	0·05	9·3	β—	α
2	0·42	0·43	11·5	β	β —
3	0·43	0·23	11·2	β	γ
4	0·48	0·41	12·3	γ	γ

TABLE II.—*Copper with Oxygen and Antimony.*

No.	Composition.		Relative Hardness.	Cold-rolling Test.	Wire-drawing Test.
	Oxygen per Cent.	Antimony per Cent.			
A 1	0·21	0·28	7·7	β	β
2	0·24	0·23	8·1	α	γ
3	0·27	0·14	9·3	α	α
4	0·30	0·38	8·6	β	β
5	0·32	0·04	9·3	δ	γ+
6	0·32	0·18	8·9	β	β
7	0·34	0·22	9·8	γ	γ
8	0·41	0·10	11·5	γ	γ+
9	0·46	0·27	10·0	δ	δ
B 1	0·08	0·14	7·4	β	β
2	0·10	0·41	7·8	α	α
3	0·14	0·24	7·4	α	α

Appearance of the Ingots.—The ingots in general showed a longitudinal depression on the surface, but in some cases were flat. With one exception all the flat ingots of the arsenical series contained from 0·05 to 0·10 per cent. of oxygen, with from 0·08 to 0·30 per cent. of arsenic. Alloys whose content of oxygen or arsenic (or both) exceeded these limits showed a depression. Of the series containing antimony, only one ingot showed a flat surface, namely B 1, containing 0·08 per cent. oxygen and 0·14 per cent. antimony. The depression was very slight in B 2 and 3.

INFLUENCE OF OXYGEN ON THE MECHANICAL CHARACTERISTICS.

Rolling Tests.—From the large ingots, pieces having the approximate dimensions 2·5in. by 0·6in. by 0·35in. were cut for rolling. These were rolled cold down to a thickness of 0·02in. with the necessary annealings, which were carried out by heating rapidly on a clear coke fire to dull redness and allowing to cool in air. This treatment had no effect on the chemical composition. All the alloys of one series were passed through the rolls in succession and received precisely the same treatment. Even those of different series should yield comparable results, for the conditions of the tests were made as nearly as possible the same. Judged by behaviour in the rolling test, the metals stand in the following order:—

Arsenic:—

Series A: 3, 4, 6 (all rolled very well), 5, 1, 2, 7 (serrations extended two millimetres inwards).

Series B: 3, 2, 9 (very good), 7, 10, 8, 1, 4, 5 (very slight cracks), 11, 6, 12 (badly cracked).

Series C: 2 (incipient cracks), 3, 1, 4.

Antimony:—

Series A: 3, 2 (good), 1, 6, 4, 7, 8, 5, 9 (badly cracked).

Series B: 3, 2 (very good), 1 (slightly cracked).

It is unfortunately impossible to make a quantitative representation of behaviour under the rolling test, but in order to present the results concisely a definite mark has been assigned to each alloy. Thus—

α signifies that the alloy rolled well, and remained perfectly sound at the edges.

β signifies that the alloy rolled well, but showed slight cracks or serrations at the edges.

γ signifies alloys inferior to these, surface cracks also being developed.

δ signifies that the alloy cracked badly.

The results of the test are given in Tables I. and II. To these may be added the following results of a similar test by Hiorns and Lamb*:—

Copper-Arsenic Alloys.

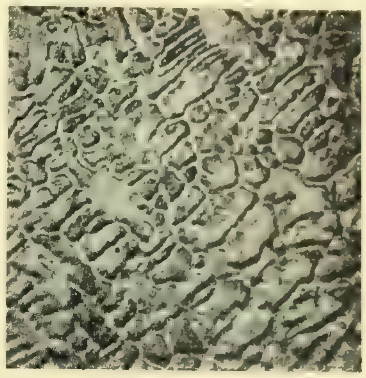
0·0 to 0·2 per cent. arsenic "slightly frayed at the edges."

0·2 to 0·5 per cent. arsenic, edges perfect.

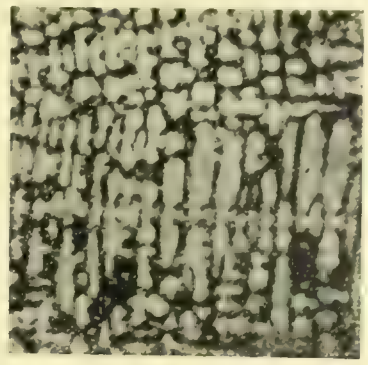
Copper-Antimony Alloys.

0·0 to 0·6 per cent. antimony. "The alloys all showed faint cracks along a plane at right angles to the rolls. The cracks increased as the percentage of antimony increased."

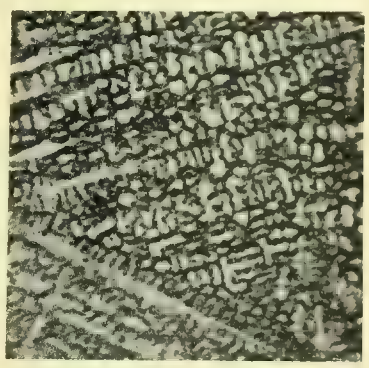
As the amount of arsenic increases up to 0·5 per cent. the metal may take up more and more oxygen without suffering



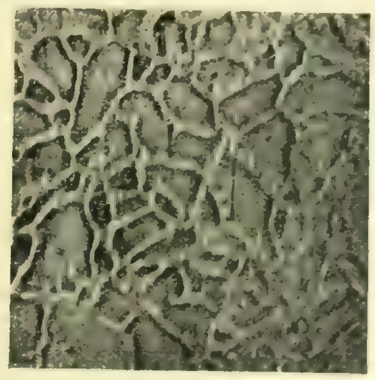
No. 1.
Copper containing 0·10% oxygen and 0·49% arsenic, as cast.
Magnified 70 diameters.



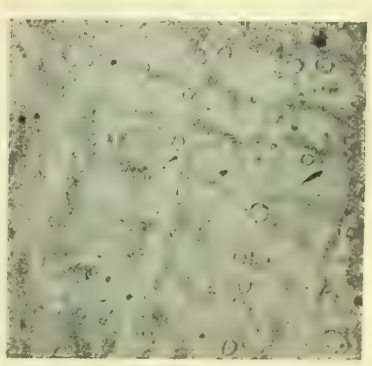
No. 2.
Copper containing 0·31% oxygen and 0·03% arsenic, as cast.
Magnified 70 diameters.



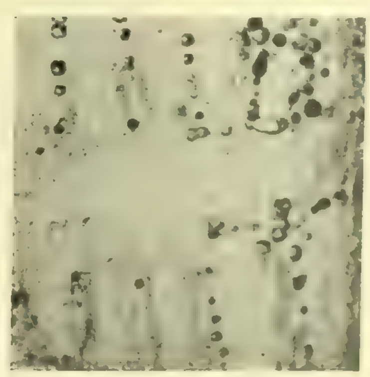
No. 3.
Copper containing 0·33% oxygen and 0·43% arsenic, as cast.
Magnified 70 diameters.



No. 4.
Copper containing 0·10% oxygen and 0·41% antimony, as cast.
Magnified 70 diameters.



No. 5.
Copper containing 0·10% oxygen and 0·49% arsenic, as cast.
(Same as No. 1).
Magnified 300 diameters.



No. 6.
Copper containing 0·14% oxygen and 0·24% antimony, as cast.
Magnified 300 diameters.

* "Journal of the Society of Chemical Industry," 1901, Vol. XX, pp. 184-187.

* "Journal of the Society of Chemical Industry," 1909, Vol. XXVIII, pp. 453 and 454.

deterioration in its capacity for rolling. This quantity of oxygen rises from about 0·05 per cent. to 0·2 per cent. as the arsenic increases from 0 to 0·2 per cent., then more slowly to about 0·28 per cent. as the arsenic increases to 0·5 per cent. Thus with constant arsenic, addition of oxygen causes no marked difference to the malleability until a certain limit (depending on the arsenic present) is reached; above this point the malleability falls off, and with still more oxygen there is a rapid deterioration of the metal, which becomes cold-short. If arsenic is increased while the oxygen is kept constant, any tendency to cold-shortness is diminished, and if less than 0·3 per cent. of oxygen is present, a metal which will roll perfectly is obtained before the arsenic reaches 0·5 per cent.

In a similar way, antimony up to 0·4 per cent. reduces the cold-shortness of pure "dry" copper. The first action of oxygen on copper containing a constant amount of antimony, however, appears to be to effect an improvement in the metal, as the cracks mentioned by Hiorns and Lamb in their copper-antimony alloys were not found in the metals B 2 and 3 (containing about 0·1 per cent. of oxygen), which rolled perfectly. Further increase in the oxygen causes a reduction in malleability.

Wire-drawing Tests.—A portion of each ingot was rolled down to 0·15in. and slit for wire-drawing, which was carried out first on a small draw-bench and afterwards by hand. The results are expressed in Tables I. and II. Alloys marked α and β may be drawn into wire, β — denoting a somewhat rough wire. Those marked γ broke before the 50-hole (diameter 0·03in.) even with frequent annealing, though a short length of wire was obtained in one or two cases (marked +). Those marked δ would not pass hole 20 (diameter 0·10in.) It will be noticed that in the presence of arsenic the compositions of the metals which may be drawn into wire are more restricted than for rolling, though in both cases the areas representing their compositions are similar in form.

Tensile Tests.—A number of samples of the cast metals containing arsenic were normalised by heating to about 550° C. in air in a glass tube for ¾ hour, and allowing to cool slowly. The pieces were then planed down to a section of about 0·3in. square, and broken in a sensitive wire-testing machine. The results are given in Table III.

TABLE III.

No.	Composition.		Tensile Strength. Tons per Square Inch.			Elongation, per Cent. on 2 Inches.		
	Oxygen Per Cent.	Arsenic Per Cent.	(1)	(2)	Mean.	(1)	(2)	Mean.
B 3	0·17	0·40	11·6	12·3	12·0	28·8	30·0	29·4
C 1	0·26	0·05	9·4	9·4	9·4	14·7	12·0	13·3
B 12	0·62	0·03	..	7·9	7·9	..	2·5	2·5
6	0·31	0·03	7·4	9·1	8·2	5·1	5·1	5·1
4	0·29	0·04	9·8	9·9	9·8	10·0	7·5	8·8
5	0·30	0·06	10·5	10·7	10·6	8·0	9·8	8·9
9	0·35	0·19	9·2	9·3	9·3	11·3	9·8	10·5
7	0·33	0·33	10·7	10·5	10·6	9·6	12.1	10·9
C 3	0·43	0·23	12·4	12·6	12·5	8·2	8·8	18·5
2	0·42	0·13	13·8	13·1	13·5	11·5	10·2	10·9

TABLE IV.

No.	Composition, Per Cent.		Tensile Strength Tons per Square Inch.		Elongation, per Cent. on 2 inches.		Fracture.
	Oxygen	Antimony		Mean.		Mean.	
1	0·05	0·35	11·09 / 11·42	11·25	22·5 / 17·5	20·0	Crystalline: a few small blowholes. Yellowish.
2	0·15	0·38	9·81 / 9·51	9·66	14·0 / 13·3	13·6	Fine radiating fibres. Slightly reddish.
3	0·18	0·48	12·63 / 12·12	12·37	18·5 / 19·0	18·8	Very finely crystalline to finely fibrous. Slightly reddish.
4	0·31	0·40	10·73	10·73	5·0	5·0	Finely crystalline Brick red.
5	0·03	0·51	11·63 / 11·28	11·45	29·5 / 27·0	28·2	Crystalline to silky; a few small holes. Yellowish.
6	0·18	0·33	10·50	10·50	8·5	8·5	Radiating fibres. Slightly reddish.

A further set of alloys was made, and cast in the form of 1in. diam. bars, about 10in. long, in a chill mould standing on sand. Each metal was cast, as nearly as could be judged, at the same temperature. The appearance of the fractures of Nos. 2 and 6 seemed to indicate that the casting temperatures were in these cases slightly higher. The bars were machined down to 0·564in. diam., with 2¼in. parallel. Analyses were made on the last turnings from the test piece. The tests were carried out in the engineering laboratory of this College by kind permission of Prof. Elliott. The results are given in Table IV.

From the results given in Table III., it appears that for metals in the cast state, containing a constant quantity of oxygen, there is a slight rise in the tensile strength and more marked improvement in the elongation as the arsenic increases. This is seen, for example, in B 6, 4, 5, 9, 7; C 3 2.

With a constant percentage of arsenic there is very little change in the tensile strength as the oxygen increases from 0·17 per cent. to about 0·4 per cent., but the elongation falls off rapidly. This is evident by comparison of B 3, C 2; C 1, B 4, 5, 6, 12; and is borne out by Nos. 5 and 6, Table IV. The same generalisation applies to metal containing antimony (Table IV.). Increase of oxygen shows no definite effect on the tensile strength, but causes a marked decrease in elongation.

INFLUENCE OF OXYGEN ON THE PHYSICAL PROPERTIES.

Hardness.—The relative hardness of the cast ingots was taken by means of the Shore scleroscope, using the intensifier hammer. The author has pointed out that the physical property really measured by this instrument appears to be the coefficient of restitution between the hammer and the material to be tested. Under certain conditions (generally fulfilled by metals in the cast or annealed state) this quantity is proportional to the hardness as measured by the scratch test. The values of the relative hardness of the alloys examined are given in Tables I. and II. To these may be added:—

Copper with Oxygen.		Copper with Arsenic.*		Copper with Antimony.*	
Oxygen per Cent.	Relative Hardness.	Arsenic per Cent.	Relative Hardness.	Antimony per Cent.	Relative Hardness.
0·04	7·5	0·05	8·0	1·0	8
0·32	11·5	0·40	9·0	..	..
..	..	1·50	10·0	..	..

The addition of arsenic or antimony to pure copper hardens it; the effect of either on copper containing oxygen is first to diminish and then increase its hardness. The addition of oxygen to arsenical copper is without any marked influence on the hardness until it reaches a limit depending on the percentage of arsenic, when the hardness rapidly increases. Thus copper, with 0·4 per cent. arsenic and 0·3 per cent. oxygen, is quite as soft as, if not a little softer than a similar metal free from oxygen. The limit of the percentage of oxygen which does not noticeably affect the hardness rises to about 0·35 per cent. as the arsenic increases to 0·5 per cent. In a similar way antimony first diminishes and afterwards increases the hardness of copper containing oxygen, while quite a low percentage of oxygen begins to harden copper containing antimony.

The hardness found after rolling down to about 0·15in. was unreasonably high (30 to 40) on the scleroscope scale, but the values given after annealing agreed almost identically with those for the cast metal.

Conductivity for Electricity.—For purposes of comparison it is necessary to know the conductivity of copper containing only arsenic or antimony without oxygen. The most complete series of determinations within the limits of composition required is that of Hiorns and Lamb.† Their results for arsenic are in agreement with those of other observers, but for antimony they are somewhat irregular, moreover different workers have obtained divergent results. With regard to the effect of oxygen, Addicks concludes that the conductivity of pure copper is slightly increased by the presence of 0·05 per

* Hiorns and Lamb, "Journal of the Society of Chemical Industry," 1909, Vol. XXVIII., pp. 452 and 454.

† Hiorns and Lamb, "Journal of the Society of Chemical Industry," 1909, Vol. XXVIII., pp. 453–454.

cent. of oxygen, and returns to its original value with 0·10 per cent.

Peters,* however, finds that "while the proportion of cuprous oxide found in ordinary good refined copper does not appear to diminish its electrical conductivity (it may even increase it slightly, yet the very highest conductivity tests are yielded by copper which contains no determinable oxygen."

Hofman, Hayden, and Hallowell† state that the presence of oxygen improves the conductivity of tough-pitch copper, a maximum conductivity being obtained with 0·2 per cent. of oxygen.

Measurement of Resistance.—The resistance of a definite length of a number of wires made as described above, was measured by the Wheatstone bridge method. The diameters of the wires were afterwards obtained by weighing a measured length in air and water. Tables V. and VI. give the specific resistance of the wires in C.G.S. units (ohms × 10^{-9}). The relative conductivity is calculated from these and from Hiorns and Lamb's value for pure copper; and since all measurements were not made at the same temperature, the latter is corrected for comparison by the temperature coefficient for pure copper, viz., $R_t = R_o\,(1 + 0·00416t)$.‡ For comparison, the tables also give Hiorns' values for the relative conductivity of the oxygen-free metal of the same arsenic or antimony content.

In every case in the arsenic series it will be noticed that the conductivity is less than that of a similar metal with no oxygen. In the presence of antimony, however, the effect of oxygen is to raise the conductivity. In order to check this result the measurements were repeated on fresh wires drawn from strips of the same ingot. For the production of these the author is indebted to Mr. H. I. Coe: they are marked (*b*) in Table VI. The post-office box used had been carefully standardised. Filings from each of the wires were taken for analysis; it will be seen that very little change in composition occurred during the operation of drawing; but making allowances for the possible slight difference in composition, the conductivity of the two sets of wires shows very fair agreement. The quantitative effect of oxygen is not apparent from these results, and the author hopes to make a further series of more accurate measurements to decide this.

Influence of Oxygen on the Microstructure.

Specimens cut from the ingots were polished and etched by means of a 10 per cent. solution of ammonium persulphate. The photographs were all taken by direct light.

Micrograph 1.—Is typical of cast metal containing arsenic with a low percentage of oxygen. The boundaries of the "cores" are very distinct on account of the rapidity of cooling. A similar metal containing antimony is shown in micrograph 4.

Micrograph 2.—Copper containing oxygen with low arsenic or antimony shows dendrites of copper embedded in a ground mass of copper and cuprous oxide, not showing a eutectic structure but occurring in isolated globules.

Micrograph 3.—With more arsenic or antimony, as the oxygen increases the cores pass into a dendritic form, the boundaries become pitted, and finally approximate in appearance to the oxide boundaries in micrograph 2. Prof. Huntington has published a micrograph similar to No. 3, but with less oxygen.* The structure of the boundaries is shown better at a higher magnification. The effect of oxygen is similar in the presence of arsenic and of antimony. The first effect of oxygen is to produce a curious ringlike formation which appears in the boundaries (micrograph 5). These develop into globular masses as the oxygen rises (micrograph 6), and increase in number until they fill the arsenic or antimony-rich boundaries.

In conclusion, the author wishes to express his indebtedness to Mr. J. Cooper Trill for assistance in making the tensile tests; to Mr. A. H. Hiorns for valuable advice, and the benefit of his judgment in the malleability tests; and to Prof. A. A. Read for the interest he has taken in the progress of the work.

Table V.

No.	Composition.		Length, Centimetres.	Diameter, Centimetres.	Resistance, ohms.	Specific Resistance, C.G.S. Units.	Temperature. Degrees C.	Relative Conductivity (Cu = 100).	Relative Conductivity, Copper-Arsenic without Oxygen (Hiorns).
	Oxygen, per Cent.	Arsenic, per Cent.							
B 1	0·10	0·49	147·6	0·0820	0·1312	4690	18	35·2	42·4
C 2	0·42	0·43	97·7	0·0826	0·0775	4251	17	38·7	45·1
B 3	0·17	0·40	128·9	0·0861	0·0850	3843	18	43·0	46·8
2	0·16	0·22	170·5	0·0863	0·0926	3178	18	52·0	59·5
5	0·30	0·06	61·0	0·0860	0·0261	2485	18	66·4	77·3
C 1	0·26	0·05	168·0	0·0831	0·0672	2169	17	75·8	79·4

Table VI.

No.	Composition.		Length Centimetres.	Diameter Centimetres.	Resistance Ohms.	Specific Resistance, C.G.S. Units.	Relative Conductivity (Cu=100).		Relative Conductivity, Copper-Antimony without Oxygen (Hiorns).
	Oxygen per Cent.	Antimony per Cent.							
A 3 *a*	0·27	0·14	168·0	0·0825	0·0580	1847	89·4	88·5	80·0
A 3 *b**	0·27	0·12	139·2	0·0832	0·0482	1889	87·7		
B 1 *a*	0·08	0·14	73·7	0·0860	0·0237	1871	88·1	88·7	77·5
B 1 *b**	0·08	0·14	79·6	0·0836	0·0269	1854	89·3		
A 6 *a*	0·32	0·18	224·8	0·0830	0·0798	1919	86·1	85·8	73·0
A 6 *b**	0·30	0·18	98·3	0·0834	0·0350	1934	85·6		
B 2 *a*	0·10	0·41	260·7	0·0862	0·1173	2629	62·7	63·6	58·0
B 2 *b**	0·10	0·37	226·0	0·0837	0·1052	2564	64·6		

(*a*) Temperature 17·5° C.; (*b*) Temperature 18·6° C. * Analyses of the wires given.

* "Principles of Copper Smelting," 1907, p. 492.
† "Transactions of the American Institute of Mining Engineers," 1908, Vol. XXXVIII. p. 38.
‡ Swan and Rhodin, "Proceedings of the Royal Society," 1894, Vol. LVI. p. 81.

* "Journal of the Institute of Metals," No. 1, 1910, Vol. III. p. 84.

Engineer Electrocuted.—John Black, an electrical engineer, was killed at Hartford Pit, Northumberland, on Monday last by coming in contact with a live wire whilst inspecting the works.

Trials of a Marine Oil Engine.—Messrs. Barclay, Curle, and Co., shipbuilders and engineers, Whiteinch, who have built for foreign owners the vessel "Jutlandia," have had running for some months in their engine works at Stobcross an engine which is one unit of the machinery which they are to fit on board the vessel. This engine has recently completed a full-load, non-stop trial of 30 days' and nights' running without any hitch whatever. When opened up for examination the engine was in such a condition as would have justified the firm in starting it, without any touching up or adjustment, on another 30 days' trial. For marine purposes the test covered a longer non-stop voyage than is called for nowadays, except on a very few routes. The trial, it may be added, was run with ordinary Scotch shale fuel oil, and the average consumption was ·35 of a pound per indicated horse-power per hour.

THE JUNKERS OIL ENGINE.

BY F. E. JUNGE.

OF the various internal-combustion engines which are competing with the steam turbine for pre-eminence in the field of large-scale economic power production and ship propulsion, the Diesel engine so far has been the only one to deserve serious consideration. Of late a new type of large oil engine is attracting attention in Germany; this is a 2-stroke engine, built to the design of Prof. Junkers, of the Technische Hochschule, of Aix-la-Chapelle. A freight vessel to be equipped with this type of engine has been ordered from the Weser Company, of Bremen, by the Hamburg-American Line. The power developed by the two engines is to be 1,600 shaft horsepower. A 200 h.p. experimental engine gave the data for the construction of a 1,000 h.p. engine which is now undergoing tests at Aix-la-Chapelle. The general arrangement of the parts of this engine, which is of the horizontal tandem type, is shown in Fig. 1. Two pistons work in each of the tandem cylinders; the extreme forward and rear pistons act on the middle crank, and the two intermediate pistons act on the outside cranks, which are set at 180° from the middle crank. The connection of the pistons, which move together with each other and with the crossheads is made by transverse yokes and side rods, as will appear from the longitudinal section and the elevation and from the schematic drawing, Fig. 2.

The engine works on the 2-stroke cycle. While the pistons in one cylinder move outward on the working stroke, the pistons of the other cylinder travel inward, on the compression stroke. When the two pistons in one cylinder have reached the state of nearest approach, fuel injection commences; the two pistons in the other cylinder have then reached the position of greatest separation, and the expulsion of the expanded gases takes place, followed by an inward flow of scavenging air through ports at the other end of the cylinder from the exhaust ports. The ports are covered and uncovered by the pistons, eliminating all valves. The ends of the cylinders are open, each cylinder being the equivalent of two single-acting cylinders with their heads removed and their barrels connected at the head ends. The use of stuffing-boxes is thus avoided.

The cycle of the Junkers engine may be more clearly understood by aid of Fig. 2, in which, for the sake of simplicity, only one cylinder is shown. At the innermost position A of the pistons, the combustion space, after a preceding compression stroke, is filled with highly-compressed and correspondingly heated air; at this moment injection of fuel is begun. The fuel is forced in by compressed air, and is in a finely-divided condition; it ignites and burns under almost constant pressure during the first part of the outward stroke, from A to B on the indicator diagram. During the ensuing part of the outward stroke, the expansion of the products of combustion takes place, from B to C.

When the pistons have reached the position shown at C, corresponding to the point C on the diagram, the front piston V begins to uncover the ports in the cylinder wall through which the burnt gases escape. In the position shown at D, corresponding to D on the diagram, equalisation of the cylinder pressure with that of the atmosphere has approximately taken place. In this position the rear piston H uncovers the rear ports and admits fresh air at low pressure, which drives the rest of the spent gases out of the cylinder through the exhaust ports at the front end. This process takes place while the pistons travel to the dead-centre positions of the cranks and back to the position F, in which the pistons have closed their respective ports. At the point F, the cylinder is filled with air alone, and the compression of this begins; the inward travel of the pistons to the inner dead-centre position completes the compression, giving the curve F A of the diagram. The compressed air becomes heated to such an extent that the fuel which is injected at or shortly before point A ignites, as in the Diesel engine, whereupon the working process just described is repeated.

The air pumps and compressors (in this case 4-stage) which are necessary for the supply of the scavenging and fuel-spray air are arranged parallel to the work cylinders and their pistons are actuated from the yoke of the intermediate pair of power pistons. In large diameters each

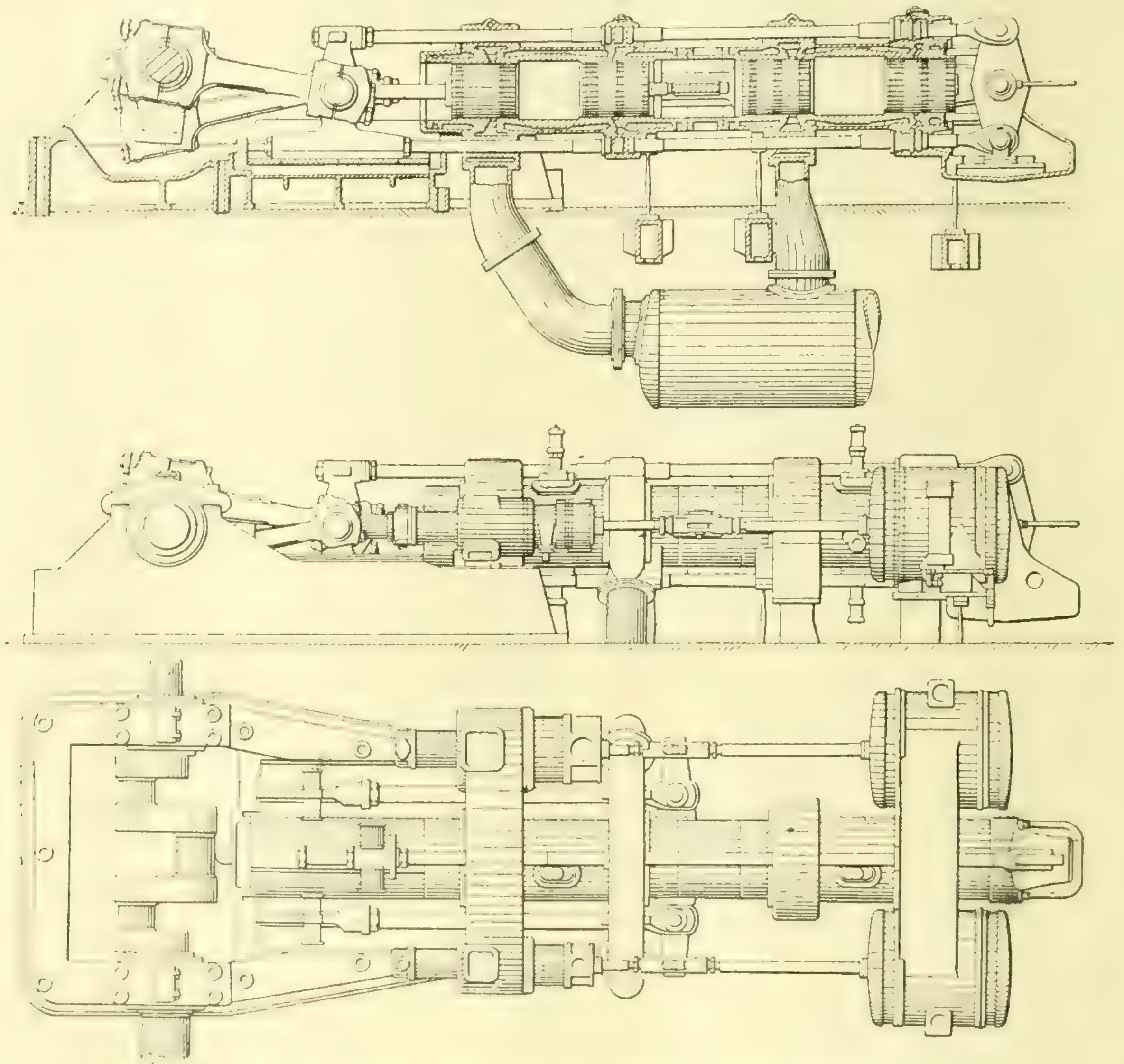


FIG. 1.—SECTIONAL, SIDE, AND PLAN VIEWS OF JUNKERS ENGINE.

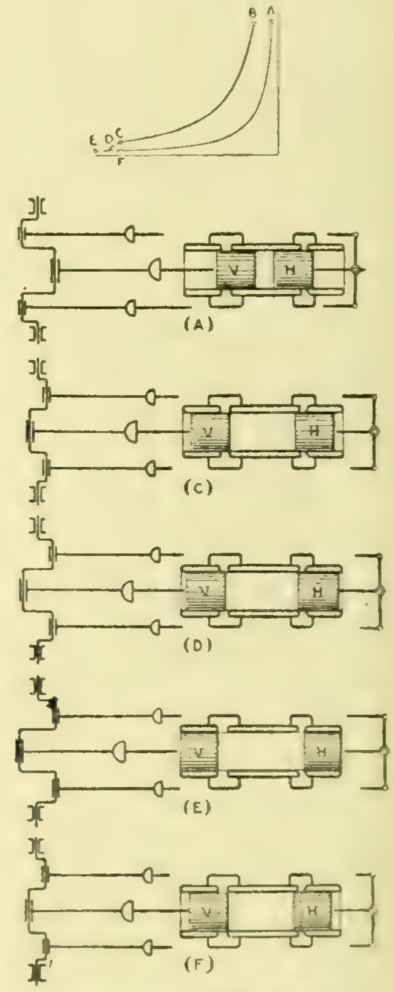


FIG. 2.—JUNKERS CYCLE.

cylinder is provided with two fuel sprays and one compressed-air starting valve. The fuel-injection nozzle is so designed as to give the fuel oil a close contact over a large surface with the combustion air.

With regard to the action of forces and the balancing of the moving parts, the Junkers engine has a decided advantage over engines of the usual type, inasmuch as the free forces are completely balanced in the centre line of the engine, neglecting the error due to the obliquity of the connecting rod; while the main bearings, due to the opposition of the forces in the driving elements, are relieved from thrust loads. Owing to the division of the total stroke between two pistons, a relatively small individual piston speed is attained at a high rate of revolution, and a high effective

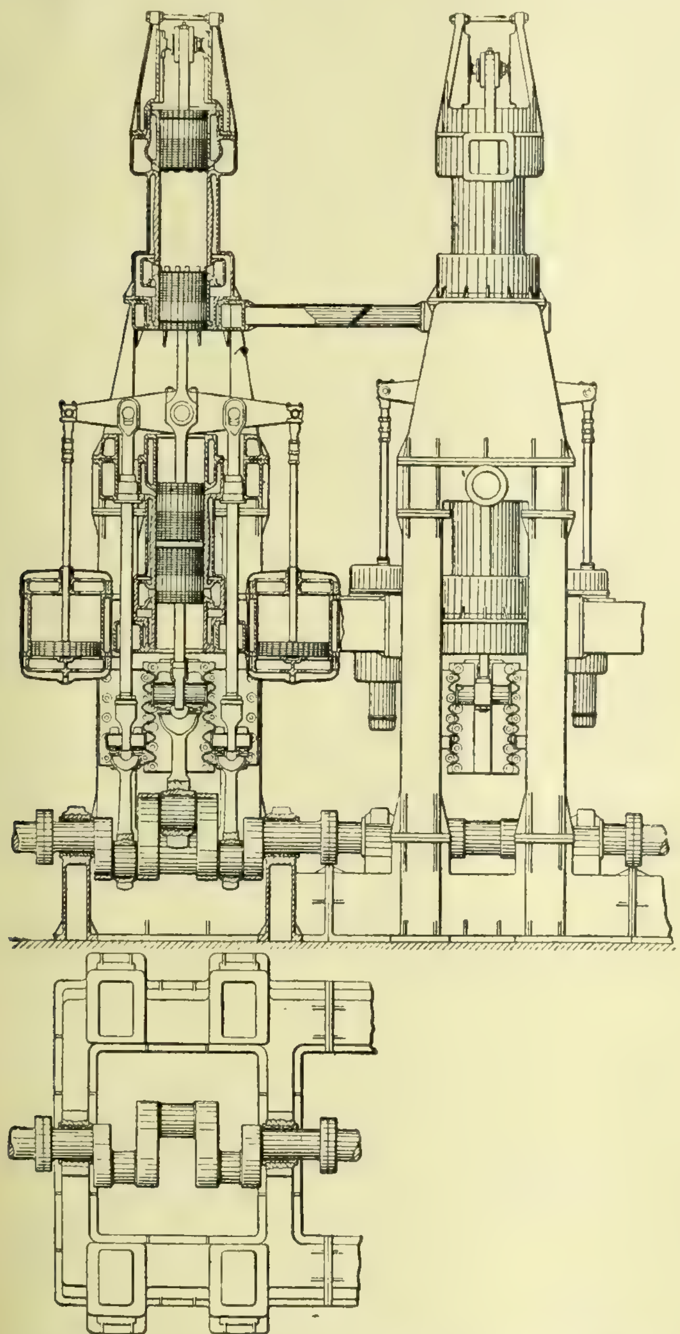


FIG. 3.—VERTICAL FORM OF JUNKERS ENGINE FOR MARINE SERVICE.

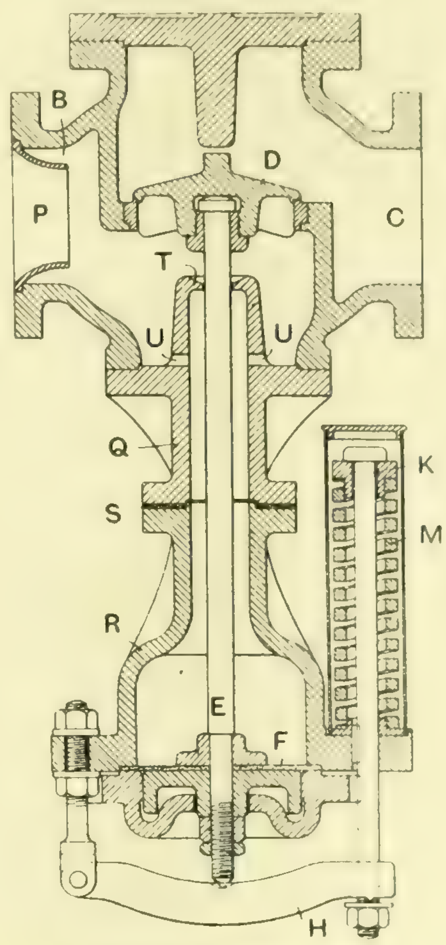
piston speed, the latter being twice the actual speed of each piston.

The general form of the Junkers engine for marine service is shown in Fig. 3. The cylinders, side rods, &c., are arranged in exactly the same relative positions as in the horizontal engine, the only important changes being in the form of the main frame supporting the crank shaft and the method of mounting the cylinders. It is this type which will be installed in the Hamburg-American freight vessel.—"Power."

Oil-burning Locomotives in the States.—According to a report recently published by the United States Geological Survey, dealing with the subject of the use of oil fuel on American railways, 21,075 miles of railways in that country were traversed by engines burning oil. The total consumption for this purpose during the year 1910 amounted to 24,526,883 barrels, while the aggregate mileage travelled by oil-burning engines amounted to 88,318,497 miles.

HOPKINSON'S REDUCING VALVE.

WE illustrate herewith a design of reducing valve which has recently been patented by J. Hopkinson & Co., Ltd., Britannia Works, Huddersfield. The valve is of the type in which there is arranged in the casing below the valve proper a flexible diaphragm connected to the valve by a rod which extends through the casing and which is controlled by a spring-actuated lever. The valve casing is formed with an inlet aperture B and an outlet aperture C of equal size. The valve D is connected by a rod E to the centre of a flexible diaphragm F, the rod E extending below the diaphragm and having its lower end resting on a spring-controlled lever H. This lever is pivoted at one end and connected at its free end to a rod K, which is coupled to the free end of a spring M. In the flange of the inlet aperture B is formed an annular groove to receive a flange on a cone P, which is curved in longitudinal section as shown. The smaller diameter of this cone is proportioned, according to the steam demand on the low-pressure side C of the valve, in such a manner that the reduction of pressure is partly produced by the cone. The spring M may consequently be set to allow the valve D to open at a lower pressure than would otherwise be necessary. The valve will thus remain open for a longer time than heretofore and will consequently not, it is claimed, be subject to such violent oscillations under a fluctuating demand as is the case with reducing valves as heretofore constructed, wherein the reduction of pressure is effected solely by the valve. The cone P is held in position by the flange of the adjacent pipe to which the valve casing is attached and thus can be readily removed and replaced by another cone of a different size when it is desired to accommodate the reducing valve to different steam demands. The tubular extension of the valve casing which carries the flexible diaphragm F is divided into two parts Q and R which are separated by a washer S of woodite or other suitable heat-insulating material, so as to prevent conduction of heat through the metal to the diaphragm F. The upper part of this extension Q reaches to a short distance below the valve D and is there provided with an inwardly-arranged flange T which serves as a guide for the upper end of the rod E. Holes U are also provided, as shown, in order to allow water of condensation to pass from the inlet end of the valve casing into the diaphragm chamber R.



HOPKINSON'S REDUCING VALVE.

American Electric Railways.—During the past year the electric railway system of the United States was increased by 1,192 miles, as compared with 1,397 miles in 1910. California led last year with 121 miles of new line, and North Carolina and Illinois followed with 104 miles each. New equipment ordered by American electric railways in 1911 comprised 4,015 cars, or 1,466 cars less than were ordered in 1910. Of the 4,015 cars ordered in 1911, 2,884 were city passenger cars, 626 urban cars, and 505 freight and miscellaneous cars. The number of electric locomotives ordered in 1911 was 81, as compared with 43 in 1910.

THE LIGHTING OF MOTOR VEHICLES.

At a meeting of the Birmingham and Midland members of the Institution of Electrical Engineers, a paper on "Dynamos for Motor Road Vehicle Lighting" was read by Mr. J. D. Morgan. During the past few years, the author said, serious attention had been directed to the development of electric-lighting systems for motor road vehicles, as it was widely recognised that something superior to the ordinary methods of oil and acetylene lighting was urgently needed. In the present paper the object was to discuss briefly the subject of current generation. By common consent the use of a battery alone for providing current was unsuitable, and a dynamo was essential. The construction of a suitable dynamo presented peculiar difficulties. The principal conditions to be complied with were: (*a*) That the dynamo must be capable of maintaining a practically constant voltage over a wide range of speed variation and under different loads, and (*b*) if voltage variations were unavoidable, the amount of variation must not seriously affect the brightness of the lamps. Regarding the first condition, it was, the author observed, usual to arrange for the dynamo to supply current at the normal voltage when the vehicle was moving at the rate of from 10 to 15 miles per hour, and to maintain the voltage constant, or as nearly constant as possible, at all superior speeds, which might reach 50 to 60 miles per hour. When the vehicle was at rest or travelling below 10 miles per hour the current was supplied entirely, or for the greater part, by a battery arranged in parallel with the dynamo circuit. Regarding the second condition, it was known that in metal filament lamps a small increase above the normal voltage was attended by a relatively large increase of brightness. Simplicity, compactness, and reliability must be obtained in a much higher degree than was essential for train lighting, where skilled supervision was constantly exercised. Much controversy centred at present in the relative merits of the mechanically and the electrically regulated machines which were capable of complying with service conditions, and this was likely to increase, not because the machines of either system were predominantly superior to those of the other, but because the advantages of each were fairly evenly balanced. It was a significant fact, however, that in spite of the enormous amount of work which has been done in the development of electrical systems of regulation for train lighting, the mechanical systems of regulation appeared to be the most extensively used.

INDUSTRIAL AND TRADE NOTES.

Large Steel Ingots. Messrs. Cammell, Laird, & Co., Ltd., are now engaged at their Grimesthorpe works on two ingots of large size. One is a steel plate, the biggest ever made, which will form the base of an armour bending or straightening press for a neighbouring firm. It weighs nearly 140 tons, and was cast from three furnaces. The firm have also on hand a 137 ton octagon ingot for a gun jacket, which is believed to be the largest ingot of that kind ever made.

Diesel Engines for Dock Purposes.—The Mersey Dock and Harbour Board have, we understand, placed an order with the Worthington Pump Company for five pumps for the new dry dock, to be driven direct by Diesel engines, each of about 1,000 b.h.p. The engines are to be supplied by the Diesel Engine Company, and will be built by Messrs. Carels Frères, of Ghent, a feature of the construction being that they will be practically of the marine type with crossheads. This plant will be the largest Diesel engine installation in this country.

Blastfurnacemen's Wages in the Midlands. Blastfurnacemen's wages in North and South Staffordshire, Shropshire, and Worcestershire were advanced on Monday last from 10 to 12½ per cent. premium upon the standard wage basis owing to the iron trade revival. The basis is 6s. 6d. per day of twelve hours for furnace keepers and three farthings to one penny per ton additional on the output at the furnaces, which is sometimes 700 to 1,000 tons per week. The men express only qualified satisfaction at the advance, and hope the premium may shortly advance to 15 per cent.

Openings for Machinery in Russia. According to a recent Austrian Consular Report, there is a tendency in the Russian engineering trades to render themselves independent of foreign machinery. Notwithstanding this, there are certain branches of engineering the requirements of which cannot yet be adequately catered for in Russia, and foreign machinery has consequently to be imported. The machines thus required include the finer types of machine tools, complex agricultural machinery, turbines, motor vehicles, and other kinds of appliances requiring more than ordinary skilled workmanship to produce.

A Large Sewage Plant Contract.—Messrs. Mather & Platt, Ltd., have just been instructed to proceed with a large contract for the Accrington and Church Outfall Sewerage Board, which comprised 24 of their pipe arm type of revolving distributors, each 62ft. diam, complete with all appurtenances, as well as a sewage pump, screening mechanism, motors to drive the machines, and also the lighting work. Messrs. Mather & Platt, Ltd., are in a favourable position to undertake such contracts, as they are makers not only of spreaders, but also of pumps, electrical machinery, &c.

Miners' Minimum Wage Demand.—The Miners' Federation Conference on the minimum wage question concluded on the 2nd inst. at Westminster. The Conference passed a resolution formulating the claims for an individual minimum wage in each district for adults working at the coal face, and resolved that each underground adult worker shall receive not less than 5s. per shift except in Somerset, the Forest of Dean, and Bristol. Questions of minimum wages for other piece workers, for men employed at day wages, and for boys were left to the districts. These resolutions will form a basis of further negotiations with the owners in the districts and at a National Joint Conference.

Dock Extensions at Liverpool.—At the meeting of the Mersey Docks and Harbour Board, held on the 1st inst., it was decided that the Engineer should proceed at once with the new works at the north end. These include the construction of a deep water approach to take vessels of 1,100ft. and two branch docks and a half-tide dock, and by means of a lock, which would be 645ft. in length, connect with the present Hornby Dock system. The cost is estimated at about £3,000,000. These north end works came before the Board in May, 1908, but owing to the depression in trade and the tightness of the money market it was thought advisable to suspend the work indefinitely. Trade having now improved, the work will be proceeded with.

Autogenous Welding and Cutting.—We have received from the Thorn & Hoddle Acetylene Company, Ltd., 151, Victoria Street, Westminster, London, their catalogue, containing particulars of some portable oxy acetylene welding and cutting plants they have recently introduced. The most important improvement connected with these machines is that it enables engineers to conveniently convey the gas-making plant and oxygen to the work, thus often effecting great economy over other portable systems, because acetylene generated in the firm's "Incanto" plants costs not more than ¾d. per cubic foot, whereas compressed acetylene in cylinders costs approximately 2d. per cubic foot.

North of England Iron Trade.—The ascertainment of the accountants of the Board of Conciliation for the Manufactured Iron and Steel Trade of the North of England of the production and net average prices secured in November and December has just been issued. The production is shown to have been 9,212 tons, and compares with 6,085 tons in the corresponding two months of 1910. The production for the whole of 1911 was 53,632 tons, compared with 41,632 tons in 1910, 34,903 tons in 1909, 40,908 tons in 1908, and 67,312 tons in 1907. The net average selling price returned is £6. 6s. 6·26d., compared with £6. 5s. 3·25d. in September and October last, and £6. 7s. 1·70d. in November and December, 1910. Ironworkers' wages, which are regulated by a sliding scale, remain unaltered.

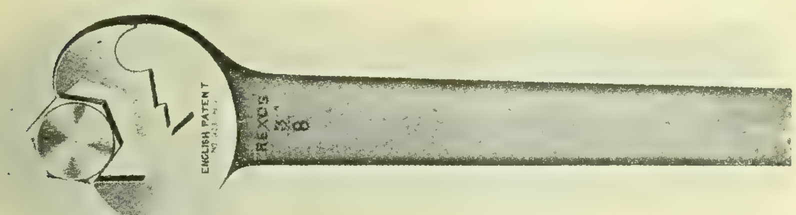
Scottish Malleable Iron Makers' Agreement.—An effort is being made by the representatives of some of the West of Scotland malleable iron makers to bring the whole of the producers in the district into line in the matter of prices, as they consider the time is opportune for a movement of this kind in view of the diminished foreign competition and the generally stronger position of the trade as well as of the advance in the price of coal. No formal meetings have yet been held, but it is understood that as the result of enquiries as to the extent of the support which the movement would probably receive, a definite announcement will be made shortly. About six firms have already agreed to advance prices to a fixed minimum selling level, which has been based on £8. 15s., less 5 per cent. per ton for "Crown" bars for prompt delivery in the district.

Iron Ore in the United States. According to the bulletin of the Geographical Survey of the United States, it is estimated from the reports sent in by twenty six of the largest iron companies controlling 80 per cent. of the American iron ore output, that the total quantity of iron ore marketed in the United States in 1911, not including stocks left at the mines, was between 43,000,000 and 45,000,000 long tons. The sales for 1910 aggregated 56,889,734 long tons, the largest ever marketed in a single year.

in the United States. According to the present estimate, the 1911 output will take fifth place, being exceeded by 1910, 1907, 1909, and 1906, in the order named. As the production of pig iron for 1911 may exceed 23,500,000 tons, a larger production of iron ore might appear to be required than has been estimated above, but there were 9,408,235 long tons of iron ore in stock at the mines in the United States at the close of 1910. Owing to the increased activity in the manufacture of pig iron towards the close of 1911, it is probable that the 1910 surplus of iron ore remained at the mines at the close of 1911.

The Yorkshire Electric Power Company.—The directors of The Yorkshire Electric Power Company, in their report to be submitted to the shareholders at the 18th half-yearly meeting of the company, to be held at the Hotel Metropole, Leeds, on Tuesday, the 20th inst., state that the gross profit on the revenue account for the three corresponding yearly periods ending 31st December is as follows: 1911, £12,572. 8s. 7d.; 1910, £11,307. 13s. 10d.; 1909, £6,087. 9s. 11d. The net profit after payment of mortgage interest for the same periods being: 1911, £7,783. 17s. 10d.; 1910, £6,503. 7s. 6d.; 1909, £2,664. 13s. 6d. The net profit of £7,783. 17s. 10d., with £9,475. 11s. 8d. brought forward from 1910, after payment of the dividend due on the cumulative preference shares up to the 31st December of that year, makes a total of £17,259. 9s. 6d. After deducting the dividend paid on the preference shares up to 30th June, 1911, a balance of £16,123. 8s. 9d. remains, and the directors propose to pay a dividend at the rate of 6 per cent. per annum on the cumulative preference shares, thus absorbing £1,746. 1s. 10d.; to write off administration and development expenses to the extent of £14,047. 1s. 4d.; and to carry forward £330. 5s. 7d. The report adds that considerable extensions have again been made to the company's system to supply new demands, and further generating plant has been ordered to meet these new demands.

The Rexos Automatic Spanner.—The accompanying illustration shows an ingenious arrangement of automatic locking spanner which is being introduced by Messrs. Frye & Co., of 46, Upper Thames Street, London, E.C. The drawback to the ordinary spanner when applied to a hexagon nut is that the difference between the radius measured over the corners and the radius measured over the flats is so little that a slight difference in the size of the spanner makes it either too small or too big, in the latter case causing it to grind off the corners of the nut, and if frequently used making the trouble of finding a right sized key more difficult still. The spanner under notice overcomes this difficulty in a very simple and effective way. Referring to the accompanying view the top half of the jaw is centred on a pin



THE REXOS AUTOMATIC SPANNER.

so that it can be easily slipped over a nut, and any tightening movement causes it to size the nut, not only over the two opposite flat sides, but also over three corners, while one leg of the L-shaped movable piece drops into a socket in the spanner head and assists the pin in resisting any force that may be applied. The spanner is one of the simplest and most effective locking spanners we have seen, while it permits of equal adaptability to nuts or bolt heads that may be a little under or a little over the nominal size. The spanner further can be used for getting a fresh grip with a small amount of rotation without removing the spanner owing to the flexibility and automatic character of the lock. The device is well worth the attention of works managers.

Grinnell Sprinklers and Fire Outbreaks.—Two further examples have recently been afforded of the remarkable efficiency of the Grinnell Sprinkler as a means of preventing serious fires. An outbreak occurred on the 10th November at the flour and provender mills of Messrs. W. Primrose & Sons, Ltd., Glasgow. The mill was equipped with an installation of Grinnell Sprinklers. In the strut house eleven of the sprinklers operated in such a manner that the fire was soon extinguished. Messrs. W. Primrose and Sons, Ltd., have written to Messrs. Mather & Platt, Ltd., stating that owing to the timely action of the sprinklers the only damage done to the strut house was that caused by water, and a few pounds damage to wood. They mention in their letter that but for the sprinklers the fire might have been serious, as that part of the mill is so inaccessible that serious damage would have been done before the fire could have been got at. On December 1st a fire occurred at the Rockliffe Mills of Messrs. A. Smart and Sons, Ltd. It originated in the cotton cleaning waste department. Messrs. Smart have written Messrs. Mather & Platt to say that the sprinklers prevented a bad fire. There was no need for the firemen to fix a hose when they arrived. These are only two of the most recent examples which go to prove how well adapted is the Grinnell system for the protection of every class of manufacturing and warehouse property. The Grinnell Sprinkler has received official recognition from fire insurance offices all over the world. So highly do insurance people esteem the sprinkler that a reduction of from 25 per cent. to 70 per cent. is allowed off the premiums on buildings equipped with it.

British Corporation Registry of Shipping. At the annual dinner of the members of the staff of the British Corporation Registry of Shipping, held on Saturday last at Glasgow, Mr. Foster King, chief surveyor, said the British Corporation Registry had just completed 21 years of active life. It was founded in 1890 with the primary object of safeguarding the interests of British shipowners by extending the administrative authority under the Load Line Act. The construction rules of the Corporation were first published in 1893 and although revolutionary in form, they were at once accepted by the technical world as a great advance, because they appealed to common sense. Starting from a standpoint which it was to be feared, regarded the existence of practice as unsatisfactory evidence of soundness, after much very hard work and sifting of fact from theory, standards of strength were laid down for the various parts of the hull, on the basis of concrete rather than abstract science. These were the society's standards to-day. It was true that as the years passed there had been changes and developments, but these had always been towards a more perfect realisation of the lessons of experience as well as of the principles on which the rules were first built. It was evidence of the conservatism which attended even radical changes in this country that it had taken 18 years of steady movement in one direction to arrive at the simplicity, efficiency, and economy of present day shipbuilding. And the end was not yet. After tracing the close association of the Corporation with new developments in ship construction and engine design, and touching on the work done in the past and on that now in hand, Mr. King concluded by saying that large as their work was and had been, it represented but a small proportion of the real value of the society to the shipping community.

METAL QUOTATIONS.

TUESDAY, FEBRUARY 6TH.

Aluminium ingot	63/-	per cwt.
„ wire, according to sizes, &c. ......from	102/-	„
„ sheets „ „ ...... „	120/-	„
Antimony .... £27/10/- to	£28/-	per ton
Brass, rolled	7½d.	per lb.
„ tubes (brazed)	9⅞d.	„
„ „ (solid drawn)	8d.	„
„ „ wire	7¾d.	„
Copper, Standard	£61/-/-	per ton.
Iron, Cleveland	49/-	„
„ Scotch	55/-	„
Lead, English	£16/-/-	„
„ Foreign (soft)	£15/15/-	„
Mica (in original cases), small	6d. to 2/-	per lb.
„ „ „ medium	2/6 to 4/-	„
„ „ „ large	4/6 to 8/6	„
Quicksilver	£8/5/-	per bottle
Silver	27d.	per oz.
Spelter	£26/12/6	per ton.
Tin, block	£191	„
Tin plates	13/6	„
Zinc sheets (Silesian)	£29/10/-	„
„ (Stettin; Vieille Montagne)	£30/-/-	„

Personal.—Mr. W. Boyd, from Cammell, Laird, & Co.'s, Birkenhead, is, we learn, to be Mr. Baird's successor in the establishment of the London and Glasgow Engineering and Shipbuilding Company, Govan. Mr. Boyd went to Birkenhead from Messrs. Workman, Clark, & Co.'s, Belfast.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1910.

Valves for internal combustion engines. Sears. 17379.
Centrifugal pumps and fans. Watson & Billetop. 18808.
Change speed or reversing worm-gearing. Dawson. 23907.
Treatment of smoke from furnaces. Thomas. 28976.
Gas generators. Salsbury & Whitaker. 29047.

1911.

Machine tools. Bungeroth & Tyrer. 1044
Driving by friction. O'Keenan. 1052
Water tube boilers. Olbricht & Gerteis. 1054.
Steam-traps. Paterson. 1070.
Reduction of ore. Sieurin. 1134.
Plunger pumps. Kirkham. 1166.
Valve gears for engines. Murauer. 1203.
Shock deadening reactive valve with single or double effect for water, steam, and compressed air conduits. Van Bonn. 1217.
Methods of compressing gases and utilising the expansive force thereof. Humphrey. 1241.
Processes for roasting sulphide ores. Renwick. 1267.
Internal combustion engines. Wolseley Tool and Motor Car Company, Remington, and Rowledge. 1421.
Blowers for tubular boilers. Mackenzie. 1479.
Manufacture of screws, bolts, and studs. Jackson. 1585.
Railway signalling. Thorrowgood. 1719.
Fluid actuated turbines. Boult. 1852.
Lathes. Dron & Lawson, Ltd., and Fulton. 1873.
Internal combustion engines. Alston & Houston. 3113.
Pneumatic hand tools. Ames. 3187.
Miners' safety lamps. Cremer. 3785.
Surface feed water heaters. Weir. 3787.
Exhauster and blower which may be also used as a liquid pump and engine. Lamplough. 4494.
Rope haulage clips. Ashman. 5216.
Chaplet for use in casting and moulding metals. Grace. 5423.
Axle trucks for railway and tramway vehicles. Curwen . 6720.
Side flues and downtakes for boilers. Hannan. 6831.
Apparatus for purifying water. Wilson. 7029.
Cutting machines for use in mining or quarrying minerals. Mavor & Coulson, Ltd., and Mavor. 7465.
Gas or fluid meters. Berry, Glover, & Meters, Ltd. 7726.
Rotary motor. Gray. 8010.
Gas meters. Glover. 8136.
Oil burners. Johnson. 8988.
Silencers for internal combustion engines. Bailey & Bailey. 9335.
Rotary engine. Urry. 9410.
Rope and cable clips for haulage. Farnsworth. 9786.
Furnace grates for steam generators. Neill. 10072.
Spanners. G. R. Smithson & Co., and Williams. 10887.
Lifting dogs. Griffiths. 11011.
Method of chlorinating roasting of ores. Helsingborgs Koppar verks Aktiebolag. 11515
Apparatus for separating oil from water. Bradshaw & Doxey. 11883.
Propellers. Coanda. 12740.
Manufacture of armour plates. Vickers, Ltd. and Benthall. 14060.
Fire tube boilers. Pielock. 14138
Valve gear for steam engines. Walter 14186.
Machines for treating gases in the production of sulphate of ammonia. Burstall. 14410
Distributing valves for steam engines. Stumpf. 14927.
Suction gas producers. Livens & Vincent. 14976.
Bearings for high speed shafts of machine tools. Dymond. 16822.
Two stroke cycle revolving cylinder explosion engines. Brivois. 18366.
Shaft governors for controlling the admission of fluid to power engines. Wygodsky. 18490.
Device for propelling vessels. Weber & Muller. 18673
Grips or clips for haulage systems. McCabe, Jamieson, and McCabe. 18751.
Valve seat for pneumatic tools. Hubers. 19090
Carburetters for internal combustion engines. Galtay. 19977
Ball bearings. Almfelt. 20168
Method of and apparatus for starting multi-cylinder combustion engines. Robert Bosch. 20623
Railroad track curves. McManama, Simonds, & Barbey. 22147
Base plates for annealing ovens. Plesch. 23218
Valve mechanism for internal combustion engines. Wadmann. 23623
Ball-bearings. Benz & Co. 24358.
Anti-friction device for radial drilling machines. Asquith and Asquith. 24547.
Water tube boilers. Fried. Krupp Akt. Ges. Germaniawerft. 24956.
Distance measuring instrument. Optische Anstalt C. P. Goerz Akt.-Ges. 25269.
Apparatus for drilling, punching, or stamping constructional metal members. Kolassa. 25661.
Means for protecting boiler stay ends and nuts and analogous projections from the effects of heat. Christie. 26624.

ELECTRICAL, 1910.

Telephonic apparatus. Graham. 23742.
Electrical condensers. British Insulated and Helsby Cables, Ltd., and Bayles. 24084.
Electric wires or cables. British Insulated and Helsby Cables, Ltd., and Bayles. 26591.
Fusible cut outs for controlling electric circuits. Hope. 29122.

1911.

Electric accumulator electrodes. Pape. 905.
Transmission of sound by electrical means. Brown. 956.
Process for obtaining rapidly the establishment or the variation of the electro motive force of a dynamo. Soc. Alsacienne de Constructions Mécaniques. 1252.
Controlling apparatus for electrical lifts. A. W. Penrose & Co., and Barlow. 1335
Electric welding. Koopman and Pontelec Welding Patents, Ltd. 1563.
Electric signalling on railways. Brown. 1566.
Electrically heated cooking apparatus. Perry. 1883.
Electrically-heated ovens. Perry. 1885.
Rheostat adapted to be regulated from a distance. Eilertsen. 8156.
Electric switches and circuit breakers. Morris & Lister. 8205.
Electric motor generators. Electric and Ordnance Accessories Company, and Bowen. 9856.
Electric meters of the electrolytic type. Mounsdon. 10689.
Magneto electric machine. Smyth. 12011.
Electric-contact breakers. Belfitt. 18479.
Electric signal apparatus. Reynolds. 18693.
Driving gear of electrically operated winches. Wilson. 18911.
Circuit arrangements for automatic telephone systems. Siemens and Halske Akt. Ges. 19186 and 19231.
Electric safety hand lamps. Simplex Conduits, Ltd., and Bennett. 19347.
Arc lamps. Korting & Mathiesen Akt. Ges. 27669.

THE DANGERS OF TUBE STOPPERS.

In multitubular boilers it not infrequently happens that smoke tubes give out in service through some local defect which could not be easily foreseen, and to permit of working until the tube can be conveniently replaced a temporary repair is effected by stopping the tube. This is sometimes done by driving in plain taper plugs at each end, and sometimes by using a long bolt screwed at each end and fitted with caps, which are screwed to a bearing over the end of each tube. As an emergency repair there is no objection to a tube stopper, but the temporary character of such repair should be recognised, and the defective tube renewed at the first opportunity. Many fatal scalding accidents have occurred through the failure of tube stoppers in one way or another. Taper plugs, for instance, are liable to work slack and be blown out, while screwed rods sometimes fracture as a result of excessive stress in screwing the caps on the ends to secure tightness. A report recently issued (No. 2,087) shows how failure of a defectively-applied tube stopper may lead to shortness of water and overheating. The accident occurred on board a steam yacht while in Loch Stewart, on September 14th last. The boiler was of the ordinary single furnace multitubular type, and it appears that in consequence of a tube failing the engineer applied a screwed bolt stopper, but failed to make it quite tight, so that leakage occurred when it was put under steam, and this, unknown to the attendant, caused the crown of the combustion chamber to be laid bare, with the result that it was overheated and torn away from the bolts securing it to three of the girder stays. Through the holes thus formed the contents of the boiler escaped, and fatally scalded the attendant.

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Smoke from Metallurgical Furnaces.

WE drew attention about a fortnight ago to a discussion in Sheffield arising out of some articles by Prof. Arnold in a local paper setting forth some elementary facts concerning combustion and the application of heat in certain processes of steel manufacture. He showed that whatever control might be exercised over excessive smoke production in the case of boiler furnaces it was impracticable, and, in fact, almost impossible, in furnaces for the re-heating of steel ingots to avoid the emission of smoke, and that any harsh measures taken against steel manufacturers for smoke nuisance at the instance of misguided, and, we fear, often ill-informed enthusiasts, might seriously prejudice Sheffield industry. Prof. Arnold has been taken to task for the attitude he has taken up on the question, but his position is, we think, incontrovertible, and on another page we give some remarks of his bearing on the subject which may be commended to the notice of those who imagine that smoke prevention in metallurgical operations is quite an easy matter. The seriousness of the subject, from a public point of view, is further testified by a communication which has just been issued by the Sheffield Chamber of Commerce to its members, as they point out that the question of smoke in re-heating and annealing furnaces, as far as Sheffield is concerned, is not a new one. A special report on the subject was made in 1889, and as the conclusions then arrived at are in many respects just as pertinent to-day they may with advantage be repeated. They stated: "We have come definitely to the conclusion that there is no known means at the present time of re-heating and annealing steel of a higher carbon than about ·5 in any other medium than that of a low smoky fire, which alone can prevent the oxidation of the carbon, the overheating of the surface, and the consequent destruction of the material. If this conclusion be correct, and your committee are unable to find a single voice, either theoretical or

practical, to the contrary, it follows that the production of smoke in such cases is an incident of the trade, and that to prevent the smoke would put a stop to a very important portion of the Sheffield trade." The committee proceeded further to remark that "they are compelled, upon the known facts, to come to the conclusion that smoke from the re-heating and annealing furnaces is as demonstrated by them a necessity . . . and that it would be the height of injustice were the Health Committee of the Corporation to initiate a campaign against re-heating and annealing furnaces, for by doing so they would be conducting a campaign against the trade itself, and, therefore, against one of the most important by which Sheffield has attained its high position as a manufacturing centre." In the course of the recent discussion it has been suggested that the heating of steel ingots could be effected without the use of a smoky flame, or, if one were used, that the smoke could be treated as it escaped from chimneys and consumed or precipitated, but those who speak glibly of these remedies have, we fear, little knowledge of the commercial and practical difficulties in the way, some of which have been outlined by Prof. Arnold, while it may be pointed out that these suggestions are by no means new. The Chambers of Commerce Committee were fully cognisant of them when the question was previously discussed, but they arrived at the conclusion that such appliances as were suggested were imperfect, while they added that none, so far as they could ascertain, "had ever been successful in even partially meeting the difficulty, and having regard to the situation and other circumstances affecting re-heating and annealing furnaces, was any arrangement likely to be produced to enable the escaping smoke to be got rid of?" No doubt the smoke-prevention enthusiasts will argue that however true this expression of opinion may have been at the time of this report, it scarcely applies at the present day, but the hard fact remains that no appliance has proved sufficiently practicable to ensure its adoption, and steel makers cannot be accused of lack of personal interest towards any improvement which could be shown to be commercially successful.

The Mossley Tram Disaster.

After a lapse of nearly four months, the report has at length been issued of the investigation made by Lieut.-Col. Donop, R.E., into the circumstances attending the tram disaster which occurred at Mossley on the 20th of October last, when, it will be remembered, a tram which was descending a steep road got out of the control of the driver and at a sharp curve at the bottom was precipitated over an embankment on the London and North-Western Railway, causing the deaths of six persons and injury to a number of others. The wreck was so complete that it is hardly a matter of surprise that Lieut.-Col. Donop has failed to diagnose exactly the precise nature of the failure of the braking mechanism, which was responsible for the disaster. It appears, however, that the driver lost control immediately the car started and never regained it, but whether this was due to some mismanagement or error of judgment on his part or to some defect in the controlling mechanism it is now impossible to say, though the Board of Trade Inspector inclines to the belief that a defect in the controller was most probably the primary cause, and points out the importance of subjecting the interiors of controllers to periodical examination and supervision. The construction of this apparatus is so simple that there is perhaps an almost excusable tendency to regard the existence of a defect as impossible. These, however, do undoubtedly at times occur, and it is to be trusted that this particular lesson will not be lost upon tramway authorities. Nothing, in fact, in connection with the brake apparatus, in view of the number of accidents that have occurred from runaway cars, should be taken for granted. In this connection it would appear that the practice of the officials of the tramway in question was open to criticism. The car was fitted both with a magnetic brake and also with a hand brake. The latter is the one on which normally reliance is placed by the driver, and had it been promptly applied when the controller went wrong it alone might have been effective, just as a little tardiness in application would render it useless. Under such conditions he could, of course, turn to the magnetic brake, but, as the Board of Trade have pointed out in reports on previous disasters, there is a risk of applying this wrongly unless drivers are continually practising its application, while, further, there is the risk of the brake itself being found defective when most urgently wanted. It would appear that at Mossley the men were not instructed to use the magnetic brake except for emergency stops or for descending steep grades, instead of being instructed, as they ought in all cases to be, to habitually use emergency brakes, as well as the ordinary one, in order to be familiar with their application and to ensure that they are in working order, and can be instantly applied if the occasion demands.

EFFECT OF CURRENTS ON INSULATORS.

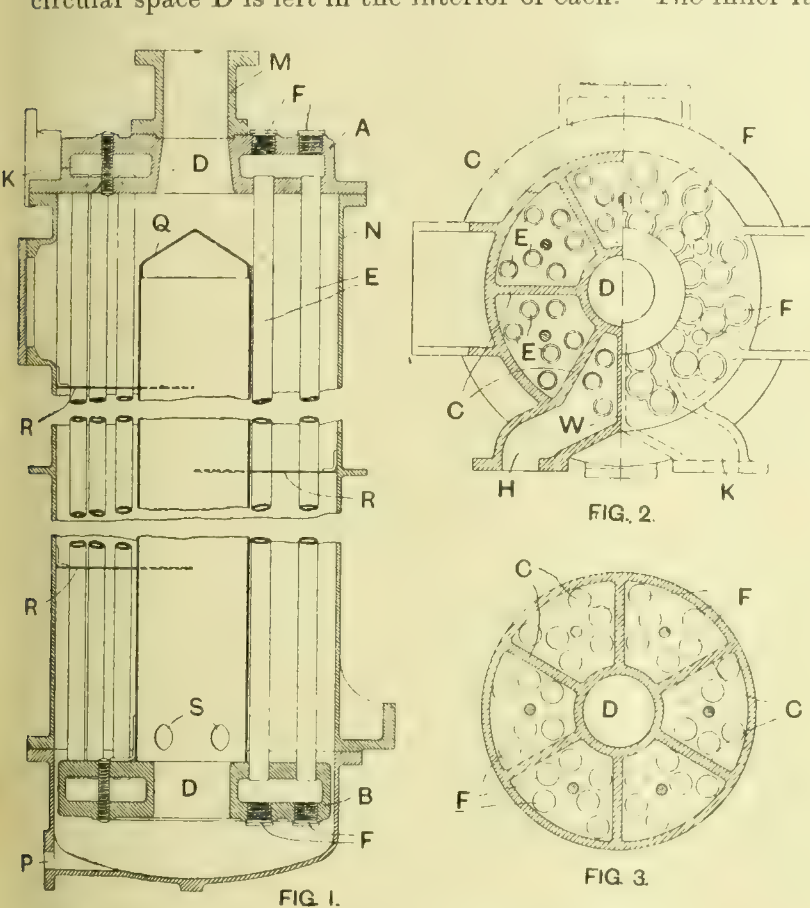
The results of some experiments carried out by MM. Laporte, de la Gorge, and Girault, on the behavious of the insulating media used for cables, with direct and alternating currents, and with alternate currents of low and high frequencies, are recorded in "The Times" Engineering Supplement. The experiments show that, although alternating currents break down the insulation much more readily than direct currents, the ratio between the voltage in each case necessary to cause a breakdown varies with the material used. In the case of dry paper, for example, this ratio is 1 : 1·8; with caoutchouc it is 1 : 2·6; well-insulated cellulose gives the ratio 1 : 3·2, and air gives the ratio 1 : 1·1. In certain cases glass gives the ratio 1 : 6·3, so that with glass insulation direct current would require less than one-sixth of the insulating medium that would be necessary in the case of alternate current. As regards the influence of the number of alternations per second on the breaking down voltage of various dielectrics, the following figures show the ratio of those voltages for currents whose frequencies are respectively 25 and 500: Glass, 1·45; presspahn, 1·42; ebonite, 1·23; mica, 1·18; oil, 0·92; and air, 0·95. The figures show that higher numbers of alternations increase the stress on the dielectrics, except in the case of oils and gases. Experiments on the effects of high-tension currents on highly-insulating oils recently carried out by Mr. T. Thorne Baker showed that the capillarity is greatly affected by currents of very high frequency, the "specific cohesion" being easily halved under the influence of oscillatory currents. Direct currents of high tension, on the other hand, produced a decided effect on the oil, of a different character, the oil being always attracted to one electrode and repelled from the other, though its viscosity was in both cases considerably lessened. The experiments indicate that the stress in the case of insulating oils lessens with greater frequency, and is greatest in the case of direct current, the former phenomenon being quite in accord with the last experiments of de la Gorge and Girault.

Mechanicians in the Navy. The Admiralty have approved of mechanicians being definitely included in the complements of His Majesty's ships. No mechanician is to be drafted to a ship smaller than a first-class cruiser until he has obtained a certificate that he is capable of taking charge of the entire watch in the engine-room department of a large ship under way. If mechanicians are not available, two engine-room artificers and one stoker are to be drafted in lieu of every three mechanicians.

WEIR'S SURFACE FEED-WATER HEATER.

WE illustrate herewith a design of surface feed-water heater of the type comprising a steam-enclosing casing and two water headers connected together by water tubes. The heater, which forms the subject of a recent patent granted to William Weir, of G. & J. Weir, Ltd., Cathcart, Glasgow, is intended to be employed for heating the feed water for steam generators by means of exhaust or other steam, and is specially adapted for use on the discharge or pressure side of the boiler feed pump. Fig. 1 is a vertical section of the heater. Fig. 2 is, as regards its right-hand portion, a plan of the heater, and, as regards its left-hand portion, a horizontal section through the upper header, and Fig. 3 is a horizontal section through the lower header.

The heater is provided with an upper header A and a bottom header B. Each of these headers is divided into several compartments which are separated from each other by radial partitions C. The headers are of circular form, and a circular space D is left in the interior of each. The inner face



WEIR'S SURFACE FEED-WATER HEATER.

of each header is adapted to act as a tube plate and is bored to receive water tubes E, which are expanded into the tube plates. Each header is cast in one piece. Holes are bored or tapped in the outer wall or cover plate of each header, these holes being opposite the tube ends; and plugs F are screwed into these holes. These holes allow of the expansion of the tubes into the tube plates, and are also useful in permitting of the examining and cleaning of the interior of the tubes.

The tubes are of relatively large diameter, say about $1\frac{1}{2}$in. external diameter. To obtain a satisfactory heating with tubes of such large diameter, and with a heater of a convenient length or height, it is necessary that the water should make many passes through the tubes, and this is the reason for the division of the headers into several chambers. By reference to Figs. 2 and 3, which are shown in their correct relative positions, it will be seen that the partitions in the upper header are staggered with respect to the partitions in the lower header, an exception to this rule being the partition W in the upper header which separates the first chamber in the upper header from the last chamber. By this arrangement the water entering at H is passed alternately downwards and upwards through the several chambers of the two headers and through the tubes connecting these and eventually arrives at the exit port K. In the design illustrated, the water makes in all 12 passes through the tubes. The steam admission pipe M is connected to the upper header, and the steam enclosing casing N is also connected to the same header. This casing encloses, not only the tubes, but also the lower header, which is not attached to the casing but is hung from the upper header by means of the tubes, so that relative expansion can take place between the tubes and the casing. P is the drain for the condensed heating steam. In the circular space in the centre of the tube nest is placed a closed sheet metal casing Q, which nearly fills the space, so that the flow of the steam is directed over the tubes. Deflecting plates R may also, if desired, be employed to give a more tortuous course to the steam. When these plates are used, holes are bored in them for the steam to pass through. Holes S are provided to allow water of condensation to drain away through the hole D in the bottom header.

By means of the construction described, the use of large, heavy flanged joints is avoided, while the steam inlet branch is located in such a position that it does not involve the breaking of a joint to enable the outer casing to be removed to facilitate cleaning and examination of the outer surfaces of the tubes.

WIRELESS TELEGRAPHY.

THE adjourned discussion on "Wireless Telegraphy" was held at the Institute of Marine Engineers, Stratford, E., on Monday, January 29th. Mr. G. W. Newall (Member) occupied the chair. In the expected absence of Mr. John McLaren, the author of the paper, Mr. A. E. Battle had been asked by the Hon. Secretary to elaborate some of the details. Mr. Battle opened with a brief account of the developments leading to the discovery of wireless telegraphy. He said that scientists like Maxwell, in the mid-Victorian era, held the theory of the existence of luminiferous ether, which was further demonstrated by Hertz. His apparatus was very simple and consisted of two metal discs, which acted as condensers, and to which an induction coil was connected. Electrical waves were set up, due to the breaking down and sparking between the two discs, and these waves were caught by means of a circular piece of wire. An electric current at high tension was thus obtained. Hertz, however, did not believe in the possibility of transmitting telegraphic messages through space without wires. The Bramley coherer was the foundation of the modern coherer used in wireless telegraphic apparatus. It consisted, roughly, of two discs in a tube, with metal filings between. Other scientists had discovered most of the phenomena connected with wireless telegraphy, but it was Marconi who had collected and used these phenomena and brought them into practical every-day use. With regard to the author's remarks on ether, it was generally accepted that ether permeated everything, but had different properties under different conditions. Ether waves had been proved to be capable of compression, reflection, and refraction, and these properties were made use of in wireless telegraphy.

Mr. Newall said he did not consider that the electric waves moved only in a series of transverse vibrations. He understood they were spherical vibrations operating from a central "core," in all directions. The late Mr. Macfarlane Gray had gone deeply into the subject, and came to the conclusion that ether was an imponderable jelly-like substance, which would suffer a pressure of millions of tons per square inch. Wireless telegraphy had assisted marine engineers in various ways. In the case of breakdowns it would be possible to communicate with the works and give full details in order that the new gear might be in readiness on arrival. It could be used in ordering fuel in advance and in cases of fog or shipwreck. He indicated the way in which marine engineers might put to good use five different instruments which had been perfected in recent years, viz., the Marconi telegraphy, the long-distance telephone, the electrical transmission of photographs and drawings, the phonograph, and the microphone.

Mr. F. M. Timpson asked if the position of a vessel in a fog could be located by means of wireless telegraphy. He understood that better results would be obtained by submarine signalling in such cases. Messrs. T. Fleming and R. Dilworth Harrison also took part in the discussion. The meeting closed with a vote of thanks to Mr. Battle and to the chairman.

RECENT DEVELOPMENTS IN STEAM TURBINE PRACTICE.*

BY K. BAUMANN.

(Concluded from page 162.)

IMPROVEMENT IN ECONOMY OF STEAM TURBINES.

THE full load consumptions and total efficiencies of the most important turbines, obtained in tests made during the last five years, are given in the following list :—

No	Manufacturer	Year of Test.	Kilo-watts	Revs. per Minute.	Lbs. per Kilo-watt-hour.	Total Effici-ency.
1	A.E.G.	1906	3,000	1,500	12·75	63·8
2	C. A. Parsons	1907	3,500	1,200	13·35	62·7
3	Westinghouse Machine Co.	1907	7,500	750	15·00	66·3
4	Brown, Boveri & Co. ..	1907	3,500	1,360	13·70	64·8
5	Escher, Wyss, & Co. ..	1908	5,000	1,000	15·17	63·1
11	A.E.G.	1909	4,000	1,500	11·92	63·8
12	El. Maschinenfabrik ..	1910	3,500	1,500	14·07	64·8
14	Maschinenfabrik Augsberg-Nürnberg	1910	2,500	1,500	15·50	64·5
18	B.T.H.	1911	3,000	1,500	15·96	64·7
21	Escher Wyss	1910	4,000	1,000	13·30	64·4
22	Escher Wyss	1910	2,000	3,000	13·03	66·0
25	Oerlikon	1911	3,000	1,500	11·62	64·1
26	British Westinghouse ..	1911	3,000	1,500	13·72	63·9
27	British Westinghouse ..	1911	5,000	1,500	13·00	67·9
28	Richardson Westgarth ..	1910	6,250	1,200	11·90	68·4

CHANGE OF STEAM CONSUMPTION WITH VARYING STEAM CONDITIONS.

The efficiency of a steam turbine is the ratio :—

$$\frac{\text{Actual work done on turbine shaft}}{\text{Mechanical equivalent of heat drop according to adiabatic expansion.}}$$

This ratio is referred to wherever efficiency is mentioned in the following discussion.

In order to compare the merits of different steam turbines, the efficiencies as obtained above are usually calculated and compared. This, however, does not provide a rational basis of comparison, as the efficiency of a turbine is itself dependent upon the steam conditions. It is well known, for instance, that the efficiency increases with the superheat. For this reason the author has adopted standard steam conditions to which the performances of all turbines can be reduced by applying proper corrections. These standard conditions are :—

For high-pressure turbines, 180lbs. per square inch pressure, 150° Fah. superheat, 28in. vacuum (30in. Bar.).

For low-pressure turbines, 16lbs. per square inch absolute pressure, 0° Fah. superheat, 27½in. vacuum (30in. Bar.).

(1) **Corrections for Turbines Designed for Particular Condition:** (*a*) *Superheat.*—According to our present knowledge the corrections to be made for superheat are independent of steam pressure and vacuum, and are therefore the same for high, low, and approximately for back-pressure turbines. The corrections are as follows :—

Between

0–100° Fah. superheat, 1 per cent. improvement of steam consumption for every 10° Fah. superheat.

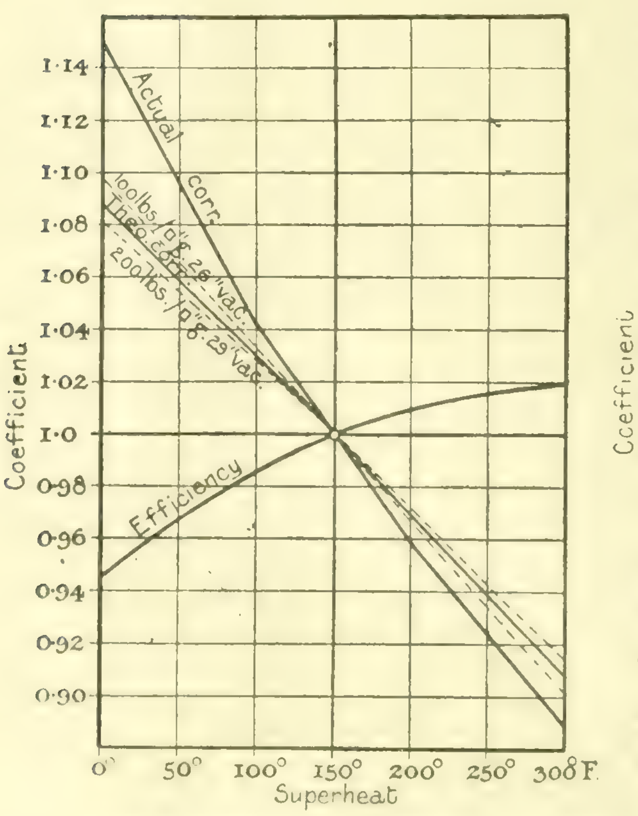


FIG. 36—SUPERHEAT CORRECTIONS FOR HIGH-PRESSURE TURBINE DESIGNED FOR SUPERHEAT

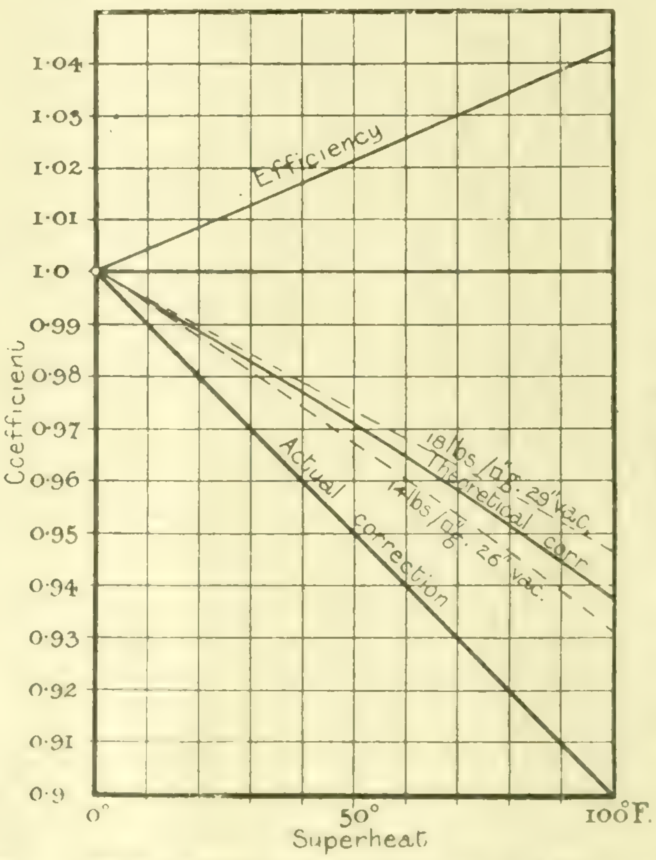


FIG. 37—SUPERHEAT CORRECTIONS FOR LOW-PRESSURE TURBINE DESIGNED FOR SUPERHEAT

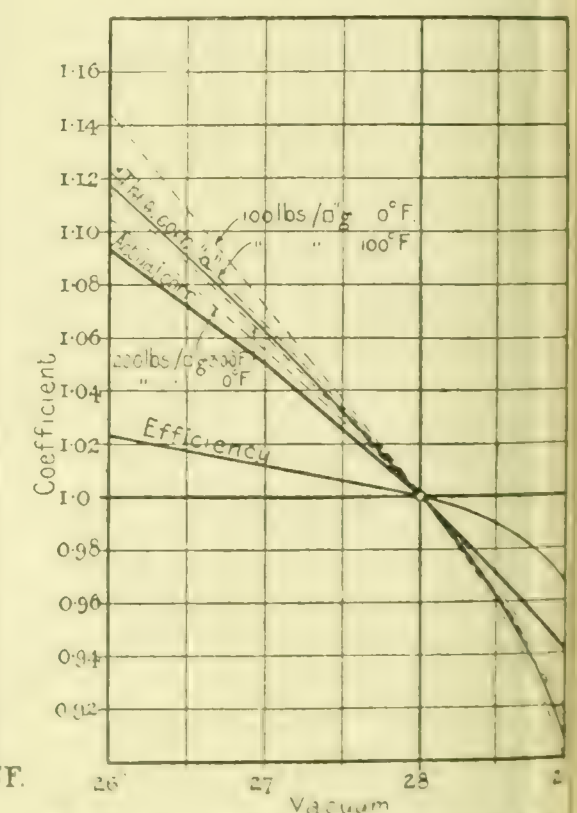


FIG. 38—VACUUM CORRECTIONS FOR HIGH-PRESSURE TURBINE DESIGNED FOR VACUUM

From this list it will be seen that the steam consumption has been improved from 12·75lbs. per kilowatt-hour in 1906 to 11·6lbs. per kilowatt-hour in 1911 ; and the total efficiency :—

$$\frac{\text{Actual output on generator}}{\text{Mechanical equivalent of heat drop according to adiabatic expansion}}$$

from 63·8 per cent. in 1906 to 66·3 per cent. in 1907, and 68·4 per cent. in 1910. This figure has not been improved upon in 1911.

The best efficiency on mixed-pressure turbines running on low-pressure steam has been obtained on a 1,000 kw. turbine running at 3,000 revs. per minute, made by the British Westinghouse Company. The efficiency realised in this case was 69·8 per cent.

* Paper read before the Manchester Section of the Institution of Electrical Engineers, January [illegible].

100–200° Fah. superheat, 1 per cent. improvement of steam consumption for every 12° Fah. superheat.

200–300° Fah. superheat, 1 per cent. improvement of steam consumption for every 14° Fah. superheat.

The efficiency increases with the superheat, and consequently the actual is larger than the theoretical correction, which is calculated from the variations of the available heat drop in adiabatic expansion. Fig. 36 shows plotted the actual superheat corrections for high-pressure turbines together with the change of efficiency, and the mean theoretical correction for steam conditions varying between the limits :—

100lbs. per square inch gauge pressure, 26in. vacuum.
200lbs. per square inch gauge pressure, 29in. vacuum.

Fig. 37 shows plotted similar values for low-pressure turbines for steam conditions varying between the limits :—

14lbs. per square inch absolute pressure, 26in. vacuum.
18lbs. per square inch absolute pressure, 29in. vacuum.

The improvements in efficiency may be taken as :—

4·25 per cent. better efficiency at 100° Fah. superheat than for dry saturated steam.

6·75 per cent. better efficiency at 200° Fah. superheat than for dry saturated steam.

7·5 per cent. better efficiency at 300° Fah. superheat than for dry saturated steam.

From which the futility of comparing the efficiencies of turbines without a knowledge of the superheat is apparent.

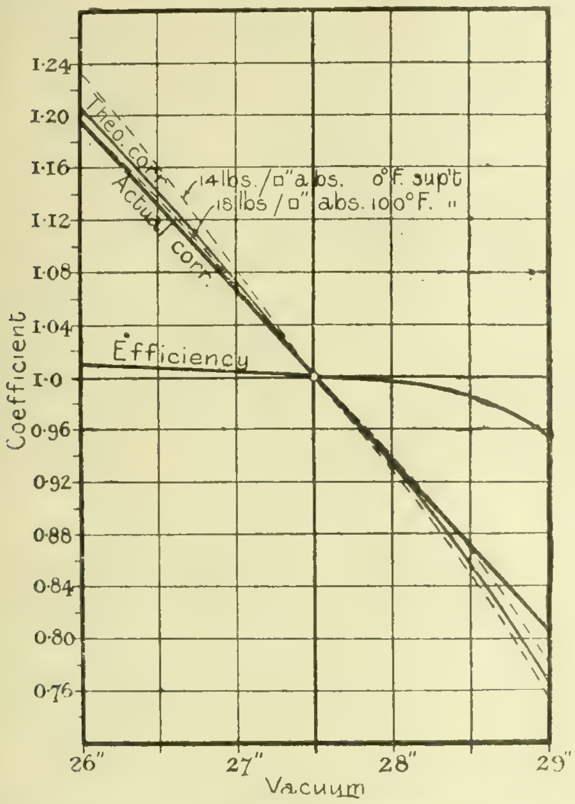


FIG. 39.—VACUUM CORRECTIONS FOR LOW-PRESSURE TURBINE DESIGNED FOR VACUUM.

The corrections given have been deduced from a large number of tests made on impulse turbines; they are probably too large for pure Parsons turbines, which are unable to utilise high superheat to the same extent as impulse or impulse reaction turbines.

Tests have shown that *when the steam is wet* the efficiency is reduced. Assuming that the efficiency follows a continuous curve for superheated and wet steam when plotted with entropy as a basis, the efficiency will change by 1 per cent. for each 1 per cent. variation in wetness. It follows therefore that the steam

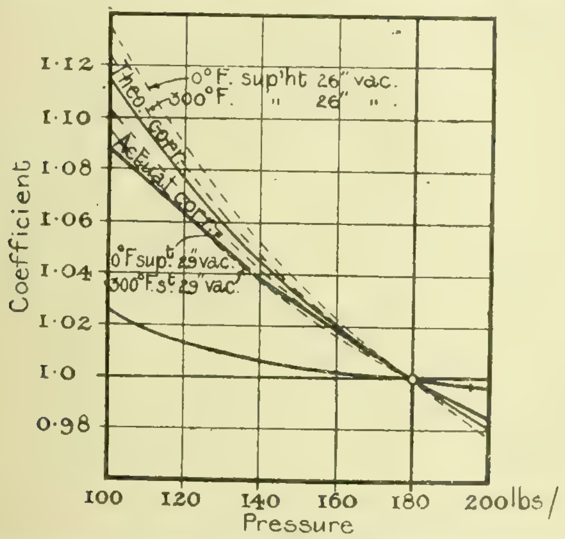


FIG. 40.—PRESSURE CORRECTION FOR HIGH-PRESSURE TURBINE DESIGNED FOR THE PRESSURE.

consumption measured as condensed water will be 2 per cent. higher for each 1 per cent. increase in moisture.

(*b*) *Vacuum.*—The efficiency of a turbine using and designed to use a very high vacuum will not be so good as that of a turbine of quite similar type, having the same number of stages, but designed to utilise a lower vacuum. The difference will be slightly larger for drum than for disc turbines, as the latter can be designed to use a higher vacuum to greater advantage than the former. The corrections for high-pressure turbines are given in Fig. 38.

The average theoretical corrections obtained by considering the adiabatic heat drop available are plotted in Curve A, and may be taken as :—

5 per cent. improvement of steam consumption for 1in. between 26in. and 27in. vacuum.

6 per cent. improvement of steam consumption for 1in. between 27in. and 28in. vacuum.

7·75 per cent. improvement of steam consumption for 1in. between 28in. and 28½in. vacuum.

11·5 per cent. improvement of steam consumption for 1in. between 28½in. and 29in. vacuum.

The actual improvement which can be obtained with the present design of impulse turbine is :—

4 per cent. improvement of steam consumption for 1in. between 26in. and 27in. vacuum.

5 per cent. improvement of steam consumption for 1in. between 27in. and 28in. vacuum.

6 per cent. improvement of steam consumption for 1in. between 28in. and 29in. vacuum.

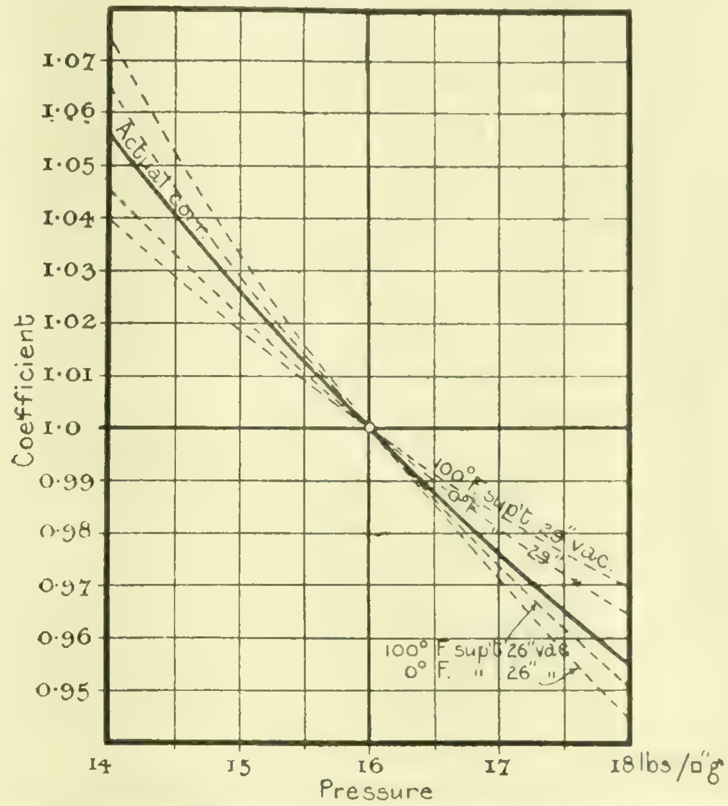


FIG. 41.—PRESSURE CORRECTION FOR LOW-PRESSURE TURBINE DESIGNED FOR THE PRESSURE.

According to these figures the efficiencies of equivalent turbines with the same number of stages using and designed to utilise different vacua would be :—

1 per cent. better efficiency at 26in. than at 27in.
1 per cent. better efficiency at 27in. than at 28in.
1 per cent. better efficiency at 28in. than at 28½in.
2·5 per cent. better efficiency at 28½in. than at 29in.

These figures represent a very fair average for any steam conditions between the limits :—

Steam pressure 100lbs. per square inch gauge to 200lbs. per square inch gauge.

Superheat 0° Fah. to 300° Fah.

Whereas the superheat correction is nearly independent of the other steam conditions, the vacuum correction depends to a great extent upon the steam pressure, and is very much larger for low-pressure turbines, the corrections for which are given in Fig. 39.

The average theoretical corrections for these are :—

12 per cent. improvement of steam consumption for 1in. between 26in. and 27in.

13·75 per cent. improvement of steam consumption for 1in. between 27in. and 28in.

17 per cent. improvement of steam consumption for 1in. between 28in. and 28½in.

22·5 per cent. improvement of steam consumption for 1in. between 28½in. and 29in.

The actual improvements which can be obtained with the

present design of low-pressure impulse turbine of similar construction, but increased number of stages for higher vacuum are :

11·5 per cent. improvement of steam consumption for 1in. between 26in. and 27in. vacuum.

13 per cent. improvement of steam consumption for 1in. between 27in. and 28in. vacuum.

11·5 per cent. improvement of steam consumption for 1in. between 28½in. and 29in. vacuum.

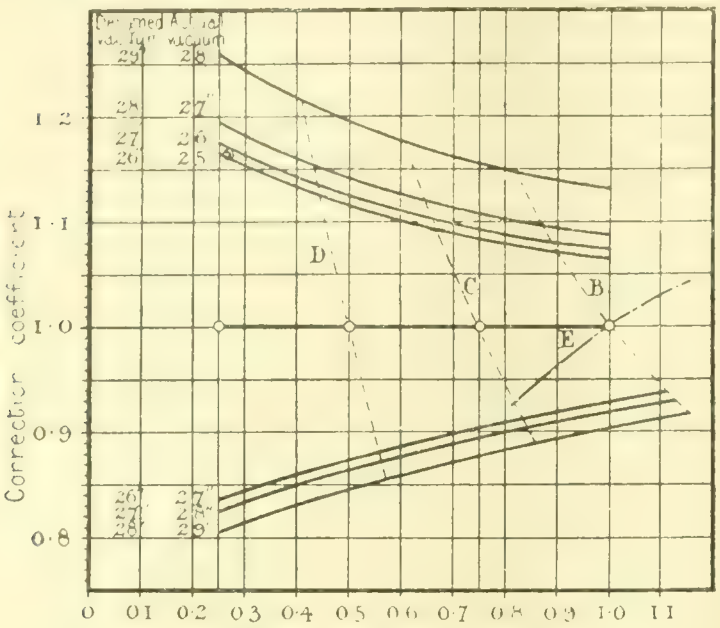


FIG. 42. VACUUM CORRECTION FOR LOW-PRESSURE TURBINES.

According to these figures turbines using and designed to utilise different vacua give efficiencies as follows :—

0·5 per cent. better efficiency at 26in. than at 27in. vacuum.
0·7 per cent. better efficiency at 27in. than at 28in. vacuum.
1·0 per cent. better efficiency at 28in. than at 28½in. vacuum.
3·5 per cent. better efficiency at 28½in. than at 29in. vacuum.

The corrections given represent a very fair average for any steam conditions between the limits :—

14lbs. per square inch, absolute, 0° Fah.
18lbs. per square inch, absolute, 100° Fah.

(c) *Pressure.*—The efficiency which can be obtained with turbines having the same number of stages depends also, but in a lesser degree, upon the steam pressure. When the steam pressure is low not only are the leakage, ventilation, and friction losses in the turbine smaller, but the blading efficiency increases as the total heat drop decreases. The corrections for pressure in the case of high-pressure turbines are shown in Fig. 40. The average theoretical corrections are as follows :—

2 per cent. improvement in steam consumption for 10 per cent. increase of pressure between 100lbs. and 140lbs. per square inch gauge.

1·95 per cent. improvement in steam consumption for 10 per cent. increase of pressure between 140lbs. and 180lbs. per square inch gauge.

1·90 per cent. improvement in steam consumption for 10 per cent. increase of pressure between 180lbs. and 200lbs. per square inch gauge.

The actual improvements in steam consumption which can be obtained with the present design of impulse turbine are :—

1·5 per cent. improvement in steam consumption for 10 per cent. increase of pressure between 100lbs. to 200lbs. per square inch gauge.

According to these figures equivalent turbines having the same number of stages, using and designed to utilise different pressures would give improved efficiencies as follows :—

0·4 per cent. better at 180lbs. per square inch than at 200lbs. per square inch gauge.

0·6 per cent. better at 140lbs. per square inch than at 180lbs. per square inch gauge.

1·9 per cent. better at 100lbs. per square inch than at 140lbs. per square inch gauge.

These corrections are a very fair average for any steam conditions between 0° Fah. superheat, 26in. vacuum, and 300° Fah. and 29in. vacuum.

For low-pressure turbines the consumption correction is plotted on Diagram 41. The range of pressure met with in low-pressure turbines is so small that the pressure correction for thermo-dynamic efficiency is negligible.

The average consumption correction is as follows :—

4 per cent. improvement for 10 per cent. increase of pressure between 14lbs. to 18lbs.

These figures may be taken as a fair average between the limiting steam conditions, 0° Fah. superheat, 26in. vacuum, and 100° Fah. superheat, 29in. vacuum.

The corrections we have already considered refer to the steam consumptions of turbines utilising steam conditions, for which they have been specially designed, and are of the greatest importance to the purchaser when fixing the steam conditions under which turbines have to work. In addition to these, however, we have to consider :—

(2) **Corrections for Turbines Running under Conditions Different from those for which they have been Designed:** (*a*) *Superheat.*—When a turbine designed for definite conditions of load, pressure, superheat, and vacuum is tested at a specified load, a rise in superheat will affect the pressure in front of the nozzles because :—

(1) The steam consumption decreases.
(2) The specific volume of the steam increases.

The steam quantity flowing through a turbine is given by the following formulæ :—

$$G = K\sqrt{\frac{P}{v}} \text{ kg. or lbs. sec. } \quad \ldots\ldots \quad (24)$$

where K = a constant for the turbine.
P = pressure in front of the nozzles.
V = specific volume of the steam in front of the nozzles.

But the law $pv = RT$ is approximately true.
here
WT = the absolute temperature of steam.

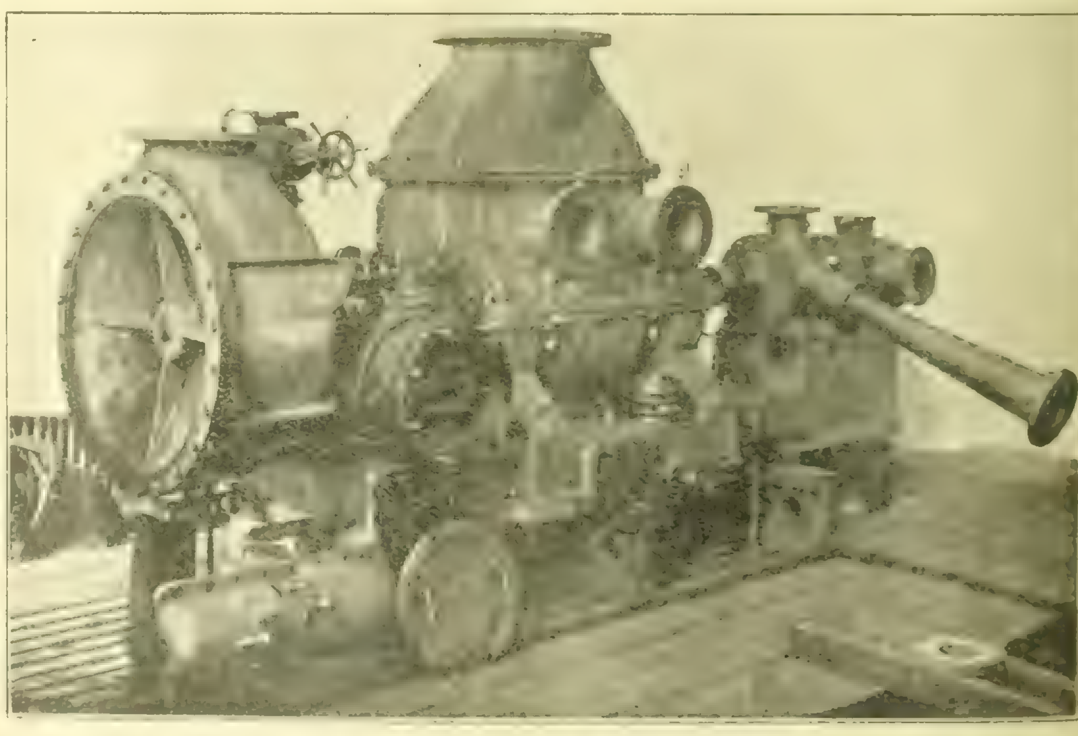


FIG. 43. TURBO-DRIVEN AUXILIARY PUMPS. THE BRITISH WESTINGHOUSE COMPANY, LTD.

R = constant of steam.
= 47·1, if p is in kg./m.^{2} and T is the absolute temperature Centigrade.
= 85·5, if p is in lbs. sq. in. and T is absolute temperature Fahrenheit.

Therefore—

$$\frac{p}{v} = \frac{p^2}{RT} \quad \ldots\ldots\ldots \quad (25)$$

from (24)—

$$G = \frac{k\,p}{\sqrt{R\,T}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (26)$$

or—

$$p = \frac{G}{K}\sqrt{R\,T} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (27)$$

In practice the temperature varies between 700° Fah. and 1,000° Fah. absolute. Now the improvement in steam consumption and therefore the decrease in G is 1 per cent. for every 10—14° Fah. increase in superheat, and with the same change of superheat $\sqrt{T}$ increases by 0·7 per cent. Thus the decrease of pressure before the nozzle will be 0·3 per cent. for every 1 per cent. decrease in steam consumption. As, however, 10 per cent. decrease in pressure only increases the steam consumption by $1\frac{1}{2}$ per cent. for high-pressure turbines or 4 per cent. for low-pressure turbines, the additional change of consumption due to increase of pressure before the nozzles can be safely neglected. The superheat corrections for steam consumptions measured at certain specified full loads, or partial loads, are therefore the same as those already given for turbines designed for the different superheats, *i.e.* :—

1 per cent. improvement of steam consumption for every 10° Fah. superheat between 0—100° Fah.

1 per cent. improvement of steam consumption for every 12° Fah. superheat between 100—200° Fah.

1 per cent. improvement of steam consumption for every 14° Fah. superheat between 200—300° Fah.

It will be apparent that the difference in turbines of the same output and designed for various superheats is negligible. For the reasons as stated above the corrections for wetness also remain the same as those given.

(*b*) *Vacuum.*—When a turbine designed for a certain load, superheat, pressure, and vacuum is tested at a specified load, an improvement in the vacuum will affect the pressure in front of the nozzles, because the steam quantity going through the turbine becomes smaller. If, for instance, an improvement of the vacuum from 27in. to 28in. causes a decrease in steam consumption of 5 per cent. the steam pressure in front of the nozzles will also drop by 5 per cent.

The turbine will now be 5 per cent. too large for these conditions and the steam will be throttled to a greater extent than if the turbine had been designed for 28in. vacuum. The improvement due to vacuum will therefore be smaller than that already given for turbines designed for various vacua.

In the case already considered 5 per cent. decrease in pressure would, for high-pressure turbines, decrease the improvement due to vacuum by $\frac{1}{2}$ per cent. The improvement will be further decreased because the efficiency of the last stages, being designed for 27in. and working with 28in., will be inferior to that of stages designed to deal with the larger steam volumes at 28in. vacuum.

From this it will be apparent that the decrease in consumption of a turbine for a certain range of vacuum will depend upon the vacuum for which the turbine has been designed.

The correction for partial loads becomes larger for two reasons :—

(*a*) As the available heat drop becomes less the change due to vacuum is relatively larger.

(*b*) As the total weight of steam flowing through the turbine becomes less, the blading of the last stages is better able to cope with the increased volume due to increased vacuum.

For these reasons the corrections will be still larger for mixed-pressure turbines where the low-pressure part is too large for the steam quantity used when running on high-pressure steam.

For low-pressure turbines the difference between the corrections given for turbines designed for various vacua, and for turbines working with vacua other than for which they were designed, is still greater. If, for example, an improvement of vacuum from 27in. to 28in. decreases the steam consumption by 13·75 per cent., the steam pressure in front of the first guide blades falls by 13·75 per cent.

As a pressure decrease of 10 per cent. on low-pressure turbines increases the steam consumption by 4 per cent., the connection is reduced from 13·7 per cent. to about 9·5 per cent.

The actual corrections for different generator loads of turbines designed for 26in., 27in., 28in., and 29in. vacuum are plotted in Fig. 42 for 1in. change in vacuum above or below that for which the turbine is designed.

When a turbine designed for a given vacuum is run at a lower one, it will not supply the designed full load with the "full load" nozzles and the designed pressure before the nozzles. The total steam quantity remains the same, but since the available heat drop is reduced the work done will also be reduced. If, for example, a turbine is designed for 26in. and is run at 25in. vacuum, the maximum load at this vacuum will only be 90 per cent. of the designed full load at 26in. vacuum. The designed full load can, however, be obtained by raising the pressure before the nozzles.

The maximum loads which can be obtained with a vacuum 1in. above or below that for which a turbine is designed, provided the pressure before the nozzles remains the same, are given on Fig. 42 by curve B. Curves C and D similarly connect points corresponding to three-quarters maximum load and half maximum load. The intercept between a point corresponding to a maximum load, and the curve E gives the ratio of the steam consumption at that maximum load to the consumption for the full load and vacuum for which the turbine is designed.

Pressure Correction.—When the steam pressure in front of the nozzles is increased the steam consumption decreases because of the increase of available heat drop.

For high-pressure turbines the improvement of steam consumption is $1\frac{1}{2}$ per cent. for 10 per cent. increase of pressure.

For low-pressure turbines the improvement of steam consumption is 4 per cent. for 10 per cent. increase of pressure.

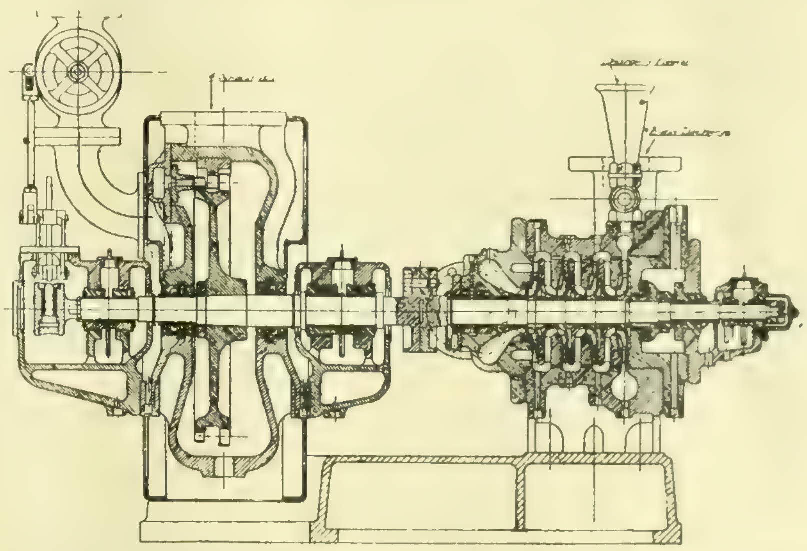


FIG. 41. -TURBINE-DRIVEN BOILER FEED PUMP. THE BRITISH WESTINGHOUSE COMPANY, 1911.

If, however, the turbine is working on constant load and the pressure before the governor valve is increased, the pressure in front of the nozzles remains practically constant, and the only advantage gained is that due to the increased superheat resulting from the additional throttling.

In this case the corrections for full or partial loads will be the same for high-pressure and low-pressure turbines—namely, 0·5 per cent. improvement of steam consumption for every 10 per cent. increase of pressure.

DEVELOPMENT OF ROTARY MACHINES DRIVEN BY STEAM TURBINES.

The most economical speed for small low-lift pumps and high-lift pumps is too high for reciprocating engines, and it was therefore necessary to drive these either by belt, gearing, or by means of electric motors. The advent of the steam turbine, however, made direct coupling possible, but it necessitated the further development in these pumps so that the speed might be sufficiently high to enable a reasonably efficient turbine to be built at a competitive price.

The advantages of steam-driven pumps are often of great importance in the case of pumps used for condensing plants. A view of such a group for a surface condenser is given in Fig. 43, which shows a turbine on an overhung shaft driving a centrifugal pump with two double flow impellers of the helico centrifugal type, a rotary air pump of the Le Blanc type, and an extraction pump consisting of one double-flow impeller. This set, which

is running at 2,500 revs. per minute, is used in conjunction with a 3,000 kw. mixed-pressure turbine for a full load steam quantity of 80,000lbs. per hour. A section of a horizontal turbine driving a boiler-feed pump running at 1,000 revs. per minute is shown in Fig. 41.

The influence of the steam turbine towards the development of rotary blowers, and particularly of compressors, has been of still greater importance.

Whereas blowers may be arranged to be driven by motors, compressors must generally be driven by turbines as the high speeds required (4,000 revs. per minute at 1,500 b.h.p., or 5,000 revs. per minute at 1,000 b.h.p, and 6,000 revs. per minute at 600 b.h.p.) can only satisfactorily be obtained by steam turbines. The economy of turbo-compressors is very high, more particularly if low-pressure steam is available for driving the turbine.

The thanks of the author are due to the British Westinghouse Company for the preparation of a great number of the blocks required for this paper, also to Mr. Halfanstein for the completion and recalculation of the test results, to Mr. H. L. Guy for the calculation of the diagrams, and to Mr. C. S. Richards for his very valuable advice with regard to the wording of this paper.

AN ECONOMISER EXPLOSION.

ALTHOUGH explosions of "economisers" are comparatively infrequent, it would be a mistake to imagine they are not capable of sudden disruption and of inflicting considerable damage. The chief danger from the failure of a weak pipe in such an apparatus is that it may inflict such blows on other pipes surrounding it that they may give way also—especially if weakened by corrosion—and a small primary explosion be thus converted into one of an extensive character. A failure of this kind is recorded in Report No. 2,080, recently issued by the Board of Trade.

ECONOMISER EXPLOSION. VIEW OF WRECKED ECONOMISER HOUSE.

It occurred at a tin works in South Wales, on the 2nd of August last. The economiser consisted of a stack of 192 vertical cast-iron pipes, about 4½in. external diameter and [illegible]in. thickness. Out of this number a section of 96 pipes were so completely shattered that it was impossible to reassemble the parts, and there appears little doubt the failure was due primarily to the giving way of one of several pipes, which

ECONOMISER EXPLOSION. VIEW OF WRECKED ECONOMISER HOUSE.

were badly wasted by internal corrosion, and that the shock resulting from its failure at a pressure of 115lbs. on the inch led to the disruption of the others. The corrosion appears to have been most severe near the centre of the tubes, where it was difficult to detect by visual inspection, but in the previous October—that is, 10 months before the explosion—the economiser was tested by hydraulic pressure to 190lbs. on the inch, or over $1\frac{3}{4}$ times the working pressure. The corrosion at that time was probably considerable, and the fact that the hydraulic test failed to reveal it shows that where tubes of small diameter are concerned the water test cannot be relied on as an infallible means of detection.

The Explosion in the Bradford Beck.—After several adjournments the inquest on the three victims of the terrific explosion which occurred in a sewer running under the centre of the city of Bradford, Yorkshire, on December 1st, and which inflicted enormous damage to property, was brought to a termination last week. The jury found that the explosion was caused by the ignition of petrol vapour in a confined part of the beck. They were also of opinion that there was not sufficient evidence to show at what point the petrol entered the beck, or whether it had been accidental or otherwise. They made no recommendations. Mr. F. W. Richardson, city analyst, expressed the opinion that the accumulation of petrol fumes that caused the explosion in the beck was not due to the steady passing down the beck of petrol in small quantities, but was due to a great amount of petrol going down at one time. The breaking of a large drum of petrol running into the beck might have been the cause of that accumulation. In reply to Mr. R. Watson (for the Bradford Dyers Association) he said it was quite impossible accurately to state the source of the petrol coming down the beck. We may add that it is rumoured the source is known, and that the case may form the subject of litigation.

A STUDY OF THE PROPERTIES OF ALLOYS AT HIGH TEMPERATURES.*

BY G. D. BENGOUGH, M.A.

INTRODUCTION AND HISTORY.

THE determination of the changes in physical properties which take place in metals and alloys as the temperature is raised has attracted the attention of comparatively few workers. This is true even in the case of iron and steel, and is more remarkable still in the case of non-ferrous metals and alloys. Yet the subject is one of considerable interest, both from the practical and the scientific point of view. In practice non-ferrous metals or alloys are sometimes called upon to withstand the combined effects of heat and stress, as in the case of the sheets and stays of locomotive fireboxes; also in the case of certain valves and other engine parts, though here the temperature conditions are less severe. Further, a study of mechanical properties at high temperatures should throw some light on the behaviour of metals and alloys when forged or rolled, and might be expected to offer some interesting suggestions as to the best limits for rolling temperatures. From the scientific point of view, the correlation of mechanical properties with phase relationships should prove a study of considerable interest.

In the case of copper alloys one of the earliest researches carried out on any considerable scale was that conducted by the Admiralty at the Portsmouth Dockyard in 1877. The test bars were heated in an oil bath, and then transformed rapidly to a tensile testing machine and broken. It was claimed that the whole operation only lasted a minute, and that, in consequence, the temperature errors were not serious. The results obtained were remarkable, and showed a sudden and big fall in tenacity at temperatures between 350° and 400° Fah. in the case of bronzes containing from 5 to 9·75 per cent. of tin, and from 10 to 2 per cent. of zinc. A copper-zinc alloy, containing 62 per cent. of copper, was also tested, but showed no such sudden drop in strength.

In 1890 Martens published an elaborate investigation on the mechanical properties of iron and steel at high temperatures, and included copper in his tests. For temperatures up to 200° C. his bars were heated in a bath of paraffin; between 200° and 600° C. in a bath of lead or lead-tin alloy; in both cases, jets of gas were used for heating the bath. Temperatures up to 400° C. were measured by a mercury thermometer; temperatures above 400° by an air thermometer, which caused much trouble.

In 1899 Unwin† re-investigated the whole matter. His apparatus consisted of a special horizontal testing machine of the manometer type, the pressure on the diaphragm being balanced by a mercury column. The bars were turned down to a diameter of $\frac{1}{4}$in. to $\frac{5}{16}$in., and elongation was measured over a 2in. length. The bars were placed in an oil bath heated from below by a gas burner, and placed between the jaws of the testing machine; the temperature of the oil bath was taken by means of a mercury thermometer. Unwin states that above 600° Fah. (=316° C.) the thermometer behaved irregularly. The highest temperature used in the research was 340° C. Some of his results are shown in Table I.

In 1900‡ Le Chatelier published a number of tests at high temperatures. His results for pure copper are given in Table I., and are plotted in Figs. 6 and 7, together with the author's. The similarity between the two sets of maximum stress results is remarkable.

In 1907 Rosenhain, and in 1910§ Rosenhain and Lantsberry, published the results of some high temperature tests on copper-aluminium alloys, with and without manganese. The apparatus used on both occasions consisted of a small electric resistance furnace placed between the jaws of an ordinary testing machine. Temperatures were measured by a thermocouple. The degree of uniformity in heating was ascertained with much care, a matter that had been rather neglected by some of the earlier workers. A special series of observations showed that no differences of temperature exceeding 5° C. could be detected in a $2\frac{1}{2}$in. length of the specimens, even at temperatures as high as 500° C.

* Paper read before the Institute of Metals, January, 1912.
† "Report of British Association," 1899.
‡ "Congrès des Methodes d'Essais," Paris, 1900.
§ "Proceedings of the Institution of Mechanical Engineers," January, 1910.

TABLE I. *Copper (Rolled).*

Atmospheric Temperature.	Tenacity. Tons per Square Inch		Elongation on 2 inches per Cent.	
	Le Chatelier.	Unwin.	Le Chatelier.	Unwin.
Degrees Centigrade.				
	15·0	17·8	42·0	10·0
100		17·1	...	9·0
110	12·9	...	41·0	...
149	...	16·1	...	8·0
200	11·4	...	36·0	..
210	...	15·9	...	9·0
260	...	15·1	...	7·0
316	...	14·3	...	1·0
316	...	14·2	...	5·0
330	9·6	...	34·4	...
340	...	13·7	...	4·5
430	8·1	...	17·8	...
530	4·6	...	16·4	...

In 1911 Hughes published in the "Journal of the Institute of Metals" the results of some experiments on copper at high temperatures, and figured his apparatus. It resembles, except for the facts that the test bar is held vertically instead of horizontally, and that an air space is introduced between the oil bath and the test piece. The highest temperature employed was 350° C.

Scheme of Present Research.—The original scheme for the present research was a somewhat extended one. It was divided into two parts. In the first place, it was desired to make a considerable number of tests, under strictly com-

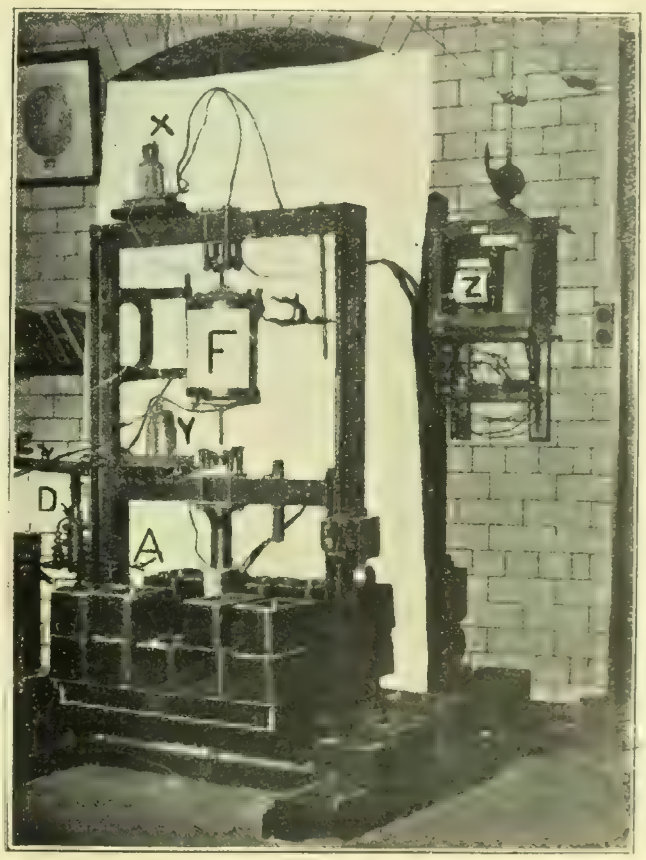


FIG. 1.—A.—Pipe from hydraulic cylinder to [illegible] B. B.—[illegible] from cylinder (Fig. 3). C.—Reservoir (Fig. 3). D.—Pump. [illegible] F.—Furnace. X.—Thermocouple cold junction. Y.—[illegible] junction. Z.—Thread recorder.

parable conditions, of the properties of copper rich alloys of the following binary series, all of which have been employed at one time or another to withstand the combined effect of stress and temperature—copper-arsenic, copper-nickel, copper-manganese, and copper-vanadium. In the next place, it was proposed to take one or two pure metals, and also selected materials from some well-known series of alloys, the constitution of which had been satisfactorily established, and to construct typical curves for all types of single phase and 2 phase systems. As regards the alloys, it was thought that the series most likely to give interesting results would be one in which

the industrially useful alloys extended over a sufficient range of composition to include both single-phase and 2-phase systems, and for this reason, amongst others, the copper-zinc series was chosen.

Work was begun on both parts of the scheme, but it soon became clear that it would be necessary to modify it considerably, since it was found necessary to investigate a number of subsidiary matters about which no information could be obtained from the literature on the subject. One of the most important of these matters was the influence of the time under stress upon the strength and ductility. At ordinary temperatures this factor has little effect in the case of static stress, but as the temperature of the test bar is raised it soon becomes of considerable importance.

The section of the research now published is confined entirely to the second part of the scheme outlined above, and the only properties discussed are the maximum stress, elongation, and contraction of area under static tension.

Description of Experimental Methods.—Rather full descriptions will be given under this head, for the reason that, so far as the author has been able to ascertain, the present paper contains the first account of an attempt to follow the variation of mechanical properties from the ordinary temperature up to the melting-points of the respective metals. Practically all previous workers, Rosenhain and Lantsberry excepted, have stopped their experiments at temperatures not higher than 350° C.; Rosenhain stopped his at 450° C., except in one experiment, when a temperature of 500° C. was used.

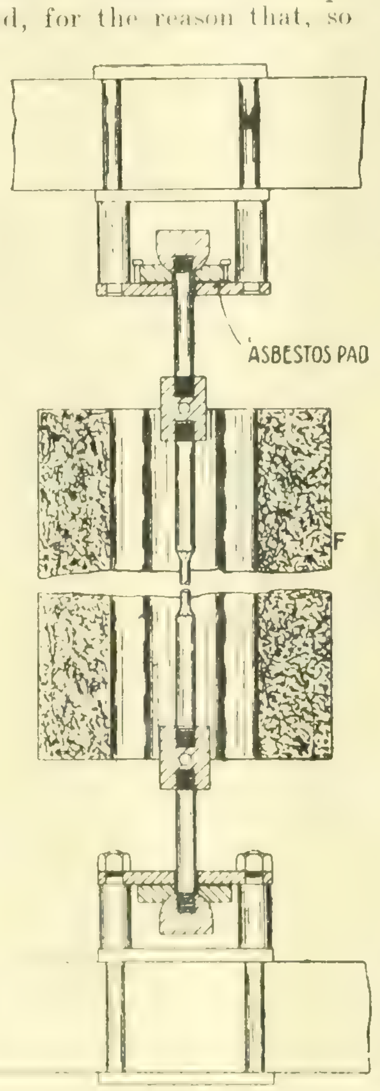


FIG. 2.

The apparatus in this research may be conveniently considered under two headings: (1) The methods of heating and measuring the temperature of the specimens under test. (2) The methods of applying and measuring the stress and strain on the specimen.

(1) Methods of Obtaining and Measuring Temperatures.—The earlier workers, including Martens, Unwin, and Hughes, heated their specimens in baths of oil or molten metal, and measured the temperature of the bath by means of mercury or air thermometers. In this type of apparatus it is obvious that the temperature must increase from the bottom of the apparatus upwards, and this will give rise to considerable variation in temperature throughout the bath. This is especially the case when the bar is placed vertically, as in Hughes' apparatus. There is a further possible source of error in both cases due to the fact that the thermometer measures the temperature of a point in the bath, and not of the metal itself. Owing to the lack of stirring apparatus, and to the difference in thermal properties (conductivity, radiative power, &c.) between the bath and the heating liquid, it is by no means certain that they take exactly the same temperature when the whole has come to thermal equilibrium. There will probably be a constant though small difference in temperature between the bar and the liquid. Both the errors mentioned become rapidly more significant as the temperature rises, and seriously vitiate all results at temperatures above 350° C. At 400° C., in an apparatus similar to that figured by Hughes, the author found a difference in temperature of 15° C. between the top and the bottom of a 2in. gauge length. Unwin and Hughes, however, carried out most of their experiments at comparatively low temperatures—below 350° C.—and the horizontal position of Unwin's bars lessened materially the chances of error in his case.

From what has been said, it is obvious that the only sound method of experiment is to use an electric resistance furnace of which the thermal gradient has been made as uniform as possible, and to measure the temperature by thermocouples kept in actual contact with the test bar itself. It must be borne in mind that the work of Martens and Unwin was carried out before the thermocouple had come into general laboratory use for experimental work.

Rosenhain and Lantsberry give the following details of their apparatus and working accuracy. The heating apparatus was a nickel wire resistance furnace used in a vertical position between the jaws of a testing machine. At first they found differences of from 10° to 30° C. between the top and bottom of their specimens; later, they were able, by carefully adjusting the packing of the lower portion of the furnace, to counteract this tendency of the upper part to attain a higher temperature, and finally they state that even at a temperature of 500° C. no differences exceeding 5° C. could be detected in the length of the specimen (2½in.).

The present author has used a vertical resistance furnace wound with platinum strip, and has been able to approach, but not quite to equal, this degree of uniformity. In some preliminary experiments two thermocouples were used, and the junctions were tightly wired on to a bar hung vertically in the furnace at a distance of 2in. from one another, each junction being at a distance of 1in. from the centre of the bar. The following results were obtained:—

Top Couple, Degrees Centigrade.	Bottom Couple, Degrees Centigrade.	Difference, Degrees Centigrade.
240	216	24
342	323	19
424	404	20
510	490	20

To improve these results, loose asbestos packing was introduced into an air space between the outside lagging of furnace and the platinum winding; also into the centre tube of the furnace around the test bar itself. After some trials the following improved results were obtained:—

Top Couple, Degrees Centigrade.	Bottom Couple, Degrees Centigrade.	Difference, Degrees Centigrade.
292	286	6
348	340	8
480	485	5
521	514	7
610	616	6

It will be noticed that in all cases the temperature of the top couple was slightly higher than that of the lower; this difference was so slight, however, that though fracture of the test pieces took place more frequently in the top half of the gauge length than in the bottom half, there were but few occasions in which it occurred either on or above the top gauge mark. When this occurred the results have not been recorded in the tables and curves.

The experiments just mentioned were carried out with the Carpenter-Stansfield potentiometer and platinum-iridium couples. All temperature measurements in the actual tensile experiments were carried out with the same couples and a thread recorder, which was particularly useful in showing graphically when thermal equilibrium had been obtained in the bar. The degree of accuracy of the temperature measurements with this instrument was not greater than ± 4° C. It should be mentioned that it is absolutely essential that the thermo junction be in actual contact with the test bar. The temperature of the heating element in the type of furnace used is always higher than that of the bar, and the temperature of the intervening space is also somewhat greater than that of the bar, even at points quite close to the latter. This arises from the fact that the thermal properties of the bar under test were different from that of the surrounding air space.

(2) Methods of Applying and Measuring Stress.—It was highly desirable to instal permanently the heating and temperature measuring apparatus, owing to the large number of

tests which it was proposed to carry out. This apparatus was somewhat bulky, and could not be conveniently fitted to the Liverpool University tensile testing machine; it was therefore decided to design a special piece of apparatus for carrying out the tests. On the ground of expense it was advisable to keep it as simple as possible, and to do away with the use of levers for magnifying the load applied to the specimen. Fig. 1 is a photograph of the apparatus used in the part of the research now published, and which it assumed after a number of preliminary trials. Figs. 2 and 3 give drawings of details. All three are lettered to correspond with one another. In Fig. 2 it will be noticed that the test bars are all screwed at the ends and fitted into extension pieces, which in turn are screwed into hemispherical nuts. These nuts are carried on spherical seatings, which rest on asbestos pads. The pads are placed on carriers attached respectively to the top framing of the machine and to a steel stirrup carrying the weights. The asbestos pads are used to lessen the amount of heat lost by conduction to the various parts of the machine.

The top carrier, with its seating, can be moved horizontally in two directions, and can thus be accurately adjusted so that the top seating is vertically above the lower. This adjustment is of great importance owing to the well-known fact that the efficiency of spherical seatings is very small with small loads. The load is applied to the specimen by placing weights on the stirrup. In Fig. 1 nine weights of 56lbs. each are shown on the near side of the stirrup; additional weights can be built up on these to the required amount. A similar load can be applied to the other side of the stirrup. The stirrup, weights, and seating hang from the spherical nut attached through the extension piece to the lower end of the specimen. Lateral play of the stirrup is limited by rollers which were placed at each side of it, and worked between the two L-shaped girders, which form the upright framing of the machine. There is about a quarter of an inch play between the rollers and the framing at each side.

The maximum load which the machine is designed to carry is 2 tons, and some arrangements had to be devised to take up this load when the specimen broke. It was also most important to arrange that when a weight was added, the additional stress could be applied to the test bar gradually, and without impact. Both these conditions were met by the use of a hydraulic ram and cylinder. This device cushions the load after the fracture of the specimen by allowing the stirrup to fall only as fast as the ram to which it is attached can drive water out of the cylinder through a pipe of very small section. The hydraulic ram is seen in Fig. 1, also the top of the cylinder, showing white amongst the weights. The top of the ram is riveted to the cross-bar of the stirrup; after the fracture of a specimen the ram sinks owing to the load on the stirrup, and drives liquid from the bottom of the cylinder through pipe A and tap B into the copper reservoir C. But this can only occur when tap B is open; when it is closed no liquid can leave the cylinder. Hence any small additional load applied to the stirrup is not transmitted to the test bar, since this load is merely employed in compressing the practically incompressible liquid in the cylinder. It follows that by slowly opening the tap B the load can be applied to the test piece as gradually as desired, and without any appreciable impact. After again closing tap B the load remains on the specimen, but no additional load placed on the stirrup will be transmitted to the specimen; in other words, the valves do not allow of back suction.

The arrangement of the valves and of a pump to allow of the stirrup being raised to the required position for attachment to the spherical nut is shown in Fig. 3. The pump D raises liquid from reservoir C, and forces it into the hydraulic cylinder, provided the tap B be closed. Fig. 1 shows the position of the cold junctions of the two thermocouples X and Y. Behind the machine can be seen the thread recorder Z.

The effective load of the stirrup, that is, its real weight minus the frictional effects of the various parts of the machine, is ascertained by means of a carefully calibrated spring balance. Frequent check tests have shown that the effective load remains constant for long periods of time. The spring balance gave scale readings from 1lbs. up to half a ton, and this range was useful in calibrating the machine for small loads. It was found, however, that the actual load on the specimen was sufficiently accurately expressed by the effective load plus the value of the weights used. In all cases the weights were arranged quite symmetrically with regard to the hydraulic cylinder, this was thought to be desirable in order to avoid any slight tilting effect which might occur in spite of the long bearing of the ram in the cylinder.

Attached to the lower part of the right hand pillar of the machine (Fig. 1) is seen an electric bell. This is put into action by the fall of the stirrup, and is useful in the experiments of the effect on maximum stress of the time under load. The furnace, marked F, is seen in the centre of the machine; it is so arranged that it can be swung out on a hinge near the pillar. This adjustment was found to be very useful in introducing and removing the test bars.

The loads actually used in the experiments varied from nearly 2 tons down to 7lbs. This last was much smaller than the effective weight of the stirrup alone, which was, in fact, nearly 1 cwt. For loads smaller than this separate arrangements had to be made. The stirrup was let down to its

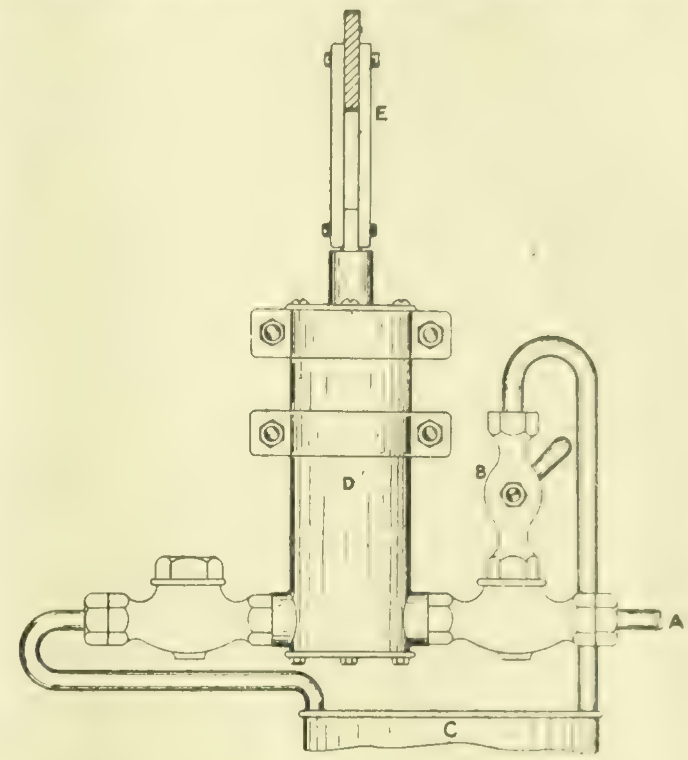


Fig. 3

lowest position, an oak board was then screwed on to the top of the carrier, and on to this was placed a flat, light scale pan of special construction, which weighed only 3lbs.; by working the pump the scale pan could be raised and attached directly to the extension piece in a simple manner. Weights could then be placed on the pan in amounts sufficient to cover the whole range of loads from 3lbs. to 1 cwt. At the beginning of the test the stirrup was lowered slightly, and the scale pan was left hanging freely from the extension piece. When fracture took place the scale pan fell on to the oak boards. The height of this drop could readily be kept very small by adjusting the height of the ram in the cylinder by hand pump and tap, so that it followed closely the extension of the test piece. For very small loads a water load, which could be increased at a slow but constant rate by means of a tap, was used. The water was run into two vessels simultaneously, the vessels being placed symmetrically upon the pan.

This machine is described as it was used in the present research; it is undergoing certain improvements and modifications, partly to allow of a reducing [illegible] being maintained in the furnace, and partly to allow of tests other than those now described being carried out with it. The machine has been made for the [illegible] by Mr. W. W. Strafford, of Crosby, Liverpool, and has given complete satisfaction in use.

(To be continued.)

Motor-bus Accident. — At [illegible] late on Saturday night last a motor omnibus containing a number of passengers skidded in taking a corner and fell on to its side. The outside passengers were hurled into the road and the inside passengers thrown together in a heap. The vehicle was wrecked. Fourteen passengers, together with the driver and the conductor, were injured.

THE GRIMESTHORPE STEAM VALVE EXPLOSION.

BOARD OF TRADE FORMAL INQUIRY.

ON Tuesday and Wednesday last week a formal inquiry was held by the Board of Trade, at the Barnsley Town Hall, into the circumstances attending a fatal explosion, which occurred on July 10th last, from the bursting of a steam stop valve at the Grimesthorpe Colliery, and resulted in the death of Mr. Frank Green, chief mechanical engineer, Mr. John Allen, enginewright, and Mr. H. Duckworth, foreman mechanic. The Commissioners were Mr. A. A. Hudson, K.C., president, and Mr. Alexander Gray, consulting engineer.

Mr. George C. Vaux, solicitor, represented the Board of Trade. Sir William Clegg (Messrs. Clegg and Sons, solicitors, Sheffield) appeared for Messrs. Vickers Ltd., Brightside, which firm were engaged laying a new turbine for the purpose of generating electricity throughout the colliery when the disaster occurred, and Mr. W. M. Gichard, solicitor, Rotherham, watched the interests of the Carlton Main Colliery Company, the owners of the Grimesthorpe Colliery.

Mr. Vaux said the stop valve which exploded was the property of the Carlton Main Colliery Company, Ltd., and was fitted at their colliery at Grimesthorpe. The boilers at the colliery were worked at a pressure of 120lbs. to the square inch, and supplied steam through a range of piping to a 500 kw. turbine driven electrical generator. In or about February, 1910, it was decided to instal another 1,000 kw. turbine driven generator, and the order for them was given to Messrs. Vickers, Ltd. It then became necessary to fit a new range of piping to supply both these turbines. Mr. Frank Green (one of the killed) was the chief mechanical engineer to the Carlton Main Colliery, and was responsible to them for the upkeep and the safe working of the steam and electrical plant. He designed the new range of steam piping and the fittings leading to the two turbines. The contract for supplying, but not the fitting, of the steam piping and two stop valves was given to the firm of Messrs. Needham, Brothers, and Brown, Barnsley, and the two stop valves were 6in. and 10in. respectively. No thicknesses or material appeared to have been specified, but it was stipulated that the piping was to be capable of a working pressure of 100lbs. per square inch, and to be tested up to 200lbs. per square inch. The pipes were made by Messrs. Needham, Brothers, & Brown, and duly delivered to the colliery company, and the same firm gave the order for the stop valves to Messrs. Marsden & Stansfield, of Brighouse. The body and cover of the valve chest were of cast iron. The thickness of the metal in the chest varied from 7-16ths to 10-16ths, and when completed the 6in. valve was tested to 240lbs. per square inch by hydraulic pressure. After being delivered at the colliery and fitted, several tests, or trials, took place, and on each occasion, Aaron Bacon, one of the mechanics, heard several shots of water hammer, which he reported. On the night of July 10th the final trial took place, a man named Duckworth, the foreman engineer, being in charge. He went into the basement and gave instructions to a mechanic named Bacon, in the employ of Messrs. Vickers, Ltd., to open the 6in. valve very slowly. Immediately he did so, water rushed out of the 1in. cock on the steam strainer, and the effect was that the valve burst with a loud report. Bacon shut off the valve at once, and ran out of the place into safety, but Green, Allen, and Duckworth were killed.

After evidence as to the actual occurrence had been presented, Mr. Vaux, on behalf of the Board of Trade, submitted the following issues for the consideration of the Commissioners: (1) Was the steam stop valve which failed properly constructed and fit for the purpose for which it was intended? (2) Did the Carlton Main Colliery Company, Ltd., entrust the design and erection of the new arrangement of pipes at the Grimesthorpe Colliery in or about June and July last to a competent person or to competent persons? (3) Was the new arrangement of pipes for the two turbines when they had been fitted up at the Grimesthorpe Colliery a satisfactory one, and was adequate provision made for draining the pipes of water resulting from steam condensing therein? (4) What alterations, if any, were made in the arrangement of the pipes and fittings before the explosion occurred? Who was responsible for such alterations, if any were made? (5) Who was in charge of the trial of the 1,000 kw. turbine which was to take place on the evening of the 10th July last? Did proper means then exist for freeing the pipes of water? Who was responsible for seeing that the pipes were properly drained of water resulting from steam condensing therein before steam was admitted to the turbine? (6) Were proper measures for safety taken by those in charge on the occasion of the trial of the 1,000 kw. turbine on July 10th last? (7) What was the cause of the explosion? (8) Did the late Mr. Frank Green, chief mechanical engineer to the Carlton Main Colliery Company, Ltd., Mr. John Allen, engineer and enginewright at the Grimesthorpe Colliery, and Mr. Herbert Duckworth, foreman mechanic to Messrs. Vickers, Ltd., know the necessity for properly draining the steam pipes of water? Was the danger of opening the 6in. stop valve and attempting to drain the pipes through the 1in. cock on the steam strainer appreciated by them or any of them? (9) Was the explosion caused by the neglect (a) of Messrs. Marsden & Stansfield, (b) of the Carlton Main Colliery Company, Ltd., or of their servants or any of them? In the latter event, are the Carlton Main Colliery Company, Ltd., responsible for such neglect? (c) of Messrs. Vickers, Ltd., or of their servants or any of them? In the latter event, are Messrs. Vickers, Ltd., responsible for such neglect? (10) Should Messrs. Marsden & Stansfield, the Carlton Main Colliery Company, Ltd., and Messrs. Vickers, Ltd., or any and which of them pay any, and if so, what part of the cost of this formal investigation?

Mr. Hudson, who presided, said they had come to the decision that of those living the manager of the colliery (Mr. Gill) was partly responsible for the cause of the explosion, and also found that Bacon was responsible morally. In their answers to the questions submitted by the Board of Trade, they considered that the valve which failed was properly constructed, and also that the Carlton Main Colliery Company had entrusted the work to a competent person in Mr. Green. They considered, in the first place, the arrangement of the pipes was a satisfactory one. There was no automatic stop-cock, but they did not see why the one provided should not have met the requirements. There had been some alteration made in the arrangement connected with the pump, and the two persons responsible for that alteration were Messrs. Gill and Green. They considered that proper means were not taken to empty the pipes of water, and this was part of the duty of Mr. Green. Proper measures for safety were certainly not taken by those in charge of the turbine on July 3rd. The cause of the explosion was "water-hammer," and Messrs. Green, Allen, and Duckworth, who were in charge of the work, would be quite aware of the necessity for having the pipes properly drained. They must have fully appreciated the danger of opening the 6in. valve when having the pipe drained. The explosion was not due to the neglect of Messrs. Marsden & Stansfield, neither was it due to the Carlton Main Colliery Company, Ltd. The manager and the engineer were partly responsible for the explosion which, though it was not due to the neglect of Messrs. Vickers, Ltd., was contributed to by the neglect of Bacon, one of their mechanics, who should have warned Mr. Duckworth of the danger before he carried out his orders in turning on the valve. They thought that Bacon must have known that a large quantity of water would have accumulated between July 6th and July 10th, when the trial took place. The Commissioners ordered Mr. Gill, the manager of the colliery, to pay £25, and Bacon, the mechanic, £5 towards the expenses of the enquiry.

Fatal Crane Accident. A fatal accident occurred at the Victoria Harbour, Greenock, on the 9th inst. A number of workmen were engaged there loading a cargo steamer with iron, and when a load of about three tons was being swung round the chain of the crane snapped, and the iron fell upon two of the labourers, with the result that one was killed and the other seriously injured.

BITUMINOUS SUCTION GAS PRODUCER.

A DESIGN of suction gas producer for use with bituminous or similar fuel is shown in the accompanying cuts. The apparatus, which is the joint invention of F. H. Livens and H. V. Senior, both of Ruston, Proctor, & Co., Ltd., Sheaf Iron Works, Lincoln, comprises a casing lined with firebrick, into which fuel is fed downwards on to the fuel bed A through a hopper B, surrounded by a water chamber C. The gases coming away from the incandescent fuel pass up through the annular space D between the hopper and the outer wall of the producer. The fuel chamber B is extended in a downward direction low enough into the fuel bed for combustion to take place in the zone marked X, for it to form part of the fuel bed also. To this chamber B a downward current of air and vapour is supplied through the branches E, and the air and vapour passing upwards through the firebars and at F from a water-sealed ashpit, are at the same time restricted. By this means the gases from the freshly-ignited fuel are compelled to pass through fuel which is already incandescent and their tarry vapours are thereby converted into fixed gas. The producer is thus converted to one of the "up and down" draught kind, but without the usual inconvenient side exits for the gases, which are liable to be choked up in time.

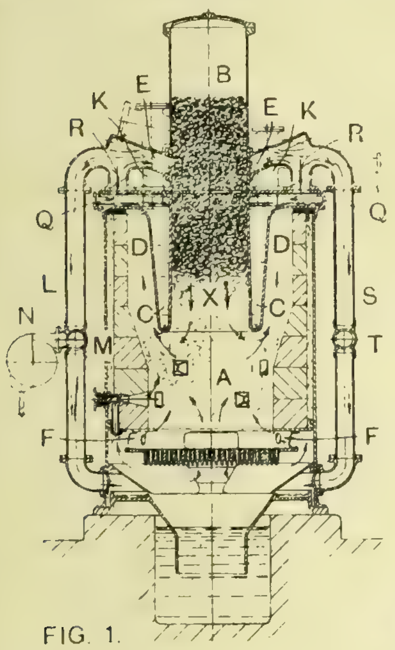


FIG. 1.

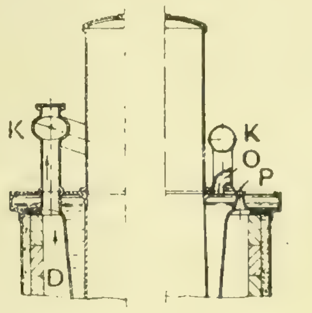


FIG. 2.

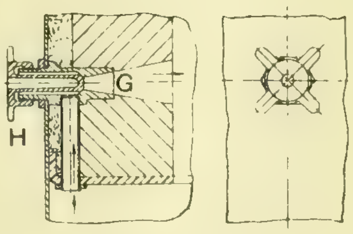
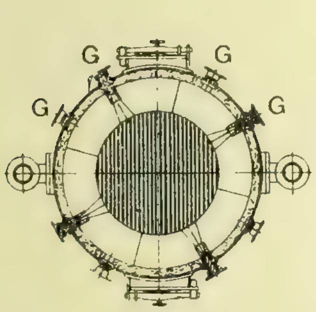


FIG. 3.



BITUMINOUS SUCTION GAS PRODUCER.

In order to regulate the height of the incandescent zone of the fuel bed so as to make sure that the fuel at the base of the fuel chamber X shall be thoroughly incandescent, a series of openings G are provided at intervals round the circumference of the producer casing and at different heights by which air and vapour can pass to the fuel bed from below the firebars through nozzles; one of these is shown in detail in Fig. 3, where it will be seen that the opening through the nozzle can be varied by turning the screw plug H, a screw thread being formed on the outside of the nozzle so that when the plug H is withdrawn altogether, a poker can be used without doing damage to the screw thread. The gases leave the annular chamber D by multiple exits K. The water space C round the hopper B may be made to supply part or all of the vapour required to mix with the air, but this water space may in some cases be omitted and the hopper protected by firebrick or other refractory material, in which case a vaporising chamber can be formed in the outer case of the producer.

In Fig. 2 is shown an inlet for the air O into the space Q above the water space C, and a hole P for passing down a bar to remove clinker if formed on the firebrick round the fuel bed. The air combined with the vapour formed in the space Q leaves by the valves R and can either pass into the fresh fuel chamber B by the branches E or down the pipes L S to the ashpit and firebars, the amount passing to the latter being varied by opening or closing the valves M T; when starting the fire these valves are turned so that T is quite closed, and air is forced by the fan N through the valve M directly to the ashpit in the usual way until the fuel in the fuel bed below the hopper mouth is quite incandescent. The valve M is then reversed so that air is forced upwards and through the branch E into the fuel chamber to create a down draught and extend combustion into the zone X. During this operation the valves R are closed so that the vapour space Q and the air inlet O are shut off. After the fuel in the zone X is quite incandescent, the valve M is turned to shut off the fan N and make a throughway of the pipe L, and the valve T is opened to make a throughway of the pipe S; the valves R are also opened so that air and vapour can pass from the space Q through the branches E to the fuel chamber B, and by the pipes L S to the ashpit, and afterwards through the grate bars, as required, by the valves M T to ensure that the draught through E shall be always sufficient to keep up incandescence in the zone X. This zone of incandescence in time will extend upwards as far as the branches E, and it is not detrimental if it does, but the continual downward movement of the fresh fuel from the space above these branches keeps such upward extension of the incandescence at a lower limit.

A PRACTICAL APPLICATION OF FLUORESCENCE IN TESTING OILS.*

BY ALEXANDER E. OUTERBRIDGE, JUN.

THOSE of you to whom the process of casting metals is familiar know that in the operation of moulding considerable attention has to be given to the production of the "core"—that part of the mould which forms the hollow portions of the casting. In cylinders for internal-combustion engines, or in locomotive injectors, &c., the interior of the casting is by far the more important part, and the accuracy of reproduction of this from the mould depends, of course, mainly on the excellence of the cores used. In view of the significance of the factor, core-making is, and has always been, regarded as a distinct and separate branch of the art of moulding.

Cores were formerly all made by "ramming" a mixture of sand and such adhesive materials as clay, flour, molasses-water, or other constituents into a "corebox" of suitable configuration, thereby producing a compacted mass that could be removed from the box without injury. The "green" core, as this was termed, was transferred to an oven, where it was slowly baked until hard. In this condition it was ready for insertion in the mould.

This method of core-making is still in universal use for large work, though for smaller cores a radically different process has come into vogue. A kind of quicksand is prepared by intimately mixing, in a suitable machine, beach or bar sand (called by moulders "sharp-sand") and some vegetable oil (preferably linseed oil) in the proportion of from 30 to 100 parts of sand to one part of oil. The mixture, being mobile, is poured into the corebox to well fill the latter, and the excess is simply scraped off with a straight edge drawn across the top of the box. Provision is made for taking apart the latter and leaving the fragile core on an iron plate on which it can be transported to the core-oven without injury.

These oil-cores so produced are not only far cheaper than "rammed" cores—they are made by unskilled labour in a fraction of the time taken to make rammed cores by skilled labour—but are, moreover, extraordinarily tough when baked, and are impervious to moisture. They require no "venting," as but little tendency to form gas is manifested on pouring the metal.

In consequence of these advantages, the adoption of this method of making cores has during recent years notably increased, so that, at the present time, large sums are being spent annually by industrial concerns in the purchase of oil for their production.

It has been already stated that the best binder for making oil-

* Abstract of address delivered before the Metallurgical Section of the Franklin Institute.

sand cores is linseed oil. In the last few years the price of this has risen considerably. "Soya" oil, pressed from beans grown in enormous quantities in China, has been found an excellent substitute. The cost of this is about 2s. 6d. a gallon for fine grades. The very best substitute for linseed oil is, however, said to be crude whale oil, which costs about the same as "Soya" oil, although its use is objected to on account of the unpleasant odour emanating from the core-ovens during the operation of baking. Cotton-seed oil has been used, but, as a large proportion of oil to sand is required, no economy results.

The high cost of the fine grades of these vegetable oils has brought about the introduction of so-called "core-oils." These usually consist of linseed oil as a base and mineral or resin oil, or both. Experience has shown that the presence of the latter "non-drying" oils materially affects the cores, renders them brittle and subject to rapid deterioration, and is, therefore, undesirable. Hitherto, however, no method except the costly one of chemical analysis, usually impracticable in industrial plants, has been available for detecting their presence and amount in oils supplied.

The method about to be described to you was some months ago tried out and put into practice at the works with which I am connected. The basis of the method is that hydrocarbon oils (incorrectly termed "mineral") and resin oils exhibit, under the rays of reflected light, the phenomenon known as fluorescence and termed in this connection "bloom," while vegetable oils exhibit no such fluorescence or "bloom." All these oils appear of their natural colour in transmitted light.

In both mineral and resin oils the degree or intensity of bloom depends on the degree of refinement of the oil, and is generally in proportion to its natural colour. Mineral oil exhibits, however, green fluorescence, while that exhibited by resin oil is blue. Fluorescence is the property inherent in certain substances of becoming self-luminous on exposure to "ultra-violet" or "actinic" rays of light. Such rays are present to some extent in daylight, and under this the phenomenon can be observed to a certain degree.

As the result of investigation using the various forms of electric light, such as that given by carbon or tungsten filament lamps, by Cooper-Hewitt mercury vapour tubes, by ordinary and flaming arcs and by enclosed arcs, it was found that the intensity of bloom in bloom oils was particularly increased under the rays of the latter. The utilisation of this observation in the practical detection of adulteration and quantity of adulteration in vegetable oils forms the subject matter of this paper.

When it is remembered that the method of chemical analysis for the detection of a small quantity of impurity is very costly, that the method of studying fluorescence by means of quartz prisms and lenses mounted in a spectroscope has the same disadvantage, and that, moreover, skilled manipulation by highly-trained observers is essential to both, the significance of the simple method under consideration becomes at once apparent.

That the method is efficient so far as discrimination between nature of oils is concerned is shown by the fact that under the rays of the enclosed arc neither linseed oil, "Soya" oil, corn oil, cotton-seed oil, China bean oil, China wood oil, nor, in fact, any of the vegetable oils, show the slightest trace of fluorescence. On the other hand, all mineral and resin oils, except the very volatile products of petroleum, such as gasolene and petroleum ether, show marked bloom, as also do samples of so-called No. 1 and No. 2 lard oils, while pure white strained lard oil is seen to be free from bloom. This latter introduces the question of oleic acid in lard oil, said to be in itself fluorescent, and the method may furnish a novel means of determining the amount of such acid present. The slight fluorescence of lard oil differs in appearance from that of mineral or resin oil, hence adulteration of lard oil by either of the latter may be detected by the method.

Processes of chemical treatment are supposed to have been discovered to "de-bloom" mineral and resin oils, thus facilitating their use as adulterants of the more expensive vegetable oils. There is at the present time a large trade in such oils. Samples of de-bloomed oils of various grades and colours were obtained. Such exhibited no fluorescence in bright sunlight or in the light from the ordinary arc. On exposure to the rays from the enclosed arc they are, however, seen to possess distinct bloom.

A metal-cutting compound now being sold as "mineral lard oil"—its name indicates its composition—shows strong fluorescence. Under the enclosed arc kerosene is seen to become a beautiful blue colour. Cheap fuel oil from the storage tank becomes quite opaque and entirely self-luminous. Resin oils of different grades and resin oil mixed with turpentine exhibit the phenomena.

Pure linseed oil and Pennsylvania fuel oil, diluted with a small quantity of kerosene, are seen to be indistinguishable under transmitted light, while under the arc the contrast between them becomes very forcible. The demonstration shows that no misstatement is made in saying that any kind of mineral or resin oil can be distinguished from any kind of vegetable or animal oil. Further, if the latter oils be adulterated with the most minute quantity of the former the impurity can at once be detected by the method, and in many cases the nature of the adulterant can be at once stated. The quantity of adulteration present is determined from the intensity of bloom produced in oils free from bloom; the nature of the impurity from the green or blue colour.

By preparing a set of standards of pure linseed oil with $\frac{1}{10}$, 1, 2, 3, 4, &c., per cent. adulteration with mineral or resin oil, in glass test-tubes mounted in a suitable frame against a dark background, a means is provided whereby the proportion of impurity in any adulterated linseed oil can be quickly determined by colour comparison on exposure to the enclosed arc. Such standards furnish a "scale of fluorescence" somewhat similar to the well-known carbon colour scale used in steel foundry laboratories for rapidly determining by colour comparison the proportion of carbon in an acid solution of steel.

These standards, having linseed oil as a base, may be used for the examination of any adulterated vegetable oil, but for lard oil a special set of standards with pure lard oil as a base must be made up. A set of standards was prepared with so-called bloomless mineral oil as the adulterant for the purpose of readily detecting the presence and amount of such adulterant in any sample of vegetable oil.

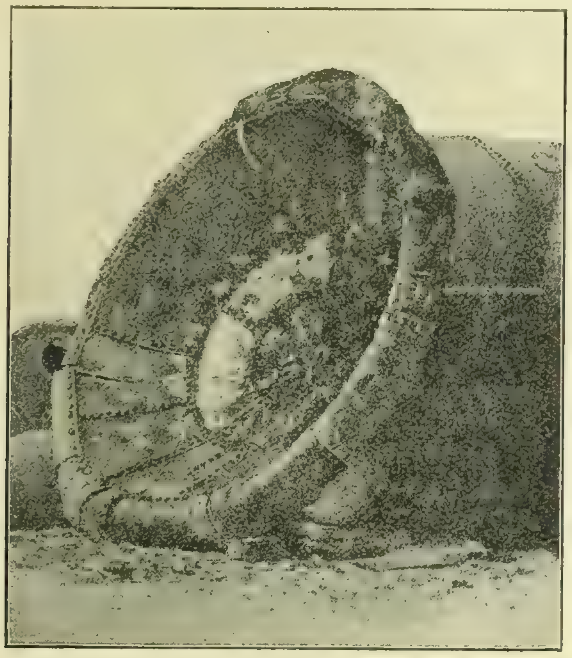
Detection of the presence of a combination of mineral and resin oil adulterants in one sample of vegetable oil is rendered possible by virtue of the colour of bloom imparted, although the "quantitative" determination of the amount of adulteration is at first difficult. In cases, too, where the adulteration of vegetable oils exceeds 10 per cent. it is necessary, in order to correctly estimate the exact amount of it, to dilute the sample with a known quantity of the pure oil, quantitatively determine the adulteration in this diluted oil, and thus in the original sample by calculation. This procedure is necessary from the fact that comparison of colour value is impossible when the bloom is of such intensity as to produce apparent opaqueness.

In practice it has been found advisable to prepare standards with fluorescent oils of different grades as adulterants. Crude mineral or resin oils are much darker in natural colour than refined oils from them, and the colour of the oil by transmitted light is often a guide to the nature of the adulterant employed, and consequently furnishes an indication of the proper set of standards necessary in making the "quantitative analysis" by comparison of fluorescence.

In conclusion, this practical application of fluorescence to the testing of oils for industrial purposes is not, of course, intended to furnish a method to supplant chemical analysis, but merely to afford a means of rapidly ascertaining whether an expensive vegetable or animal oil is or is not free from suspicion of adulteration. At the same time, however, the method is so sensitive in the case of mineral oil adulterants most commonly used as to furnish a correct indication of the amount of adulterant present. The fluorescent tint is one so characteristic that after a little practice it cannot be confused with the slight fluorescence of some oils in which no mineral oil is present. The fluorescent test for kerosene adulterant is, however, not sufficiently sensitive to be of practical value, for the reason that kerosene is not of itself fluorescent enough to tinge other oils to which it is added in small amounts.

SAFETY VALVES ON OIL STILLS.

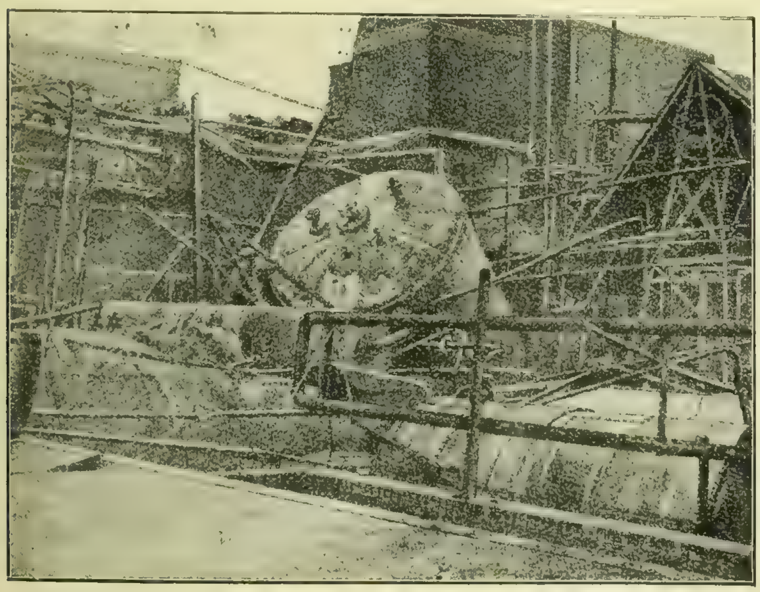
SOME of our older readers may be able to recall certain extremely disastrous explosions of vessels used for the distillation of tar or oil. They invariably occurred as a result of excessive pressure from the choking of the "worm" in the still by the condensation of certain constituents, such as wax, carried over in the distilling process. Ordinarily these vessels were worked without any safety valve, as the outlet of the worm when in proper working order was open and there was no pressure in the evaporating vessel. But with the choking of the worm, danger at once arose, and the



OIL STILL EXPLOSION.—BOTTOM OF STILL AFTER EXPLOSION.

explosions were often of a deadly kind, as the inflammable contents of the still caught fire and were scattered around like a discharge from a volcano. After a time the users of these vessels adopted the precaution of equipping such vessels with pressure gauges to give warning, and safety valves to afford relief if necessary.

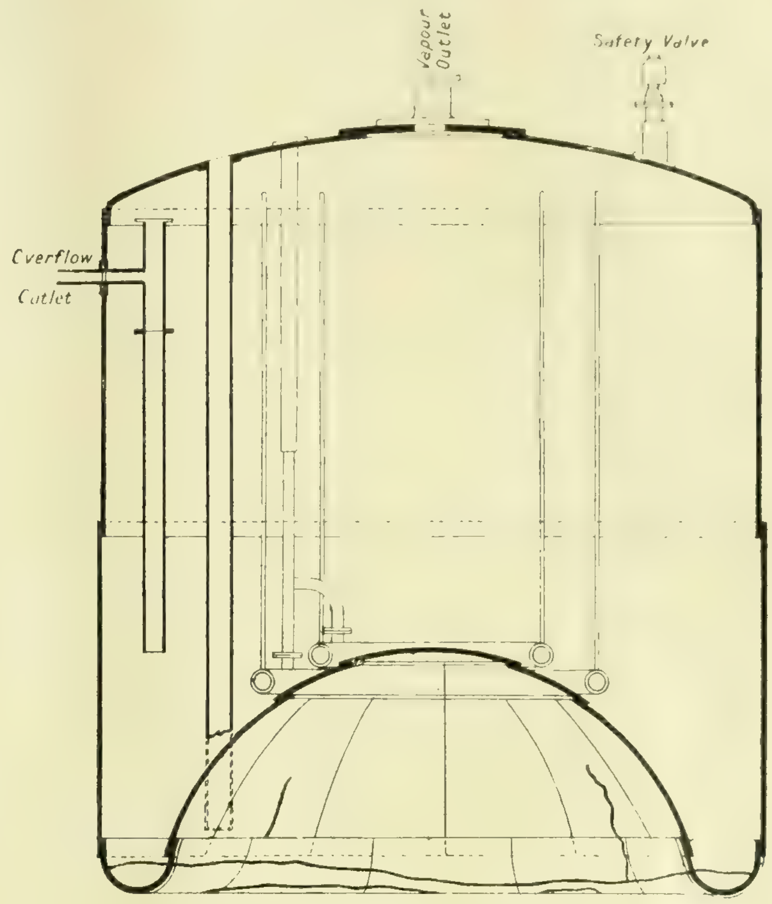
A recently published Board of Trade report shows that even when safety valves are affixed care should be taken not to depend upon it blindly unless it is large enough to provide

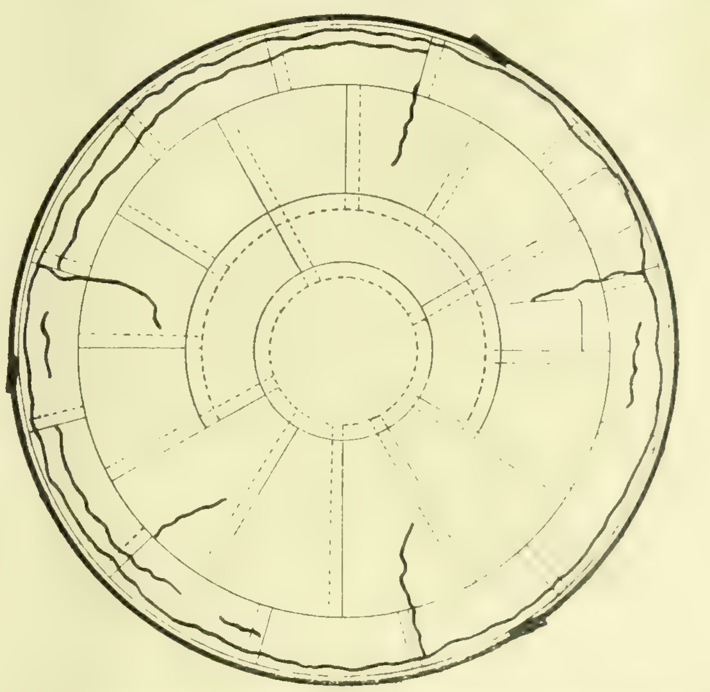


OIL STILL EXPLOSION.—VIEW OF STILL AFTER EXPLOSION.

against a sudden access of pressure, as this may ensue with much greater rapidity than in an ordinary steam boiler, in the event of the feed supply being turned on, when the still has boiled dry and become overheated, owing to the much more volatile character of oil as compared with water. From the report in question (No. 2,085), it appears that the still, which was about 9ft. in height by 9ft. diam., and used for distilling creosote oil, had been allowed to boil dry, owing to the feed supply pipe getting choked. When the obstruction was removed, and the feed turned on again, the over-heated plates generated vapour so rapidly that the safety valve, which had a free area of escape of only 2 sq. in., and was loaded to about 4lbs. on the inch, was incapable of relieving the pressure so suddenly generated, with the result that the bottom was blown out and the body of the vessel shot over a wall, where it crashed into another part of the works, as shown in accompanying photo views.

Fortunately the explosion occurred at five o'clock in the morning, before the day workmen had arrived, and when no person was about, so that there was no injury to life or limb,





OIL STILL EXPLOSION.—SECTIONAL ELEVATION AND PLAN OF STILL, SHOWING POSITION OF FRACTURES.

but the results might easily have been disastrous, for the explosion was followed by fire, and in view of the possibilities demonstrated by previous disasters it behoves all users of oil stills to recognise that when the safety valve blows off danger exists, and the fire should be at once extinguished. Further, safety valves should be of ample area to prevent the sudden accumulation of pressure which is likely to accrue from overheating. It may be remarked that this is the second still explosion which has occurred at these works, and further, that the still was not insured or inspected by any independent authority.

PELLETS AND SEGREGATION IN IRON CASTINGS.*

BY E. L. RHEAD, M.SC. TECH. F.I.C.

THE segregation and concentration of the constituents of cast iron has an important bearing not only on the characters occasionally displayed by iron when some extraordinary features such as pellets, &c., are prominent, but also on the ordinary properties of the metal. If no such separation occurred, the use of cast iron for the purpose for which it is now employed would be impossible.

The complex nature of the material is known more or less to all intelligent foundry men, and the names of its constituents have become quite common words in use. Any foundry man who could not talk of silica, manganese, carbon, and the rest would be considered very much behind the times. Many, however, who talk freely do not appreciate the manner in which the substances occur, or the quantities of the substances of which they are talking. It is this kind of somewhat loose talk that has led to so many misunderstandings, and, in some cases, prejudice to interference by chemists in the work of the foundry Quotations of the percentage composition of cast iron are nowadays in every man's mouth, but it is doubtful whether everyone appreciates the meaning of the quantities he talks about.

The general idea entertained, &c., as simple individual substances. One per cent. of silica suggests that of every hundred particles, one is silica and 0·5 per cent. phosphorus; that of every 200 particles, one is phosphorus. These quantities may or may not appeal to you as large amounts according to the habit of mind. It will be more apparent if some actual evidence of what is meant is visibly shown. A cubic foot of a fairly close iron weighs more or less about 4 cwts., say 450lbs. If it contains 3 per cent. carbon, 2 per cent. silica, 1 per cent. phosphorus, 0·5 per cent. manganese, 0·15 per cent. sulphur, the actual weights are: 13lbs. 8ozs. carbon, 9lbs. silica, 4lbs. 8ozs. phosphorus, 2lbs. 4ozs. manganese, 10¾ozs. sulphur; total, 29lbs. 14¾ozs. The volume of these cannot fail to strike everyone who for the first time considers the matter in this light, nor can he fail to appreciate the enormous effects they must necessarily exert on the metal.

This, however, is not all. The weights of the substances do not represent the whole effect either as regards weight or the nature of the substances in the form in which they occur in the iron. Only one of them—carbon—occurs in the metal in the free state. The rest and some of the carbon are chemically combined, silica, phosphorus, and sulphur with the iron and manganese.

It must not be forgotten that chemical combination destroys the specific properties of the bodies that combine and produces fresh substances with properties quite distinct from the original substances.

Thus carbon produces the carbide Fe_3C, in which the carbon only amounts to one fifteenth of the whole, or 6·76 per cent.

Silicon forms a silicide Fe Si, in which the silicon is only one-third, or 33·3 per cent. of the compound.

Phosphorus forms phosphides Fe_3P or Fe_2P_2: the latter with 31·1 per cent., and the former with 15·5 per cent. only of phosphorus.

Sulphur forms a sulphide Fe S or Mn S, with 36·3 per cent. only of sulphur.

Hence 1 per cent. of combined carbon represents 15 per cent. of carbide; 1 per cent. silicon, 3 per cent. of the silicide; 1 per cent. phosphorus, at least 15 per cent. of the phosphide; and 0·1 per cent. sulphur, nearly 0·3 per cent. of the sulphide.

Speaking generally, on this showing, something like 5 per cent. to 7·5 per cent. of silicide, 12 per cent. to 14 per cent. of carbide, and 10 per cent. of phosphides may be present in an ordinary casting. The rest is iron and the graphite.

It will be seen that the properties of the metal will depend on the readiness and completeness with which these bodies mix with each other and with the remainder of the iron, both when molten and after cooling and becoming solid. If they are completely soluble, no separation will occur, and the metal will have a uniform structure.

Saturated Solutions.—When a body dissolves it becomes diffused through the other known as the solvent, and forms a solution. The solution is said to be saturated when under the existing conditions no more of the substance will dissolve This point may be arrived at in two ways:—

(*a*) By adding the dissolving body till no more is taken up.

(*b*) By altering the conditions so that under the new conditions the solution is saturated.

A supersaturated solution is one that under the existing conditions contains more of the dissolved body than it is capable of permanently retaining; such a condition often results from slow cooling without disturbance. The excess separates when agitated, or when a crystal of the dissolved body is added.

The amount of a substance taken up by a solvent depends on various considerations. It rises with the temperature and may increase or diminish in the presence of other bodies. In a melted mass, the solubility of the constituents is further influenced by the temperature or solidification of various constituents. The withdrawal of these from the mass as the temperature falls will influence the solubilities of the remainder and the degree of concentration attained.

The lowering of melting points by substances in solution is well known. The diagram is a curve illustrating the behaviour of a solution of salt. On one side the curve shows the temperature at which the water begins to freeze with increasing amounts of salt; on the other the temperatures at which salt separates from the solution. In all solutions containing salt no water separates at the freezing point of water.

A solution containing 23·5 per cent. solidifies completely and at once at 22° C. All solutions behave in a similar manner. There is a certain strength of solution from which neither constituent separates, and which solidifies as a whole at the lowest temperature attained in the series. It is the eutectic.

In every mixture undergoing solidification there is the tendency to produce mixtures whose melting points are nearer those of the eutectic composition.

The complex nature of cast iron causes the changes to be very complicated, and the raising or lowering of the mean melting point would be dependent on all the constituents. Such a system has not up to the present been fully investigated. In such a system it will be seen that the possibilities are very great. As the temperature falls the excess of one constituent after another may separate, and the withdrawal of these from the main mass may cause a separation of others, either separately or in solution, leaving at each step a fusible residue constantly depleted of the bodies of higher melting point.

The greater the range of temperature over which this occurs the greater will be the degree of separation possible. Quenching and rapid cooling prevent the completion of the changes, but they may be recommenced and completed by heating to the temperature at which it was arrested as in annealing. The highly complicated structure of cast iron is due to these causes, and its strength, uniformity, and other properties are dependent on the selection of a mixture that under the conditions of treatment will give the structure required.

Separated bodies may therefore be of two orders

1. Those that separate from a saturated solution.
2. Those that are left fluid or rejected in the solidification of a mass.

The second division may be divided into (a) those left fluid which solidify as a whole, and (b) those that separate after solidification. Class 1 will comprise bodies of high melting point and low solubility.

Graphite.—When cast iron is perfectly melted all the carbon is in solution. The solubility depends on the temperature and the presence or absence of other bodies Metal in the ladle often contains less carbon than the original mixture, due to the pig iron having been produced and saturated with carbon at a higher temperature than is attained in re-melting. Often on standing the molten metal throws up kish as a scum. The graphite is separating while the metal is molten, and being comparatively light is floating up Its production points to the fact that for its composition the metal contains more carbon than is suitable for making strong castings Even when poured, such metal will, as it enters the mould, continue to separate carbon, and as long as it is fluid this will collect and rise to the highest attainable point as in the example shown It may be the edge of a hollow casting

After solidification has commenced, the remaining carbon will separate in the usual manner, and the size of the flakes will depend on the rate of cooling

* Paper read before the Manchester section of the British Foundrymen's Association February 3rd 1912

Such metal may make satisfactory this casting, providing the separated graphite can be got rid of in a riser or head, or similar way.

When the iron is not saturated at the pouring temperature the metal may enter and fill the mould completely without any separation taking place, but as it cools, the saturation point is passed, and a deposit of carbon commences. Nuclei are first formed, and on these further deposits take place as the temperature falls and the saturation limit is lowered. This continues as long as the metal is sufficiently hot to permit of free movement and produces coarse graphite. Carbon concentration occurs in the vicinity of the graphite flakes. As the freedom of movement becomes more restricted, the carbon particles cannot be so readily transmitted, and fresh centres of deposition result, producing finer graphite. This continues till cooling is completed.

When the saturation limit is not reached till the metal has cooled considerably and freedom of movement of the particles is restricted, coarse graphite does not form.

If at any stage the liberty of movement is arrested as by cooling, the condition of the constituents remains as it was at the temperature at which it was arrested.

Slow cooling, therefore, permits the most perfect separation.

Certain bodies, such as silicon, in some form of combination promote the decomposition of the carbide and lower the saturation limit, thus promoting the formation of graphite, and irons yielding kish are usually high in silicon.

Effects on Casting.—The separation of this lighter body, occupying a larger space than it did in solution helps to compensate for the contraction taking place as the metal cools, and thus prevents the development of internal stresses of as great a magnitude as would otherwise be produced, and the separation of the temper graphite that occurs when the separation is recommenced and completed in softening and annealing or malleablising is responsible for the increase in size of the casting.

The action of the silicon in promoting decomposition of the carbide and segregation of the graphite is well shown by the absence of graphite from white iron—always low in silicon—and the retention of the carbon as the carbide further by the lower temperature at which the separation recommences when irons containing more silica are heated. The following figures by Charpy will make this clear:—

	With Silicon, Per Cent.	Carbon, about	Temperature at which Carbon begins to Separate.
1	0·07	3·60	1,150° C.
2	0·27	3·40	1,100° C.
3	0·80	3·25	800° C.
4	1·25	3·2	650° C.
5	2·1	3·3	650° C.

No. 5 deposited 85 per cent. of its carbon during six hours' heating at 650° C., leaving 0·52 in the combined state.

Hardness. — The decomposition of the carbide and the separation of graphite secures a soft casting, and the ordinary softening process is carried on to continue the change with which the rate of cooling has interfered.

The formation of graphite flakes divides up the casting into areas in which the silicon and the remainder of the carbon are present.

Phosphorus.—Phosphide of iron is the most fusible constituent of the iron, and consequently lowers the melting point of solutions into which it enters to a greater extent than any other substance present.

It is completely dissolved by cast iron when the metal is molten.

Iron free from carbon will retain iron phosphide in solution up to 1·7 per cent. phosphorus. It is not soluble in the carbide on cooling, and as the carbon contents increase, the phosphide is separated as the metal cools. It is not, however, completely separated by as much as 3·5 per cent. carbon.

Silicides retard the separation, and much may be retained in solution till some of the graphite has been separated. As the temperature falls, the excess of phosphide forms with the other fluid portions a liquid portion having a low melting point. This liquid portion continues to deposit some of the constituents of higher melting as the temperature falls, becomes enriched in phosphorus, and remains molten till the final solidification.

It consequently occupies in general middle areas, which may unite and form a meshed network showing up in patches on sections of the metal. The continuity of these will depend on the amount of phosphorus and composition of the metal and rate of cooling. If they are continuous, the properties of the casting will be dominated by those of the phosphide. It will be brittle when cold and weak when hot. It will also be harder.

The brittleness cold unfits such castings for strong machinery or where jarring and vibration have to be encountered.

The weakness hot may lead to fracture while cooling where hard parts of the mould offer resistance to contraction.

The inferences to be drawn are clear. In strong, close-grained castings, the silicon contents of which are kept low to ensure closeness and strength, phosphorus must be kept low. In some cases, for great strength 0·2 or 0·3 is the maximum.

The relative behaviour of carbon silicon and phosphorus will explain the vagaries observed when examining different samples of cast iron in which the phosphorus contents as shown by analysis are the same. In some cases a singular but well-known effect is produced, viz., the formation of pellets. These sometimes occur in the metal, occupying a kind of cell, which they often do not completely fill, a crack being visible. Sometimes they are found loose in cavities in the casting. Examples of both kinds are shown. The loose ones were taken from a large cavity near the end of tool bed, the metal of which had the following composition:—

		The pellets have the composition—	
Si	1·9	Si	2·4
P	1·5	P	4·33
M	0·78	S	0·44
S	0·11		

The other examples examined have yielded—		The iron contained—	
Si	0·8	Si	2·26
P	4·06	P	1·9
C	1·24	C	3·5
M	0·6	M	0·6

The brilliance, hardness, shape, and brittleness will be noted.

Those found embedded in the metal have resulted by the separation of the phosphide while the matal has been sufficiently fluid to permit of its contraction to a globular form. The specific gravity of the pellets not being much different from the metal, the tendency to rise has not caused them to float up. In all cases where such pellets have been observed by the author the metal has been highly carbonised and not especially high in silicon. The extrusion of the pellets into cavities has resulted from the contraction of the already solidified part of the casting squeezing the still liquid eutectic into the cavity, the direction of cooling favouring this. In the case of the tool bed in question, the hole in which they were found was a shrink hole near where the casting had been run, and was of considerable size. It was produced by the abstraction of metal to feed the casting, this part remaining hot and fluid longest because all the metal had passed this point and heated up the mould. This state of affairs favoured the expulsion of the fusible eutectic towards the cavity.

The difficulties in drilling and machining arising from the hardness and the tendency of embedded pellets to drop out is well known. Another point connected with segregation of the phosphide is the possibility of producing hard places in castings where no separation of pellets takes place.

In very thin castings it is the universal practice to use phosphoric iron both for success in casting and to obtain as sharp a casting as possible.

If the metal cools in running over the surface of the mould, it follows that the least fusible portions will be first abstracted, leaving a more highly phosphoric fusible metal to go forward. This would result in the part furthest from the runner being more phosphoric and harder in consequence.

If in filling such a mould two streams of metal meet, they may amalgamate perfectly owing to the greater fluidity caused by the presence of the phosphide, but give a hard place across the junction as the result.

Sometimes in the interior of pig iron portions are met with of a different character from the outside of the sample. Such a case was investigated recently, with the following results:—

	Silicon.	Phosphorus.	Sulphur.
Outside	2·7	0·378	0·072
Inside	2·7	0·49	0·096

The figures show the same sequence, and pointed to the fact that the more fusible constituents were collected in the last solidifying portions.

INITIAL CONDENSATION IN STEAM ENGINE CYLINDERS.*

BY PROF. A. L. MELLANBY, D.SC.

THE nature of the problem to be discussed can be readily seen by a glance at Fig. 1, which shows an indicator card from the high-pressure cylinder of a compound engine. The cylinder volume may be represented by the length LM and on the same scale NL will indicate the clearance volume. If it be assumed that the cushion steam is dry, and saturated near the compression point, the dotted line will represent the volumes occupied by this steam at different pressures. If, therefore, only the amount of steam shown by the indicator card were passing through the engine the line BC would represent the volume of the steam that had entered the engine up to the point of cut-off. The line DK represents, however, the volume which the actual quantity of steam that has passed through the engine would occupy if it were dry and saturated at the different pressures. We have, therefore, to find some reason for the difference—represented at cut-off by CD and at release by HK—between the indicated and actual weights of the steam used.

The most popular explanation is that this difference is due to initial condensation. The exhaust steam is said to cool the cylinder walls, so that when fresh steam is admitted some of it condenses upon the colder metal. This condensation up to the point of cut-off would be represented by CD. This explanation appears to be quite feasible until it is critically examined and certain experimental observations are made.

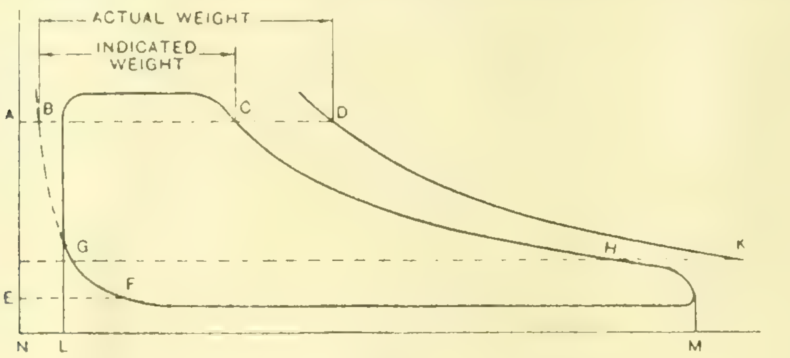


FIG. 1.

The following remarks are intended to show that the quantity of steam initially condensed is much smaller than is generally supposed.

It is quite obvious that the metal in contact with the steam will be alternately heated and cooled, and thus will in turn absorb and give out heat. There must, therefore, be some initial condensation during admission and some re-evaporation during expansion. Note, however, that the amount of this condensation and re-evaporation will depend altogether upon the temperature range of the metal itself.

It can be shown that if a metal surface undergoes a simple harmonic periodic temperature change, the heat absorbed may be represented by the following formula:—

$$\text{Heat absorbed per square foot per cycle} = \frac{2\ T}{\sqrt{N}} \text{B.Th.U.'s.}$$

Where T = temperature range in degrees Fah.
N = number of cycles per minute.

In the steam engine the temperature changes do not follow the simple harmonic law, but it has been shown that the above formula may be applied with very little error. It is obvious, then, that if the temperature range of the metal can be measured the amount of steam initially condensed may be readily calculated. Various attempts have been made to measure the actual temperature range in an engine under working conditions. The late Mr. Bryan Donkin was, perhaps, the first experimenter in this direction, but as he used mercury thermometers his attempts were not very successful. One important result obtained by him was that the average temperature of the metal was generally considerably higher than the average temperature of the steam. Although it does not appear to have been noticed, this conclusively proved that the temperature range of the metal is much less than that of the steam. The most noteworthy experiments, however, were those made by Messrs. Callendar and Nicolson. They showed that the temperature range was much smaller than had ever been suspected even when the engine was running at a moderate speed. The result of one of their experiments may be seen from the table below, which gives some steam and metal temperatures when the engine was running at 73 revs. per minute.

	Maximum	Minimum	Mean.	Range.
Temperature of steam (° Fah.)...	324	212	245	112
,, metal ,, ...	304·4	297·6	301	6·8

If one refers to the formula for the heat absorbed per cycle it will be seen that the temperature range of 6·8° Fah. would account for a very small amount of initially-condensed steam. It was as the result of these experiments that Messrs. Callendar and Nicolson brought forward their theory that initial condensation was as a rule comparatively unimportant and that the greater part of the steam lost in a steam engine was due to valve leakage. Experiments of a similar nature have been made upon a gas-engine cylinder by Prof. Coker, who has found that in this type of engine also the fluctuations of temperature in the walls are very small.

The laws governing the steady rate of steam condensation upon metal surfaces are still imperfectly known. As the result of a limited number of experiments, Messrs. Callendar and Nicolson suggested that this rate could be expressed by the following equation:—

Heat given out by steam per square foot per second

$$= 0{\cdot}74\ (T - \theta)\ \text{B.Th.U.'s}$$

Where T = temperature of steam, and θ = temperature of metal in degrees Fah.

From an elaborate series of experiments made at the Glasgow Technical College by Mr. Gordon C. Webster, it appears that the velocity and the density of the steam have some influence upon the rate of condensation. For high-pressure steam moving at the velocities generally existing in steam-engine ports, this formula gives, however, a fairly close approximation to the actual amount of condensation.

It has already been shown that the temperature fluctuation of the cylinder walls is very small, so that if the average temperature of the clearance surface be known, the amount of initial condensation can be calculated with approximate accuracy by using this simple formula for steady condensation. A thermometer inserted into a conveniently-situated hole will give the average temperature of the metal, and the indicator card will give the necessary information about the steam temperature. So long as the steam temperature is above that of the metal condensation will be taking place.

Examples will now be given to show that the theories of Callendar and Nicolson are supported by other experimenters, and that they supply a reasonable explanation of many of the phenomena observed in steam-engine trials.

Particulars from the High-pressure Cylinder of a Compound Engine.

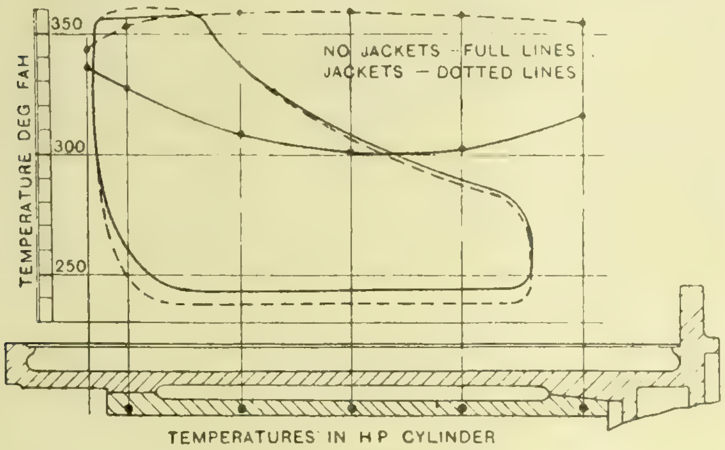
	No Jackets	Jacketed
1. Steam used per hour (lbs.)	2,184	1,980
2. Indicated weight at cut-off (lbs. per hour)	1,431	1,470
3. Indicated weights at release	1,781	1,760
4. Difference between actual and indicated weights at cut-off (lbs. per hour)	753	510
5. Difference between actual and indicated weights at release (lbs. per hour	403	220
6. Increase of indicated weight between cut-off and release (lbs. per hour) .	350	290
7. Mean temperature of clearance surface (degrees Fah.) .	335	342
8. Mean temperature of steam (degrees Fah.) .	284	282

These trials are to some extent illustrated by Fig. 2. It will be noticed that the indicator cards are here shown with temperature substituted for the usual pressure ordinates. These temperatures have been obtained from the steam tables on the assumption that the steam is always at saturation temperature during its stroke. On the same scale the average temperature of the metal along the cylinder is shown. The temperatures have been obtained by thermometers inserted in the metal at the points marked by the circles. As would be

* Paper read before the Institution of Engineers and Shipbuilders in Scotland, November 21st, 1911.

expected, the jacketing has raised the temperature of the metal very considerably.

Line 4 shows that in the engine without jackets there is an apparent initial condensation of 753lbs. per hour, and that the application of the jackets has reduced this to 516lbs. per hour. The apparent re-evaporation between cut off and release is shown in line 5 to be 350lbs. per hour for the unjacketed, and only 290lbs. per hour for the jacketed. That is to say, the hotter the walls the less readily will the water on them be evaporated. It is obvious that these figures cannot be explained on the initial condensation theory. The actual amounts of initial condensation, as estimated from the



TEMPERATURES IN H P CYLINDER

FIG. 2

formula given previously, are, for the jacketed engine 114lbs. per hour and for the unjacketed 80lbs. per hour. The remaining part of the difference between indicated and actual weights is to be attributed to valve leakage.

Note also that in the unjacketed trial the maximum temperature of the steam is 356·5° Fah., and the mean temperature of the metal 335° Fah. The greatest possible range of temperature in the metal could not be, therefore, more than 2 (356·5 – 335 = 43° Fah. Assuming this range, and using the formula for the heat absorbed during periodic temperature changes, it is found that under these conditions the steam initially condensed per hour would be 557lbs. The actual weight of steam to be accounted for is 753lbs. per hour, so that even if the smallness of the actual temperature range were not known from Callendar and Nicolson's work, and the excessive range given above be assumed, the initial condensation theory again breaks down.

Another point upon which there is much discussion is the condition of the cylinder walls during a revolution. Several writers state definitely that in their opinion the walls are never dry, and it is on account of the wetness that initial condensa-

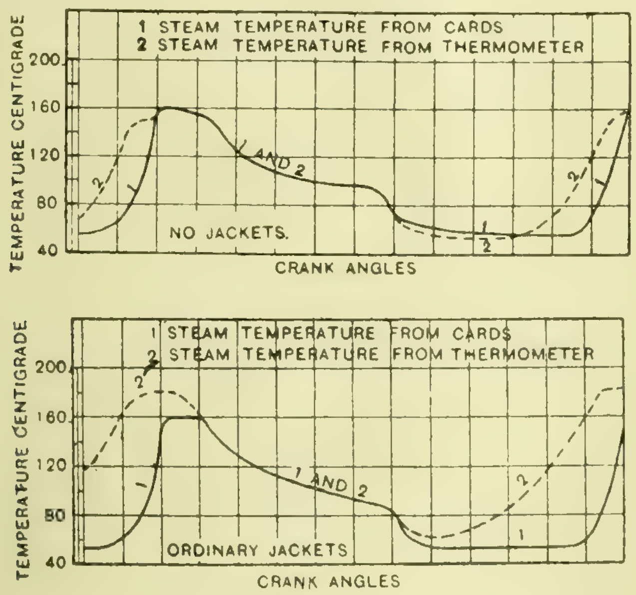


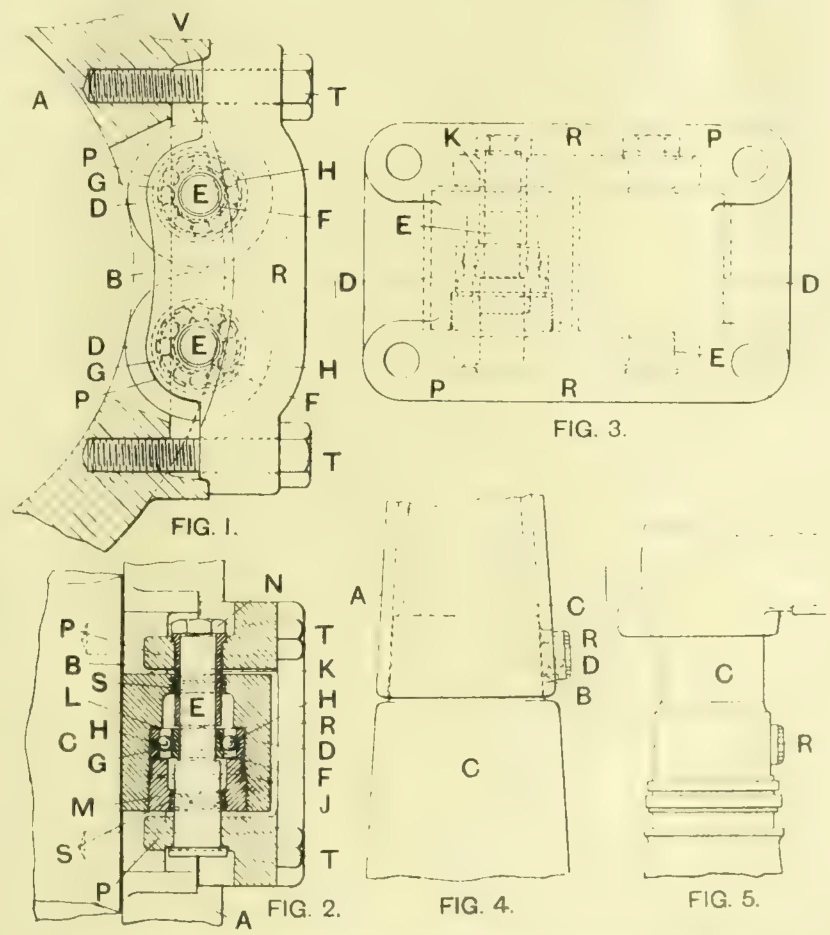
FIG. 3.

tion is so large as it is. The bulk of experimental evidence is, however, against this conclusion, and it is certain that in most engines the walls are dry for a considerable proportion of a revolution. As indirect evidence there is the fact that the average temperature of the metal is higher than the average temperature of the steam. There are also records from Callendar and Nicolson of their measurements of the temperature of the steam during a revolution. With the aid of a fine platinum wire-resistance thermometer they found that during compression (1) the main body of the steam seemed to be slightly superheated, (2) that the steam in a small hole in the cylinder was very highly superheated. It would, therefore, appear probable from these experiments that all the steam in the neighbourhood of the walls was to some extent superheated during compression. Further proof of this was obtained by M. A. Duchesne in his experiments at the University of Liége. He measured the temperature of the steam near to the walls by a thermometer that extended for a considerable distance round the cylinder. In Fig. 3 are shown diagrams drawn from the data given by M. Duchesne. It can be seen from these figures that the steam is very appreciably superheated during compression, when no jackets are used, and is superheated during compression, admission, and exhaust when the cylinder is jacketed. There is, therefore, direct experimental proof that (1) the main body of the steam is slightly superheated, (2) that steam in a pocket may be very highly superheated, (3) that the steam near to the walls is considerably superheated during compression.

These figures ought to conclusively dispose of the idea that the cylinder walls are continually wet, and a little consideration will show that the walls in circumstances like these can have very little condensing effect.

ANTI-FRICTION DEVICE FOR RADIAL DRILLING MACHINES.

The accompanying illustrations show an arrangement of anti-friction device for radial drilling machines which has recently been patented by William Asquith, Ltd., High Road Well Works, Halifax. The device has been designed with a view to reduce to a minimum the friction of the arm sleeve or the drill pillar sleeve upon the drill pillar during a radial adjustment, while at the same time a solid bearing for the arm is maintained during working. With the use of their device, Messrs. Asquith claim that little force is needed to adjust



Asquith's Anti-friction Device for Radial Drilling Machines.

the arms of the heaviest machines no matter what the position thereon of the spindle slide. In the application of the device, a slot or opening is formed in the arm sleeve at the front and near the bottom. Within this opening are placed two anti-friction rollers mounted upon a cap or cover secured by set screws to the radial arm sleeve. The rollers now become a part of the sleeve and bear upon the drill pillar at the point frictionally most affected by the weight of the arm and the

position of the spindle slide. In order, however, to render the adjustment of the arm still easier, each roller revolves on ball bearings mounted on its supporting spindle.

Referring to the illustrations, Fig. 1 is a sectional plan of a segment of the radial arm sleeve, with the anti-friction bearings secured thereto. Fig. 2 is a sectional elevation. Fig. 3 is a front view. Fig. 4 shows the position of the bearings upon the arm sleeve of a fixed arm radial drilling machine, and Fig. 5 shows the position upon an elevating arm radial drilling machine. In the front of the radial arm or pillar sleeve A, a slot or opening B is formed, giving access to the drill pillar C. Within this opening is mounted the anti-friction device consisting of two or more rollers D, free to revolve upon their supporting spindles E. The rollers are hollow or cupped and provided with ball bearings centrally situated therein. The ball bearing of each roller consists of two concentric rings F G forming an intervening ball race containing balls H. When fixed within the roller the lesser ring F rests upon a shoulder J on the spindle E, and is prevented from any undesirable vertical movement by the sleeve K. The ring G is held in position and locked against a shoulder L in the roller by means of the screwed bush M. The nut N, whilst securing the sleeve K upon the spindle E, also locks the latter in the bearings P in the cover R. S are worm grooves filled with lubricant which also serves to prevent dust or the like getting to and affecting the efficiency of the ball bearings. The anti-friction device is secured in position by set-screws T passed through bolt holes in the cover R and screwed into the arm or pillar sleeve A, thus bringing the peripheries of the rollers D flush with the inner surface of the sleeve. The amount of frictional contact of the rollers with the drill pillar C is regulated by tightening up the cover R.

STEEL MANUFACTURE AND THE EMISSION OF SMOKE.

In the course of a series of honours lectures to metallurgical students in the Applied Science Department of the Sheffield University, Prof. Arnold made some further references to the bearing of the smoke question on steel manufacture, to which our readers will remember we alluded in a recent issue (see page 121 ante). About nine years ago, Prof. Arnold said, there was a similar ebullition of anti-smoke literature to that which was taking place at present. Shortly before that time there had been—for the first time, he believed, in the history of Sheffield—a prosecution and conviction for the emission of metallurgical smoke. The City Council were so alarmed at the storm which was roused by it that they commissioned the then University of Sheffield to make an investigation as to whether or not black smoke was necessary in re-heating steel. Since the report of that investigation was presented, there had only been one prosecution for metallurgical smoke in Sheffield, and it failed. In the management of furnaces required for reheating steel, he remarked, "The furnaceman cannot tell you why he does certain things. It is almost intuitive. He does not understand the science of it: I do. He can re-heat steel: I couldn't. It is one of those things in which science and practice must work together." The flame must be kept "green"—carburised—so as not to decarburise or oxidise the skin of the ingot, which would ruin it. Re-heating might be divided into three distinct periods—the period of much smoke, the period of moderate smoke, and the soaking or finishing period, when there was very little smoke.

Describing the emissions of smoke found in the case of the official observations of nine years ago, he called attention to the fact that the first period began with 11 minutes of black smoke. At that stage it was very useful and necessary, but even if it were not, it could not be avoided, because, after the first firing, considerable quantities of heavy hydrocarbon gases were given off, and these, striking the cold ingot, liberated great volumes of finely divided carbon. The furnaceman had to be on the "qui vive" the whole of the time, to see that his flame never got "dry," and he prevented this either by rousing the fire, which meant the emission of more smoke, or by putting on more coal. He gave figures of the smoke emissions, showing that there were 10 periods of black smoke, amounting to 28½ min. in the first hour; commenting on the "almost rhythmic" way in which the furnaceman kept his flame "green" in the second; and pointing out how little black smoke there was in the third, during which, at one time, there was no smoke for 32 minutes. The furnacemen could not explain why they made these emissions of black smoke. He did not think they knew—it was done as the result of long experience and intuition. The consequence was that when a furnaceman came into Court—probably with a very fierce lawyer against him—he made nothing of a case.

Counsel would hand up the records of observations, and, referring to the first 11 minutes of black smoke, would say, "I suppose you were in a hurry to get home, weren't you?"

The furnaceman would look at him astonished, and say, "Well, it's the way we always do it."

"Never mind about that," counsel would say. "Here you go for 32 minutes without making any black smoke at all. Why couldn't you do that at first?"

He simply badgered the witness to pieces, and the magistrates, if they did not understand the question, were naturally unfavourably impressed, and a conviction was very likely to follow.

Alluding to the proposed appointment of a committee by smoke prevention enthusiasts to investigate the matter, Prof. Arnold said that being fallacious and unscientific, he would not be on it, but he had had 33 years' experience in studying the metallurgy of Sheffield, and he ventured to give a little advice, though it might not be very encouraging. After the ebullition of nine years ago, a good many manufacturers were convinced by the arguments put forward, and they started installing gas furnaces. Some four years ago, a big firm did this, and there was a very big trouble in a very short time. He was asked to go down and examine the steel ingots, which were very badly injured. The gas plant came out, a coal re-heating plant went in, and the trouble ceased. That had happened over and over again.

He would suggest that the proposed committee should put down various sizes of gas furnaces for different masses of steel. They should have one to re-heat, say, Cammel Laird's 140-ton ingots. He had no doubt the firm would supply them with a series at a price. Then they should have another for one-ton high-speed steel ingots, which several firms would supply at £100 each. To vary the proceedings, they might try a few heats of manganese steel. Lastly, let them try a gas-fired sheet mill re-heater. "If they do this," said Prof. Arnold, "we shall see what we shall see; but I will venture to predict that the whole matter will end in smoke."

Pit-cage Accident: Eight Men Injured.—On the 6th inst., an accident occurred in one of the shafts at the Newdigate Colliery, Astley, Nuneaton. A number of day men had been lowered into the pit, and while a cage containing a dozen employés was on its way to the bottom, it was over wound, and came to grief. The cage struck the bottom of the shaft with considerable force. Some of the men were jerked from the platforms of the cage, while others were hurled from side to side, and two-thirds of the party sustained more or less serious injury.

Memorial to the Late Prof. Ashcroft. In a recent issue we referred to the sudden death of Prof. Ashcroft, assistant professor of Civil and Mechanical Engineering at the Central Technical College. Prof. Ashcroft was so universally liked by all those who came in contact with him at the college, and he did so much to help his students, both in and out of college hours that there is a very strong feeling that his old students should unite to found a memorial to his name and work. After careful investigation by the Old Students' Association it is considered that the most suitable plan to adopt is to place a tablet to his memory in the college, and to collect funds for the purpose of aiding his son, who is now about 14 years old, to follow and complete the course of training which the late Professor had planned for him. It is suggested that if each of his students would subscribe even a small sum sufficient funds would be available to carry out the scheme. Donations should be addressed to E. F. Armstrong, 98, London Road, Reading, if possible before the end of February, so that immediate action may be taken.

THE PARSONS MARINE STEAM TURBINE AND ITS APPLICATION TO VARIOUS CLASSES OF VESSELS.*

BY E. H. B. ANDERSON.

THE object of this paper is to put before the members of this Society some of the various arrangements of turbine machinery in past and present vessels which are fitted with Parsons turbines. Dealing with the well-known pioneer vessel "Turbinia" it is of interest to note that in torpedo boats and small fast steam yachts of this type, a similar arrangement of machinery is still installed and there are about 40 such vessels at sea, and in addition 10 are under construction at the present time for the Spanish Navy. In the "Turbinia," the astern turbine is in a separate casing and no cruising turbine was fitted. This arrangement combines simplicity with extreme lightness of parts and good economy over a very wide range of power. In the earliest turbine destroyers, "Viper," "Cobra" and "Velox," four shafts were fitted, having two sets of independent ahead turbines, consisting of two high-pressure and two low-pressure with astern turbines on inboard shafts only.

This design was followed in the next destroyers by the standard 3-shaft arrangement to which was added two cruising turbines in series, arranged at forward end of each low-pressure turbine. There are about 100 vessels constructed with such an arrangement having shaft horse-powers varying from 7,000 to 20,000 and speeds from 26 to 34 knots. In the United States Navy there are 15 of this type at sea and four being built, all of which have speeds of 29 knots and upward. In the French destroyers having the usual 3-shaft arrangement only one cruising turbine is fitted, and the machinery is arranged in two compartments.

For small fast cruisers, the 3-shaft arrangement has been found very satisfactory, and this design was adopted in H.M.S. "Amethyst" and in the first turbine warship, "Mogami," built for the Japanese Navy, and in two scouts completed for Brazil in 1909. No cruising turbines were installed in the ship built for Japan. Three small cruisers of the 3-shaft type are at present under construction for the Chinese Navy. In these installations no separate cruising turbines are being fitted, but the high-pressure turbine has been arranged with an additional stage to improve the economy at cruising speeds and at full power by-pass valve arrangements will be made use of admitting steam to the second stage.

Among the smaller cruisers and scout cruisers, the 4-shaft arrangement has been adopted largely. In England there are 14 vessels of this type at sea, some of which have cruising turbines in parallel, but in the latest design the machinery arrangement is similar to battle-ship and cruiser practice. Two are under construction for the Australian Colonies. The first German turbine cruiser "Lubeck" had such an arrangement, and three others have since been completed for the same Navy. A similar design was adopted in U.S.S. "Chester," the first Parsons turbine warship in the United States Navy. In the case of the large experimental turbine destroyer H.M.S. "Swift" the machinery was arranged on four shafts with the turbines in two engine rooms, and on trial this vessel made an average speed of about 35·25 knots.

Dealing with battle-ships and cruisers of the Dreadnought type, four shafts are fitted, which are driven by two independent sets of ahead turbines consisting of two high-pressure on outboard shafts and two low-pressure on inboard shafts. Two cruising turbines are arranged in parallel at forward end of each low-pressure turbine. All shafts are arranged with astern turbines, which are in two sets. Each set consists of a high-pressure and low-pressure turbine respectively.

In the latest ships of this type, cruising turbines have been dispensed with, and although it was recognised that the addition of cruising turbines improved the economy to a large extent, the complication, together with the fact that such turbines are often running idly, decided against installing them in ships of this type, especially where cruising turbines are fitted in parallel. The saving in weight, by omitting cruising turbines, was not made use of in cutting down the machinery weights, but the main turbines were increased in size so as to improve their efficiency, and at the forward end of each high-pressure ahead, an additional expansion was fitted which is used when cruising, and for full power conditions by-pass valve arrangements are made use of. Five vessels of this type have completed all trials most successfully, four of which are battle-ships and one a battle-ship cruiser. Twelve additional ships of a similar type are now under construction in England, having speeds varying from 21 to 28 knots, two of which are being built for the Australian Colonies.

In the United States, four battle-ships are being installed with Parsons turbines, of which the "Utah" and "Florida" are in commission. The "Wyoming" and "Arkansas" are launched and will shortly be completed. The main difference in the machinery lay-out of these ships compared with those of the Dreadnought type, is that the cruising turbines are arranged in series instead of in parallel. In France, six battle-ships with arrangements of machinery similar to U.S. vessels have completed trials; two more are in an advanced state of construction and contracts have just been awarded for two others. All of these vessels have 4-shaft arrangements of turbine machinery.

In Germany, the cruiser "Von der Tann" has given splendid results in commission and on trial made a speed of 27·63 knots. This ship has been followed with the cruiser "Moltke," which has made a speed of about 29 knots on a preliminary trial. There are three others under construction, which have four shafts, with the turbines arranged in series. In addition, three battle-ships are being built, these ships having triple screws and turbines of the Parsons type, but with details special to the German Navy. In Italy, there are at the present time four battle-ships under construction to be driven through four shafts. In Russia, four large battle-ships are in course of construction, having turbines arranged to drive four shafts. In Austria, two battle-ships are in construction and a third has just been ordered, which will have four shaft arrangements of turbines.

In Spain, three battle-ships having speeds of 19½ knots are in course of construction. No cruising turbines are to be fitted, but one high-pressure and one intermediate-pressure on separate shafts take the place of the usual two high-pressure turbines, and the intermediate-pressure is arranged to divide its exhaust steam into two low-pressure turbines arranged on the outboard shafts. Japan has recently ordered a large battle-ship cruiser, which is being built at Barrow. This vessel will have a high speed. Three others are to be built in Japan and will be fitted with turbines of the Parsons type, driving four shafts. Three battle-ships have been ordered for Brazil, Chili, and Turkey respectively, and all are to be fitted with four shafts. The Brazilian naval authorities decided to fit turbines in their battle-ships after the success of the scouts.

In the mercantile marine, the 3-shaft arrangement of turbine machinery similar to that installed in the first ship, the "King Edward," is still used in almost all ships, except those of very large power. This ship has been in regular service now for eleven seasons, and is giving splendid results both as regards speed, economy and small amount of upkeep and repairs. There are upward of 75 ships at sea fitted with similar installations, having speeds varying between 17·0 and 25 knots. The pioneer liners "Victorian" and "Virginian" have the standard 3-shaft installation, and these ships are maintaining speeds of 17½ knots on round trips across the Atlantic. On the Pacific Ocean, the Japanese vessels "Tenyo Maru" and "Chiyo Maru" hold all speed records and can average about 20 knots. Among other well-known ships of this class may be mentioned the following:—"Queen," 21·73 knots; "Onward," 22·53 knots; "Manxman," 23·14 knots; "Viking," 23·53 knots; "Ben-my-Chree," 25·0 knots; "Jan Breydel," 24·30 knots; "St. George," 23·0 knots; "Carmania," 20·0 knots; "Newhaven," 23·85 knots.

* Paper read at the eighteenth general meeting of the American Society of Naval Architects and Marine Engineers, held in New York.

In 1905, a 2-shaft arrangement of machinery was installed in the steam yacht "Narcissus." In this installation, the two ahead turbines are arranged in series and an astern turbine is fitted to each shaft. Pipe and valve connections are arranged so that the high-pressure exhaust steam can pass direct to the condenser, and a live steam connection is fitted to the low-pressure turbine, so that the vessel can be manœuvred similar to an ordinary twin-screw reciprocating engine installation.

The first vessel built in the United States fitted with Parsons turbines was the "Governor Cobb," having a speed of 18 knots. This vessel was followed by the "Yale" and "Harvard" with speeds of 21 knots. Another vessel, the "Old Colony," has a speed of 19 knots. All these ships have the regular 3-shaft turbine arrangement with two condensers.

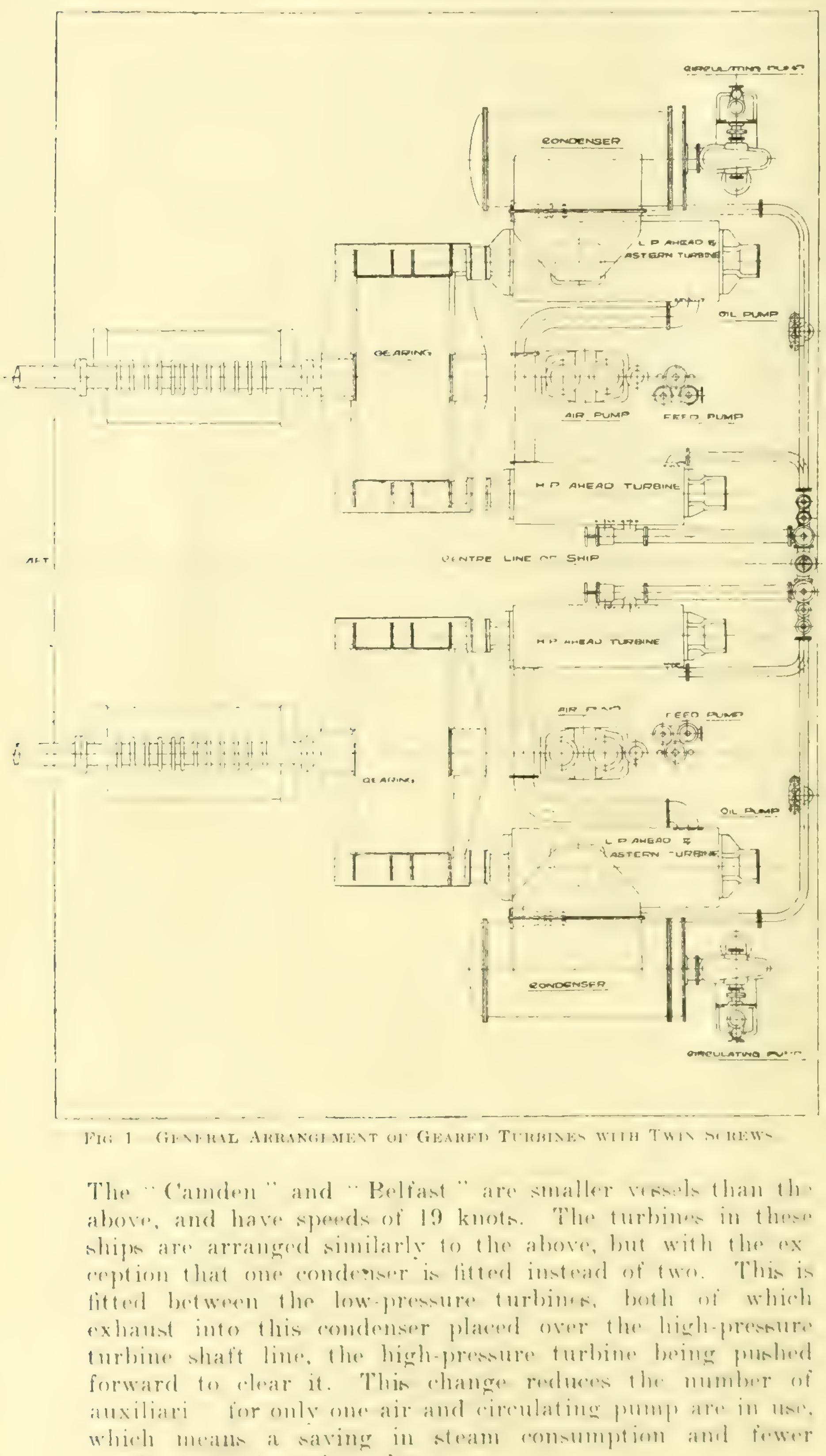


FIG. 1.—GENERAL ARRANGEMENT OF GEARED TURBINES WITH TWIN SCREWS.

The "Camden" and "Belfast" are smaller vessels than the above, and have speeds of 19 knots. The turbines in these ships are arranged similarly to the above, but with the exception that one condenser is fitted instead of two. This is fitted between the low-pressure turbines, both of which exhaust into this condenser placed over the high-pressure turbine shaft line, the high-pressure turbine being pushed forward to clear it. This change reduces the number of auxiliari for only one air and circulating pump are in use, which means a saving in steam consumption and fewer auxiliaries to keep in order.

The Cunard liners "Lusitania" and "Mauretania" have 4-shaft arrangements of turbines which consist of two independent sets. Each set is composed of one high-pressure and one low pressure on separate shafts and similar to the usual battle-ship arrangement. In these ships separate astern turbines are fitted to the inboard shafts only. These ships hold all records on the Atlantic and easily maintain 25½ knots with fair weather conditions, the turbines making about 190 revs. per minute.

A modified arrangement of turbines has been adopted in the French liner "France," now nearing completion, which will further improve the economy as the turbines are arranged in series similar to the Spanish battle-ships. It is expected that this ship will have a speed of 23 knots at sea. A similar arrangement of machinery is being adopted in the new Cunard liner "Aquitania," now under construction on the Clyde. In Germany, there are under construction for the Hamburg-American line, two large vessels with 4-shaft arrangements of machinery. The Canadian Pacific Railway Company have also under construction two large liners for the North Atlantic trade, and these ships are being fitted with an arrangement similar to the "France."

The combination arrangement of turbines and reciprocating engines has also given good results. This was first carried out in the destroyer H.M.S. "Velox" completed in 1903, in which two sets of twin engines were arranged at forward end of the low-pressure turbines on inboard shafts and connected to exhaust into the high-pressure turbines on outboard shafts. This was done to improve the economy up to a speed of 12 knots, above which the engines were disconnected, and it proved very successful.

In 1908, the New Zealand s.s. "Otaki" was installed with a 3-shaft arrangement of machinery. The wing shafts were driven by triple expansion reciprocating engines, arranged to exhaust into a low-pressure turbine on centre line of ship. This ship was followed with the "Laurentic" having a similar arrangement to the "Otaki," and the decision to install this system in the White Star liners "Olympic" and "Titanic" was based on the successful results obtained with the "Laurentic." The "Olympic" has now made four round trips and the designed speed of 21 knots has been exceeded by 1 knot on service and with a remarkably low coal consumption.

The slow-speed French Transatlantic liner "Rochambeau" has a combination arrangement of machinery driving four shafts. In this installation, two sets of reciprocating engines are installed on the inboard shafts and the exhaust steam from each is passed into low-pressure turbines arranged on the outboard shafts. This vessel has completed her trials very successfully and will shortly be put in service. Two ships with similar installations have just been put in hand to the order of Spanish shipowners. The Orient Line has also a large vessel in course of construction for the mail service between England and Australia, and having an installation similar to the previous 3-shaft ships. At the present time there are 12 vessels completed and in course of construction having installations of this type. The American steam yacht "Vanadis" represents an alternative arrangement of a reciprocating engine and low-pressure turbines. In this case there are three shafts, the centre one being driven by a triple-expansion reciprocating engine, arranged to exhaust into low-pressure turbines on the wing shafts.

The first application of a geared turbine was made by the Parsons Marine Steam Turbine Company in 1897. This installation was made for a 22-foot launch and consisted of one combined ahead and astern turbine, coupled to a pinion which was arranged to drive two gear-wheels connected to two shafts. In this case single helical gear was used.

In 1910 the s.s. "Vespasian" was fitted with a geared installation of turbines. This ship was originally fitted with one triple expansion surface condensing engine. After carrying out a series of trials with this engine, the engine and condensing plant was taken out, and in its place two fast running turbines, arranged in series and each driving by means of a pinion a double helical gear wheel connected to the line shafting. It should be mentioned that the original propeller, line shafting, and thrust block were left alone. This ship has now been in regular commission for 18 months giving splendid results, and absolutely no trouble has been experienced with the gearing, although the vessel has steamed about 32,000 knots. Further, it is of interest to note that there is no appreciable wear on the teeth of either pinion, and the original pair being still in use.

At the present time, two fast destroyers are nearing completion in England having geared turbine machinery driving two shafts. Two Channel steamers for the London and South-Western Railway Company are also under construction. These ships will have two shafts, each shaft being driven by two fast-running turbines in series connected to a double helical gear wheel through pinions. (See Fig. 1.)

With regard to the question of multiple shafts, the present tendency among certain naval authorities is to cut down the number of shafts and turbines in vessels of the destroyer classes. A difference of opinion appears to exist as to whether two, three, or four shafts are most suitable from an economical and a practical point of view. The builders of the "Curtis," the "Zoelly" and similar types of turbines favour 2-shaft installations, although in three large warships, which have Curtis turbine machinery, three shafts have been adopted.

In a 2-shaft arrangement of turbine machinery, a slightly better propeller efficiency may be obtained as compared with 3 or 4-shaft installations, but the fact should not be lost sight of that propeller efficiency has to go hand in hand with turbine efficiency, and increased propeller efficiency can only be obtained by reducing the revolutions with a certain sacrifice in turbine efficiency.

There is a great deal to be said in favour of the distribution of the total power over several shafts, and the system of placing the turbines in series not only reduces the weight of the machinery and increases the propulsive efficiency of the steam, but improves the conditions for examination and overhaul carried out on board ship. Further, by the subdivision of power over three or four shafts the turbines are much smaller, the weights to be dealt with are considerably less, and the work of opening out is greatly facilitated.

Contracts have recently been awarded for eight destroyers in the United States, six of which are to be fitted with twin screws and independent turbines. In addition, all these vessels are being installed with two sets of reciprocating engines for cruising speeds up to 15½ knots. These engines are arranged to exhaust into the turbines up to this speed, above which they will be disconnected. At the present time there are only two battle-ships being constructed with twin sets of reciprocating engines, namely the U.S.S. "New York" and U.S.S. "Texas."

It is not my purpose in this paper to describe at any length the arrangements of the engine-room bulkheads and the sub-division of the machinery space. In the 3-shaft arrangements, both in merchant work, torpedo boats, destroyers, and including small cruisers of this type, the engine-room is generally contained in one compartment having the turbines, condensers, and the various auxiliaries. In the first vessels of the Dreadnought type, including the United States ships, the turbines and auxiliaries are arranged in one athwartship compartment divided along the centre line of ship by a fore and aft bulkhead.

In the latest ships, the machinery is arranged in three compartments, in which both low-pressure ahead and astern turbines are in one compartment, while the high-pressure ahead and high-pressure astern turbines are in separate compartments at the sides. The middle compartment contains the starting valves, condensing plant and various auxiliary machinery. Arrangements are also made so that in case the wing engine rooms are flooded, the high-pressure turbines can be shut off and direct steam connections used to each low-pressure turbine, both ahead and astern. In the case of the Cunard liners "Lusitania" and "Mauretania," the turbines are arranged in three compartments similar to the foregoing installations, both condensers in a separate watertight room aft of engines, and air and circulating pumps further aft in two compartments.

As regards the steam consumption of turbine machinery, in the "Turbinia" the measurements figure out giving a water rate of about 15lbs. per horse-power, all purposes at full power. In H.M.S. "Amethyst" the water rate in pounds per horse-power for all purposes at full power averaged 13·60lbs. This agrees very closely with a figure of 14·0lbs. per shaft horse-power which was obtained with United States destroyers. In battle-ships of the Dreadnought type, the water consumption in terms of shaft horse-power of main engines averages about 13·0lbs. for turbines only. In large cruisers of the "Indomitable" type, the consumption for turbines only averages about 12·0lbs. per shaft horse-power.

In ships of the mercantile marine, the steam consumption of the turbine machinery for all purposes in terms of shaft horse-power of main engines averages about 15lbs., and in large installations such as the "Mauretania" about 14lbs. In vessels fitted with a combination system of reciprocating engines and low-pressure turbines, a saving in coal consumption of about 12 per cent. is made, compared with similar ships having quadruple expansion reciprocating engines only.

In a battle-ship or cruiser installation an arrangement of geared cruising turbines would effect a saving of at least 20 per cent. at a cruising speed of 12 knots, this comparison being made with an installation having direct coupled cruising turbines. A further increase in economy can be obtained by increasing the coefficients of the turbines. This would improve the results without any increase of machinery weight, due to a saving in the boiler-room installation. A further economy of steam consumption is realised by arranging to pass all available auxiliary exhaust steam at suitable stages into the turbines instead of passing this direct to the main condensers.

In 1905, the total amount of Parsons turbine machinery of the marine type completed amounted to about 270,000 h.p. At the present time the total horse-power completed and under construction amounts to approximately 6,400,000, of which about 5,300,000 is to be fitted in warships; of this total, 1,900,000 h.p. was ordered during the past year. In the German Naval Programme of last year a total shaft horse-power amounting to 281,000 is being installed in ships fitted with Parsons turbine machinery, being 58 per cent. of the total ordered in that year.

ELECTRIC POWER FOR DRIVING MACHINES.

BY O. R. WM. PAUL.

The usefulness of the electric motor in some instances for individual drive is not a matter of opinion or of speculation. There is, however, no rule without exceptions. To insist upon having a motor for each individual tool probably is carrying individual drive to the extreme. In large machine shops every tool that requires above 4 h.p. may be driven individually, but smaller tools should be grouped. Group drives are desirable in tool rooms where one small motor can be connected to a short line shaft transmission, as usually only one machine is in operation at a time, or at least a few machines. The motor need not be much larger than is required to drive the largest machine and the line shaft. This rule holds good in the foundry for the emery wheels needed for grinding castings. A very short shafting is required, as the wheels can be placed close together and the friction loss will be nominal. Since an electric motor takes only as much power as is required for the work, group lines are generally installed where short shafting can be used advantageously. Portable tools, of course, should always be driven individually, even if, as in rare cases, the necessary motor is small.

Motors should be placed as near as possible to the tool to be driven, so that only one belt or a single set of gears is required. The floor should be dry, the motor fully protected from dust, and if there is danger of flying pieces getting into the motor, screens should be provided. In some departments of a factory, such as the blacksmith, the carpenter, and patternmaker shops, considerable dust is created that seems to penetrate even walls. In such cases the motor should be properly covered by a wooden box lined with asbestos or a sheet of tin or iron. To prevent an abnormal rise of temperature inside the box the wall should have holes near the bottom and top so as to permit a circulation of air. These holes should be covered with a fine wire screen. A number of machines are installed on the same base with their motors, or have the motors conveniently located upon the frames. This is in many instances an advantage, but may be a menace to accurate work, especially if the machine is small or light. The only instance where such trouble occurred that has come to my knowledge is in connection with a small planer, but in this particular case the motor had to be taken down and installed on the floor.

The special advantages arising from the use of an induction motor for planer drive are: At the instant of reversal of a planer bed, after the tool has completed the cut, and when it is important to accelerate the bed quickly in the opposite direction to get the tool into the cut again as quickly as possible, an enormous increase of torque is demanded from the motor, involving a rush of current sometimes three or four times as great as the average current required for the work. If a direct-current motor should be subjected to this sudden rush of current injurious flashing and frequent burn-outs would result, unless the motor is considerably larger than would normally be required after the machine was accelerated.

Direct-current motors can have variable speeds, which offer unlimited advantages for use on such machines as require different operating speeds at different times. They may be so arranged that the speed changes may be made without causing inconvenience or loss of time to the mechanic. Very little manual effort is required to make small variations of speed while the motor is loaded. A motor with a suitable controller can give speed increments of from 10 to 14 per cent.

Table I. has been computed from the results obtained from a variable-speed motor and a 16in. engine lathe. The open belt speeds on this lathe were 523, 293, 178, and 107 revs. per minute, and the gear speeds obtainable 57, 32, 19, and 12 revs. per minute. In facing a disc, a comparison of the two systems can easily be shown. Take the cutting speed at 40ft. per minute, and the radial feed 0·02in. a revolution. The table gives the spindle speed and the corresponding radii, which give a cutting speed of 40ft. per minute, and also the radii and cutting speed which obtain just before the belt is shifted to the next pulley to increase the speed.

TABLE I.

Revs. per Min.	In. Radii.	Feet per Minute Cutting Speed.		Mins. for Cut 10in. Long.
		Max.	Min.	
12	6·37	40		41·6
	4·02		25·2	
19	4·02	40		26·3
	2·39		23·8	
32	2·39	40		15·6
	1·34		22·4	
57	1·34	40		7·7

The electric drive with increments of 14 per cent. gives approximately a 1 to 6 speed variation. Applying the same analysis to the above lathe gives the following table:—

TABLE II.

Revs. per Min.	In. Radii.	Feet per Minute Cutting Speed.		Mins. for Cut 10in. Long.
		Max.	Min.	
12	6·37	40		
	5·58		35·2	41·6
13·7	5·58	40		
	4·90		35·2	35·5
15·6	4·90	40		
	4·32		35·2	32·0
17·7	4·32	40		
	3·78		35·1	28·2
20·2	3·78	40		
	3·32		35·1	24·7
23	3·32	40		
	2·92		35·2	21·7
26·2	2·92	40		
	2·55		35·0	19·1
30·0	2·55	40		
	2·23		35·0	16·6
34·2	2·23	40		
	1·96		35·1	14·6
39·0	1·96	40		
	1·72		35·1	1·28
44·5	1·72	40		
	1·50		34·9	1·12
50·7	1·50	40		
	1·32		35·2	9·89
57·7	1·32	40		
	1·16		37·1	8·66
65·7	1·16	40		
	1·02		35·1	7·62
75·2	1·02	40		
				6·65

This table shows that with the electric drive the deviation from the permissible cutting speed is in no case greater than 12½ per cent.

The induction motor is specially well suited for duty in mines, powder houses, oil-cloth manufactories, and any place where inflammable gases or explosive materials are used, since it is absolutely free from sparking or flashing on any movable contacts.

The installation of an electric motor depends, of course, on the machine to be driven, and the first question arising is: What shall be the size of the motor, or how many horse-power are required? Conditions are so varying that it is impossible to present the exact horse-power which should be used in all cases. The formulæ given are based on the assumption that tools are made of water-hardened steel, and the average cutting speed is taken at approximately 20ft. per minute. In case high-speed tool steels are used the necessary horse-power will increase practically proportionally to the increase in the cutting speed. Machine tools may be divided into two classes: machines with direct rotary motion of either the work or the cutter, and machines which have a reciprocating motion of either the work or the cutter. Under the first class come lathes, drill presses, boring mills, &c., while planers, shapers, slotters, &c., may be classified under the second heading.

Shunt-wound variable-speed motors should be used for driving lathes, drill presses, boring mills, &c.

Engine lathes using one cutting tool of water-hardened steel at about 20ft. per minute:

$$\text{Horse-power} = 0{\cdot}15\ S - 1.$$

Heavy engine lathes, such as forge lathes:

$$\text{Horse-power} = 0{\cdot}234\ S - 2.$$

S = swing of lathe in inches.

Boring mills: For the operation of standard boring mills using one water-hardened cutting tool, cutting at approximately 20ft. per minute. The following formula represents good practice for heavy work:—

$$\text{Horse-power} = 0{\cdot}25\ S - 4.$$

S = swing of mill in inches.

Milling machines: For ordinary milling machines, using water-hardened steel cutters running at about 20ft. per minute:

$$\text{Horse-power} = 0{\cdot}3\ W.$$

W = distance between housings in inches.

Drill presses: For ordinary drill presses, using water-hardened steel drills, running at a peripheral cutting speed of approximately 20ft. per minute:

$$\text{Horse-power} = 0{\cdot}06\ S.$$

For heavy radial drill presses:

$$\text{Horse-power} = 0{\cdot}1\ S.$$

S = Swing of drill in inches.

Reciprocating machines are from their nature less productive than purely rotary motion machines, and should be driven by compound wound motors. As at the instant of reversal of the machine tool the torque of the motor increases considerably above the normal, the compound winding of the latter holds the inrush of current within reasonable limits.

Slotters: Normal crank slotters, using water-hardened steels at cutting speeds of from 15ft. to 20ft. per minute:

Stroke.	H.p.
10in.	5
18in.	7
30in.	10

Shapers: Shapers using water-hardened tool steels at cutting speeds of from 15ft. to 20ft. per minute:

Stroke.	H.p.
16in.	3
16in.	3½
24in.	5
30in.	6½

Planers: Normally the length of the bed of a planer in feet is approximately two-tenths the width between the housing in inches. For example, a 48in. planer has a length of platen of practically 9·6 or 10ft.:

$$\text{Horse-power} = 3\ W.$$

For heavy forge planers, horse-powers = 4·92 W. Planers with two tools in operation, and a ratio of cutting speed to return speed of 1 to 3. W = width between housings in feet.—"Southern Machinery."

A COMPARISON OF OIL AND SUCTION-GAS ENGINES FOR SHIPS.

A correspondent of the "Glasgow Herald" gives a few interesting notes on the relative merits of oil and gas engines for marine propulsion. So far, oil engines seem to have made the most progress in this direction, though makers of suction gas power plants are now making strong efforts in this direction also. One reason put forward for this is that anthracite is fairly steady in price, and can be obtained in Belgium for about 17s. 6d. per ton, while the price of oil is, or was, more inclined to vary and, moreover, is not stored in large quantities—in the lower grades—whereas anthracite or gas coke is obtainable almost everywhere. It is, however, on its economy that suction gas makes its greatest claim, coupled with its cleanliness in working and its ease in starting, and the writer asserts that as suction gas has in many instances displaced oil engines on land so will it eventually oust it for many services at sea.

Regarding economical working, he expresses the opinion that suction gas will probably be most successful when the plant does not exceed 300 h.p. to 500 h.p., unless some type of engine similar to the Diesel is produced, capable of operating successfully on this fuel; and states that in Belgium oil engines are being altered to use gas instead of oil. There fuel oil can be bought for about 2½d. per gallon, and oil engines up to about 300 h.p. to 500 h.p. are on the market which claim to use on an average about ·65 of a pint of this oil per horse-power per hour. The cost of running 100 h.p. for 100 hours is £8. 9s. 3d. Makers of suction gas plant claim that 1lb. of coal, and sometimes less, is required per horse-power per hour, but, he adds, lest oil engine makers think the previous consumption of oil too high let the coal consumption be taken at 1¼lbs. of anthracite per horse-power per hour. Take the price as 23s. per ton and see what 100 h.p. for 100 hours will cost. The total consumption is 5·58 tons or 5 tons, 11cwt., 2qr., 11lbs., which would cost £6. 8s. 4d.—a saving of £2. 0s. 11d. in a little more than four days' continuous running. Stoking is a simple matter, unlike firing a boiler furnace. A certain quantity of coal is fed into a hopper every four to six hours, and occasionally the fire has to be "poked" from the top to prevent arching of the fuel.

Even in the best designed installations, and with the best workmanship, he points out, oil has a propensity for leaking, with its attendant annoyance. Further, with all oil engines, other than the Diesel or petrol engines, there must be some preliminary heating before the heavy oil is used. This is done either by a lamp or by using petrol for a short period to start and then using a heavy oil. With a gas producer the fire may be left smouldering for days, and then started in a minute or two with the aid of a fan.

The supporters of the oil engine urge two points against the gas producer. They allege that it is more difficult to run, and that it requires more space, that it weighs a lot, and adds to the cost of the plant. These objections, it is contended, are not supported to any serious extent, and more than set off in other ways. As regards, for instance, the additional weight, the following figures are given: A producer for a 100 h.p. engine weighs about 3½ tons, and if this does reduce the carrying capacity to that extent, and if it does add to the cost of the engine by £300, there is a saving on 100 hours' working of £2. 0s. 11d. Taking a year of 52 weeks of 6 days and 12 hours per day—that is 3,744 hours, or 37·44 times 100 hours—there is £76. 11s. 10d. saved as compared with oil, which sum will more than meet upkeep and interest, and make up for the cargo which was not carried because of the weight of the producer.

Northampton Institute Engineering Society.—On Friday, the 2nd inst., a paper on "Steam Turbines Utilising the Impulse Principle, with Special Reference to the Disc Drum Type," by Messrs. T. R. Houston and F. G. Parnell, was read before this society. In the course of their papers the authors described turbines made by various firms, including the Brown-Boveri, Parsons, Willans, the Brush Company, De Laval, Rateau, Zoelly, and Curtis types. The meeting closed with a good discussion.

ELECTRIC CRANES FOR STEEL MILL SERVICE.*

By E. Friedlaender.

The rapid and cheap handling of all kinds and sizes of material by means of electric cranes has greatly influenced the making of steel products and helped considerably to reduce cost of same. As cranes can now be built to suit every condition, they are coming every day more in use. To avoid the least delays in the operation of electric cranes, special attention must be paid to the proper design of every detail, whether electrical or mechanical. Most cranes are built from specially prepared plans, and differ in design from others furnished to perform probably similar work under exactly the same conditions. Each purchaser has his own ideas about crane construction and is willing to pay for extra development work. Co-operation between crane builder and purchaser will finally result in standard cranes to meet all requirements.

Electric cranes are not nearly so wasteful in power consumption as hydraulic cranes: power is used in direct proportion to load lifted; on hydraulic cranes, however, cylinders have always to be filled, regardless of whether the hook is handling full, light, or no load. Nevertheless, the large number of gears, shafts, bearings, ropes, &c., on electric cranes cause a great amount of frictional resistance, which should not be overlooked. Good lubricated cut gears have an efficiency of from 96 to 98 per cent., but when dry, worn, and out of alignment as low as 92 per cent. Each bearing causes a loss of from 1 to 7 per cent., according to lubrication and alignment. Rope stiffness reduces efficiency from 1 to 3 per cent., depending on the diameter of sheaves and drums.

The total mechanical efficiency of electric cranes hardly ever exceeds 65 to 75 per cent., and, together with electrical losses in motors, controllers, and conductors, brings overall efficiency down to 50 to 60 per cent. It is, therefore, very important to use the least possible number of shafts, bearings, and gears to reduce dead weight to a minimum, and, last, but not least, keep all frictional surfaces properly machined, aligned, and well lubricated. This will not alone decrease power consumption, but will at the same time reduce considerably the cost of maintenance and repairs of motors and controllers.

The wrong application of brakes can also greatly increase power consumption on cranes and punish severely all mechanical and electrical parts. Motors should not work against friction of brakes, but be released from it on the first step of the controller. This is easily accomplished by the use of magnetic-actuated brakes, but is entirely dependent on the skill of operator with hand or foot brakes.

The proper speed control of crane-motors is important; their rapid starting, stopping, and reversing by unskilled men is not only very wasteful in power, but also very hard on all machinery, especially electrical. The best remedy is, probably, to take the control out of the hands of operators and predetermine acceleration, speed, torque, and current through magnetic switches. This means, however, extra complication and expense, but will in the end pay for itself.

In regard to working efficiency of electric cranes, wherever a great amount of material has to be handled, the general rule of keeping material always going in same direction should be adhered to as much as possible. It is very inefficient and costly to handle small loads at very high speeds over long distances on large and heavy cranes.

In deciding on the speed of different motions we should not lose sight of the fact that the normal load hardly ever exceeds one-fourth maximum load, and speed should rather be made to suit normal load; work in foot-pounds should then be made the same for the maximum load. Series direct-current motors are better adapted to this than alternating-current motors, and will give a better working efficiency.

The proper type of girders should be selected for the work to be done by cranes. Heavy double or single leg gantries should not be used where fast and continuous bridge work is required. It does not matter whether box, lattice, single-

* Abstract of paper presented before the Iron and Steel Electrical Engineers, New York.

web, or rolled-beam section is employed for girders; all will give equal satisfaction if properly designed. It is erroneous to think that lattice girders on outdoor cranes are not so susceptible to wind pressure; experience has proved that the four rows of angle braces of girders cause as much resistance as plated girders of same capacity. The fish-belly girder allows material to be used to best advantage; the square lattice girder, however, is easier fabricated, as all sections at different points are alike; it makes a rigid and stiff construction, if properly braced, with the least dead weight.

Gears, bearings, and shaftings may be regarded as the most important parts of cranes. On their proper design depends largely the efficiency, safety, and cost of maintenance of cranes. Wherever possible, worm, bevel, split, and overhanging gears should be avoided. All gears should be of steel, with standard involute-cut teeth; all high-speed gears should be made of high carbon steel, properly tempered and to run in oil bath. No pinions with less than thirteen teeth should be used, as they will run rough and are liable to be mechanically weak. Although only one-half maximum load can come ordinarily on one tooth, for the sake of longer life and safety each tooth should be made amply strong to stand entire maximum load. As all gears on cranes are worked in either direction and continuously reversed, teeth should be made so strong that they will resist absolutely all bending stresses; otherwise crystallisation and breaking of teeth would be the final result. One cannot recommend too strongly to run all gears, wherever possible, in oil bath; the resultant noiseless and easy running of the crane, as well as better efficiency and lower cost of upkeep, would soon pay for it.

All brackets and bearing supports should be made strong enough to avoid deflection of shafts and their binding in bearings. Where, on account of the light weight, it is impossible to prevent working and twisting of bearings, they should be made of swivelling type and be self-aligning. The use of roller or ball bearings on cranes for mill work cannot be recommended, and should only be allowed where, on account of hand-power, friction must be reduced to a minimum. It is surprising that more use is not made by crane builders of oil-ring bearings similar to those on motors. Cranes equipped throughout with such bearings are always ready for work, much cleaner, do not drop oil on men and objects below, run easier and quieter, with less power consumption and cost of maintenance.

Cranes generally receive much rougher handling than any stationary machinery, and require continuous attention. They are naturally located in very inaccessible places, often high up, very hot, dirty, and smoky. Proper means should always be provided to give easy access to them without necessitating climbing of ladders or building columns; good stairways with railing, platforms, and galleries on top for necessary inspection and repairs should always be furnished with crane structure. Crane girders should always have walks all around girder, and, if possible, trolley, to prevent slipping or falling from crane.

The use of over 275 volt currents on cranes cannot be recommended, as accidental touching of conductors is liable to be fatal. Even where electric shock is not dangerous, it may cause serious injury through fall by fright; therefore, bare conductors should be avoided as much as possible or be plainly marked by some bright colours.

Means for preventing cranes from running away and wrecking themselves through wind pressure or accidental starting of motors should always be provided.

The proper location and arrangement of operator's cab is of great importance. Over yards, when material is often obstructing clear view, where operator handles material by means of grab buckets or lifting magnets without any assistance below, cab is best mounted direct on trolley. Man trolleys can be operated at higher speeds; manual brakes can easily be provided to control trolley and hoist motion, and crane can be wired easier and cheaper. Locating cab in centre of one side of crane, instead of on end of girder, gives operator often a much better view.

Crane motors are called upon to work mostly under very trying conditions, such as shocks, vibrations, frequent starting, stopping, and sudden reversing, high lowering speeds, overloads, and many others, not to mention dirt, heat, rain, and, last, but not least, lack of attention. The ordinary commercial motor has been found unable to withstand continuously such conditions, and special mill-type motors had to be developed for this work. Through co-operation with operating men, all weak, defective, and undesirable features have been remedied, and there should be no trouble in getting crane motors which will stand operating conditions of mills and at the same time reduce cost of maintenance and repairs to a minimum.

Motor frames are now made entirely of steel, and allow easy access and removal of armatures and fields, being split horizontally through field castings and bearings. The spider construction makes it possible to renew shaft or commutator without touching windings. Shafts are made much heavier, with larger keys and taper ends; core is pushed on spider instead of on shaft in such a way that it cannot get loose and damage windings or leads. Ample ventilation with very low core losses is provided; brush-holders have adjustable tension springs; bearings are arranged for oil-ring lubrication. Insulation is almost fireproof, and will stand higher temperatures than on standard motors.

The poor commutation of high-peak current has always been a defect of crane motors, and caused frequent renewals of brushes and commutators. The introduction of interpoles on all crane motors has greatly helped to improve commutation and do away with rough and worn commutators, short-circuiting of bars, and final grounding of motors and burning of controller contacts, as well as blowing of fuses. Sparking and flashing over at brushes even with three times full-load current is not often encountered on interpole motors. The slower speed of these motors allows quicker acceleration and stopping, with less braking effect and current consumption.

The usual practice of rating railway motors after one hour full-load run with maximum temperature not to exceed 75 C. is the one that should be adhered to in most instances, especially on bridge and trolley motions, where, on account of fast acceleration of large and heavy masses, current values are liable to become very high. The half-hour rating will give motors large enough for cranes, which are generally not worked so hard and steady; as, for instance, in shops, engine-rooms, and over machinery in mills.

It should not be overlooked that the rate of temperature rise of crane motors is slow, in order to meet the one-hour rating, but that the maximum temperature is often finally exceeded and liable to deteriorate insulation if surrounding temperature is excessive, as is often the case in mill buildings. Manufacturers of electric machinery should state the maximum temperature their apparatus can be submitted to without any danger of injuring insulation, also what influence continuous high temperatures would have finally on motor windings.

In deciding on the proper size of a motor for certain work, not only weights, speeds, and efficiencies should be taken into consideration, but, on account of rating of motors, the time of work and rest and average speed and load should be given attention. The great speed variation of series direct-current motors under changeable load should also be considered in determining size of motor, independent from the power required. The maximum speed of motion is always considerably higher than the mean speed, and could, of course, be reduced by accelerating and stopping in less time, but this would increase load of motor and necessary braking power and make wear and tear on gears, shafts, and brakes heavier.

As the combined mechanical and electrical efficiency of cranes is only about 50 to 60 per cent., not more than 22,000 foot pounds of work can be got out of a 1 h.p. motor for crane work. This may give a somewhat bigger motor on small cranes, but would hardly be objectionable, as such cranes are working generally faster and more continuous than large cranes and are subjected to rougher treatment.

As the capacity of direct-current motors is mainly limited by the rise in temperature, and motors are liable to exert torque greatly in excess of the capacity of the crane and cause serious breakdowns, devices should be provided to limit

torque and current to a predetermined maximum and stop the motor before any harm is done.

In lowering a load the motor is assisted by the descending weight and is liable to attain very high speed, causing sparking and flashing at brushes and often serious injury to armature and field windings. The controller should, therefore, be arranged to prevent the speed from exceeding twice full-load speed. Alternating-current motors do not permit speeds much in excess of synchronous speeds and can be counted on to take the place of mechanical retaining brakes. Operators, however, must be careful and not shut off power, as the motor would then be liable to attain very high speeds.

The alternating-current motor has encroached more and more into the field of the direct-current motor and successfully replaced same where speed and direction of rotation is constant. Their introduction for crane work, however, has been slow, for many reasons.

The series direct-current motor has speed-torque characteristics especially well adapted for crane service. To give similar characteristics to the alternating-current motor much of the simplicity and advantage of the alternating-current motor had to be sacrificed. The simple squirrel-caged motor had to be changed to a wound-rotor motor with slip rings and brushes. On account of closed slots, windings are tedious and difficult to put in place and to form into the required shape. Open or semi-closed slots would greatly simplify winding, but decrease efficiency of motor. The maximum starting torque is not as great as on direct-current motors and regulation much poorer, as speed will exceed very little synchronous speed, even at no load, and if maximum torque is exceeded the motor is liable to pull out and stop entirely, and cannot start again unless load is decreased.

The large magnetising currents of alternating-current motors under all load conditions are liable to heat them up considerably when worked steadily, and must not be overlooked. These wattless currents do not represent energy and do not increase power consumption, but will heat up motors, transformers, generators, and conductors. Voltage drop should be avoided as much as possible on alternating-current motors, as torque varies as the square of the applied electromotive force; this, of course, means heavier conductors on cranes and feeders than for direct-current cranes, where drop in voltage affects mainly speed, not torque. Efficiency at light loads decreases rapidly, and is it therefore advisable not to make motors too large for the normal work.

Although alternating-current cranes can handle a load just as delicately as direct-current cranes, they cannot perform as much work, *i.e.*, act as quickly as direct-current cranes. Only the maximum loads can be hoisted at the same speed on both cranes, the speed of light loads and lowering being much higher on direct-current cranes. The suggestion of slowing down alternating-current motors for heavy work by means of resistance and of speeding-up for light loads, to approximate direct-current crane work, means larger motors and lower operating efficiencies.

Single-phase commutator motors have about the same characteristics as series direct-current motors, and are better adapted for crane work than three-phase synchronous motors. However, they have been very little in use on account of complicated construction of motor and their inability to commutate large currents.

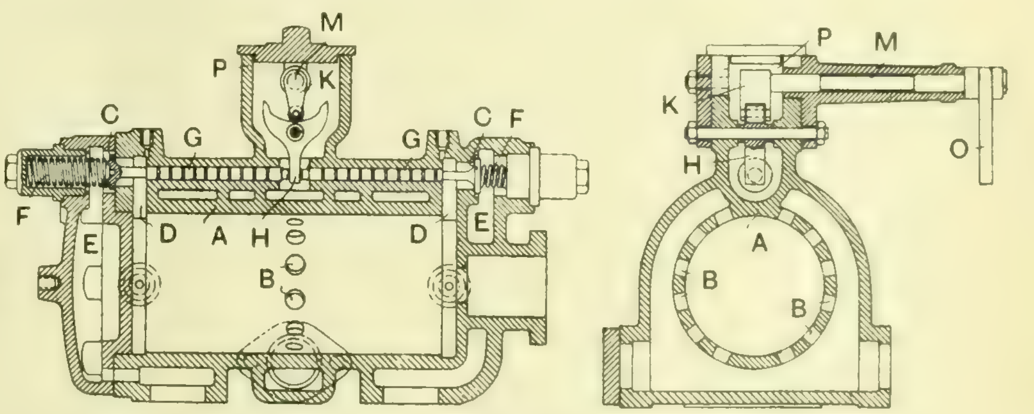
Since the introduction of electric motors on cranes and their ability to generate electric energy, great efforts have been made to use the generative control and do away with mechanical retaining brakes. The very same characteristics which make series motors and their rheostatic control best adapted for crane work, are very detrimental for regeneration and do not permit very readily lowering step by step by means of dynamic braking. The self-excited series generator is slow in building up its field with resistance in circuit, allowing load to descend until the field is strong enough. Unless the operator handles the controller properly and the weight is sufficient to overhaul the drum, this rheostatic dynamic-brake control is hardly satisfactory.

By giving the series motor shunt characteristics, dynamic-brake control has become almost perfect. The operator can handle the controller as usual, and is able to lower either the empty hook or the maximum load step by step at any desirable speed. By dividing the armature and field in two separate circuits and exciting fields separately, counter electromotive force can be lowered or raised above line voltage as desired. This, however, requires large rheostats in addition to controller resistance and brakes, which will release the motor when current is at its minimum value. The use of shunt brakes, or placing of series brakes with resistance directly across the line, would easily overcome all trouble.

A number of different devices are in use to limit the travel of hook in the highest position. To prevent serious breakdowns and perhaps injury to men, all such devices must be absolutely dependable at all times without requiring any attention. To avoid delays and losses, limit switches should not interfere with lowering of hook at any time, and must not require any re-setting or readjusting after once put in service. Overhoisting should open the device and stop motion before any damage is done; lowering should then reset device automatically. Limit switch must always be normally closed in such a manner that hoist is inoperative, should limit device for any reason whatsoever get out of order. The safest and simplest arrangement is a single-pole switch placed into the passage of the hoist block, which opens switch in time to allow brake to stop motion.

STUMPF'S VALVE GEAR FOR STEAM ENGINES.

THE accompanying sectional views show the construction of valve mechanism for double-acting steam engines having separate spring-pressed valves, the invention of Prof. Johann Stumpf, 33, Kurfürsteudamm, Berlin W. The exhaust from the steam cylinder A is effected through the ports B, which are controlled by the piston during its travel. The inlet of steam from the steam spaces E on the ends of the double-acting cylinder is controlled by lift valves C, which admit steam from the spaces E, to the cylinder A, through the ports D. The valves C are of the unbalanced type and are pressed to their seats by means of springs F. Owing to the high pressure which is obtained in engines of the type illustrated, such unbalanced valves may be employed without unduly loading the valve-operating mechanism. The stems G of the valves C are arranged parallel with the axis of the cylinder and extend towards one another, so that they are only separated by one arm H, of an oscillating horned lever. The stems G are pro-



STUMPF'S VALVE GEAR.

vided with grooves which assist in the lubrication of the parts and also assist in packing the stems. The lever H is an idle member, and is provided with two horns, between which there is a circular part over which a roller of a lever K may travel. The lever K is power driven, and is mounted on an axis M, which is caused to oscillate by an arm O. The oscillation of the arm O may be effected in any convenient manner. The horn lever H and its roller are contained in a casing P, filled with oil, so that the parts work in an oil bath. During the running of the engine, the lever K oscillates so that at the ends of its oscillatory movement it coacts with the two horns to oscillate the lever H, and thereby alternately open the valves C against the action of their springs F.

SIMPLIFYING SOME THERMAL CALCULATIONS BY THE USE OF THE THERMAL OHM.*

BY CARL HERING.

The purpose of the present article is to show how, by the adoption of a new unit for a quantity for which no unit has existed, the mental labour in a certain class of calculations can be greatly simplified and reduced. In general, when no definite unit exists, we naturally refrain from using that quantity by adopting some roundabout methods, or, when we must use it, we have to define a unit of our own—a home-made unit, as it were—which generally results in different writers giving their data in different units, thereby causing the waste of much mental effort by the one who desires to combine and use such data from different sources.

One of the groups of calculations in which no definite units exist for certain quantities is that concerned with the flow or transmission of heat by conduction, convection, and radiation. It therefore concerns such calculations as the thermal insulation of steam or refrigerating pipes, of electric and other furnaces, the transference of heat from the flames to the water in boilers, or from the flames or the arc of a furnace to the metal to be melted, the insulation of thermos bottles, the cutting of metals with flames, the repairing of broken metal machines by local fusion, &c.

For measuring heat energy itself, statically, plenty of units exist; too many, unfortunately: the large calorie, the small calorie, the B.T.U., the mongrel pound-centigrade unit, the joule, and the erg, some of which have several names; in name there exists a seventh, the "heat unit," which may mean nearly any of the others, according to the fancy of the writer, and is, therefore, meaningless unless defined by the user.

When a flow of heat is involved, that is, a rate of transmission of heat, the element of time must be introduced, and here there is again the choice of the hour, minute, or second, according to the fancy of the writer. Six heat units combined with three time units make 18 possible units of heat flow, from among which different writers seem to delight in choosing that one which they think other writers have slighted. However, each one of this family of 18 would be an intelligible unit for expressing a flow of heat if its particular make-up is clearly specified by its particular admirer.

Flows of heat through bodies are conducted, and they then meet with more or less resistance in that body, which resistance, for instance, is said to be about twenty or thirty thousand times as great through a piece of flannel as it is through an equal piece of copper. And as this thermal resistance varies so greatly and is of great importance, it becomes very desirable, and sometimes even necessary, to use it as a quantity capable of being measured, calculated, and specified; hence there should be a unit in terms of which this can be done. But no such unit existed, and the consequence is, as usual, that an author either evades this quantity, or else makes up a unit of his own; this results in a great multiplicity of units, ambiguity in their meaning, and, in general, much wasted mental effort on the part of the one who has to apply the data to practical cases. Some authors seem to take particular pleasure and pride in making up new composite units in such cases, and sometimes the only originality in an article is the invention of a different unit which no one else has cared to use.

Thermal resistances have in the past been generally avoided by using the reciprocals instead, namely, conductances (often incorrectly called conductivities, which are really specific conductances). But in by far the most cases in practice a flow of heat passes through several bodies in succession, that is, in series, as the electrical engineer terms it. Even in simple cases there are generally several successive contact resistances in series with that of the material itself, and these are sometimes extremely high; in fact, at times the most important of all, as in steam boilers, for instance, in which by far the largest part of the virtual thermal resistance is at the contact of the flames and the outside of the water tubes; this is so very great that the difference between the resistance of copper and iron tubes (about four to one) falls into insignificance.

When heat or electricity flows through several bodies in series it is far simpler to use resistances in the calculations, instead of conductances; and when they are in multiple the reverse is the case. The former being by far the more general case, it is much more rational to use thermal resistances than the older and more common conductances. This is the first of the improvements which is here recommended for the purpose of economising mental effort in such calculations.

But in view of the fact that conductances have in the past been used almost exclusively, let us consider for a moment the question of the units of conductance and conductivity. Such units are composite and must be made up, and this particular case is a good illustration of how each writer is apt to make up one of his own without the slightest regard for uniformity. Moreover, it seems that no one, until recently, has ever suggested a unit of conductance itself, but only of conductivity. Notwithstanding the convenience which the former would be, let us consider here only the latter.

A unit of conductivity is defined by a certain flow of heat through a specified cross section for a specified length, hence involves areas and lengths. For the latter the physicists usually take the square centimetre and the centimetre, hence they specify the heat flow through a centimetre tube; yet the inch is also often used, and until we have abandoned this irrational unit it is convenient to give conductivities in inch cube units also. Besides these two, some writers also use the metre cube, others the square foot combined with 1in. thickness, &c.; in one noted case of an otherwise excellent article descriptive of some valuable research work, the author of it even introduced the inexcusable mongrel combination of one square metre area with 1in. thickness. But assuming that there are only four sets of these linear and superficial units, then with the 18 different possible units of heat flow mentioned above, this makes 72 possible units of thermal conductivity—enough for the most fastidious writer to choose from if he wants something different from what others use; something "original."

This absurd and deplorable state of affairs, and the waste of mental effort which it involves, led the writer some time ago to investigate the subject with a view to finding, if possible, that unit in each case which is at the same time the most rational and reduces the calculations to the least possible.

The units used in the absolute system are those which bring nearly all coefficients to unity, hence involve no troublesome conversion factors. Hence, whenever we are in want of a new unit it is best to go to this absolute system, and, as the units in that system are often inconveniently small or large, to take some decimal multiple of them. This is what was very wisely done when our system of electrical units was devised, and those who enjoy the simplicity of electrical calculations should be thankful to our forefathers for their good judgment and wisdom.

A flow of heat is a particular case of the transmission of energy, the particular one in which the transmitted energy is in the form of heat, but as it may be transformed from or into other forms of energy, it is best, in the selection of a unit, to consider energy in general, and not only one form of it. The unit of energy in the absolute system is the erg, which is equal to the force of a dyne acting through a centimetre. The unit of time in that system is always a second; hence the absolute unit for measuring a transmission of energy of any form is an erg per second. This being inconveniently small for practical work, it has been decided, for electrical purposes at least, to make the practical unit 10 million times as great, and this unit is known as the watt.

Hence the most rational unit for measuring a flow of heat is the watt. To say that the heat flow in a certain case is so-and-so many watts means that the amount of heat is that which would be set free if that many watts were converted into heat, as in an electrical heater, for instance. Hence, if this unit were used, all coefficients and reduction factors would drop out (or be some multiple of 10), at least for all calculations with electrical quantities, such as electric furnaces or heaters, &c.

As a watt is a joule per second, the coefficients and conversion factors would also drop out in all our heat calculations if the tables of thermal constants were reduced once for all to joules. Specific heats, which are generally given relatively to water, would then be given by their true, absolute values in joules. But such a revolutionary change as that, which would involve the dropping of all four of our "home made" units of heat, for which we seem to have such an affection, and using only the two natural or absolute ones, the erg and joule, is

* Abstract of paper read before the Franklin Institute.

foreign to the present paper and need not be further discussed here.

Having found that the most rational unit of heat flow is the watt, and having decided that thermal resistance was a more generally useful quantity than conductance, the next question is, What is the correspondingly rational unit of thermal resistance? It is evidently that one which again reduces the coefficient to unity. The law of heat flow is, that the amount of flow increases in proportion with the temperature drop (which causes the flow) and decreases in proportion with the resistance (which opposes the flow); hence just like with electricity. This might be termed the thermal Ohm's law; or, represented by letters, if W is the heat flow, T the temperature drop, and R the thermal resistance, then $W = T/R$. It is in this fundamental law that the coefficient is to be made unity.

In the absolute system of units there is no temperature scale as temperature has not yet been reduced to absolute measure. Hence, until it is, we are compelled to use some one of the artificial temperature scales, and among these the centigrade is certainly the more rational.

Hence, as T is to be in centigrade degrees and W in watts, it follows that the unit for the thermal resistance R must be so chosen that the coefficient in this law will be unity. Hence R must be made equal to that thermal resistance which will allow one watt to flow when the temperature drop is 1° C.; this is the unit that the writer has termed the thermal ohm, a name originally suggested by Dr. A. E. Kennelly for thermal resistance, though for a quantitatively different unit.

Hence, when the physical property of a given body through which heat is flowing is stated in thermal ohms, and the temperature drop in centigrade degrees, the quotient of the latter by the former will give the heat flow in watts directly without any further reductions. It has, therefore, been reduced to the simplest possible kind of a calculation.

For calculations involving electric heat, such as those concerning electric furnaces and heating devices, nothing simpler could be desired, but even in other cases it will often be found to be simpler to make the calculations in thermal ohms and watts, and merely convert the final result back to the older and more cumbersome units, in which it may be desired.

The physical property of materials, called resistivity (specific resistance), as given in tables, is then stated in thermal ohms for one centimetre cube or 1 in. cube, and with the aid of these the total resistance of any given block of material is determined just as for electrical resistance, namely, by the usual formula $R = rL/S$, in which R is the total resistance in thermal ohms, r the resistivity in thermal ohms, L the length, and S the section, centimetres or inches being used consistently throughout.

The use of thermal resistances as such, in calculations, is often a great convenience and time-saving device. For instance, in determining the insulating walls of electric furnaces the temperature drop is known, and so is also the allowable loss in the form of a percentage of the total input. The former divided by the latter then gives the resistance which the walls must have in thermal ohms. With the resistivities of the various materials and the inside dimensions of the furnace, the thickness of each layer of the different materials making up the total wall can then be calculated so that the sum of all the resistances is equal to that required. This would be an extremely tedious calculation to make with conductances. The temperature at the junction of any two layers can then also be readily calculated with the same formula; W and R being then the known quantities, T is equal to their product.

In the insulation of steam pipes the temperature drop from the inside to the outside is known, and the permissible loss in power (reduced to watts) is decided upon; their quotient then gives the total insulation resistance in thermal ohms, hence per foot or per inch of pipe. Knowing the resistivities of the various insulating materials, the thickness of each can then be readily calculated, hence their respective costs, which can then be properly compared. It may thus be found, for instance, that it is cheaper to use a thin layer of a better insulator than a thick layer of a poorer one, or the reverse; or, perhaps, that a combination of two layers is better. For thick layers over small pipes, the outer layers count for much less than the inner. Several such trial calculations would show to what extent the value of the steam energy which is being saved is worth the cost of saving it. In such cases the reduction to and from watts is made once for all, the simple Ohm's law being then available for the more numerous trial or comparative calculations.

For a certain limited class of simple calculations involving steam or fuel energy alone, when the physical constants are avilable in the best form for direct application, it may be more convenient to use the older method based on conductivities and without reducing to watts; but when anything different from the ordinary is involved, it will probably be found to be simpler to perform the computations in terms of watts and thermal ohms, and reduce merely the end results to the units desired, just as it is often simpler, in the more involved calculations, to reduce values to the metric system, perform the calculations in that system, and convert the end result back to our old units. It is also possible, of course, to establish other units of thermal resistance, based on the particular thermal temperature, time and length units, which one may be accustomed to using, by a method which reduces the coefficient to unity, similar to the one here used to establish the thermal ohm.

Another advantage of such a unit as the thermal ohm is that, being based on the absolute system, it is a rational one to which all values determined in other units could be expected to be reduced by the authors, hence it could be used as a sort of standard international thermal unit in terms of which all determinations can be readily compared, and from which they can readily be reduced to any other specific units desired; a sort of clearing-house for the 72 possible units of resistance.

Attention is here called to the fact that in not a few books and papers the heat flow and thermal conductivity units based on the gramme calorie per second, centigrade, and centimetre cube are claimed to be the absolute units. This is an error, although a very common one; this can be shown by the fact that they are incommensurate with the true absolute units. There is no heat unit in the absolute system; heat is energy, and the energy unit in that system is the erg and not the gramme calorie. The units recommended by the writer (watt and thermal ohm) are the ones which are the decimal multiples of the true and correct absolute units, and they are incommensurate with the so-called absolute units just described.

A table of about 150 values of the thermal resistivities of different materials, taken from various sources and reduced to thermal ohms by the writer, is published in the December issue of "Metallurgical and Chemical Engineering." The values in centimetre cube units range from about 0·24 to about 3 for the metals; 25 to 180 for various bricks and solid stones; and from about 250 to 5,000 for granular or fibrous materials mixed with air. It will, therefore, be seen that the unit is of a convenient size.

A table of conversion factors for reducing the various units of thermal resistances, conductances, resistivities, and conductivities to one another is given in the writer's paper on the thermal ohm, in "Metallurgical and Chemical Engineering," January, 1911, page 13.

PROPERTIES OF METALLIC CERIUM AND ITS ALLOYS.

CERIUM is a member of a group of rare metals known as the "cerium group" and which have already found extensive use in the arts. The metals themselves have not been used, but the oxides are employed in the preparation of the well known Welsbach gas light mantles. Cerium alloys are also used in self-igniting match boxes, &c. The extensive use of these oxides, known as the "rare-earths," led Alcan Hirsch to carry on some very extensive experiments both in the preparation of metallic cerium and its alloys. The physical and the chemical properties were all carefully investigated. The result of these experiments were given in a paper read before the American Electrochemical Society, for the following abstract of which we are indebted to the "Brass World".

The method used for the preparation of metallic cerium, and which the author found to be the most satisfactory of any tried, was by the electrolysis of the anhydrous chloride of cerium in an iron vessel. A graphite anode was used. A small amount of sodium and potassium chlorides was first fused, and then the cerous chloride added. More of the sodium and postassium chlorides was added as the electrolysis went on.

At the end of two hours, with a current of 110 amperes, 40 grammes of a fairly well fused metal was obtained. This first experiment indicated the feasibility of the process, and it was afterwards used on a larger scale.

The metallic cerium thus obtained was not quite pure but contained about 1 per cent. of iron, with small amounts of cerium oxide and carbide. The purification of the cerium was affected by amalgamating it with mercury (it readily forms an amalgam), and the distilling in an iron pipe with a long portion at the top for cooling the mercury vapour. The iron and other impurities float to the top and can be removed. The cerium amalgam, thus freed from foreign substances, is strongly heated in a magnesia crucible to drive out all of the mercury and pure cerium results. A very high temperature is required for this purpose, and the heating is carried on in a magnesia crucible placed in a quartz vessel, in a vacuum in order to remove the last traces of mercury. The cerium thus obtained is quite pure. Unless the magnesia crucible is used, the high temperature required will soften the quartz. The cerium thus obtained has the following properties:—

Properties of Metallic Cerium.—According to the author, metallic cerium is a white metal resembling steel in colour. It is highly malleable and ductile, and may readily be rolled into sheet or drawn into wire. A strip of the metal was rolled down to thin sheet 0·015in. in thickness. It is quite soft and seems to resemble tin in this respect. The author states that it is not quite as soft as lead. It is easily cut with a knife.

The melting point was determined by the author and found to be 635° C. (1,175° Fah.), or practically that of aluminium (very low red heat). When melted, cerium oxidises rapidly in the air, so as to render the casting difficult. In order to cast it successfully it must be poured in an inert atmosphere, such as that of hydrogen or carbon dioxide. When this precaution is taken, the metal may be readily cast in regular moulds.

The specific gravity of cerium was found to be 6·92, or about the same as zinc. The atomic weight, as determined from pure salts, is given by the author as 140·25.

While the author made no direct determinations of the heat conductivity of cerium, it appeared to be fairly high, he says, and if so is an example of a metal which has a high heat conductivity and low electrical conductivity.

The electrical conductivity was measured on a cast rod and the specific resistance is given at 71·6 microhms per cubic centimeter.

The hardness of the cerium was measured by means of the scleroscope, and found to be 9·5 (hard steel is taken as 100).

The tensile strength of a cast cerium rod was found to be 12,900 lbs. per square inch. This is quite low, and approximates that of pure tin.

When cerium is filed, the filings will ignite unless care is taken and this property has been made use of in the preparation of the so-called "pyrophoric alloys," which are usually composed of about 70 per cent. of cerium and 30 per cent. of iron.

Pure cerium is very slightly attacked by cold water, but when boiling it is more strongly attacked and hydrogen gas is slowly given off. At the same time, the surface of the metal is blackened. Concentrated sodium hydroxide solution, concentrated sulphuric acid alcohol or ammonia have no action on the metal. Dilute sulphuric, nitric, and hydrochloric acids attack the metal vigorously. Salts, such as ammonium or sodium chloride, have moderate action on it.

When heated in the air to 160° C., if in a comparatively finely divided condition, cerium burns with luminescence.

Alloys of Cerium. A number of alloys were studied and were in most cases high in cerium, usually containing about 70 per cent. of this metal. The method of making the alloys was first to melt the cerium in a porcelain crucible under a layer of common salt, and then add the other metal in small pieces.

Silver alloys with cerium and the metal is hard and brittle. It has a silvery white lustre.

The alloy of gold and cerium is soft and has a reddish colour. Upon standing in the air it disintegrated to a purplish black powder.

Cerium and platinum alloy to a hard, white metal that is pyrophoric. It disintegrated slightly upon standing in the air.

With copper, cerium alloys to a hard and brittle metal which disintegrated to a powder upon standing.

Tin and cerium form a pyrophoric alloy which, standing a few months, disintegrated to a powder.

Cerium and antimony alloy to a soft metal which seems to be permanent in the air.

With arsenic a fairly soft alloy was produced which was apparently permanent in the air.

Carbon combines with cerium and hardens it. This carbide is produced in reducing the cerium in presence of it.

Silicon and cerium combine with the formation of a hard and brittle silicide. When about 15 per cent. of silicon is used, a good pyrophoric alloy is formed.

Tellurium unites with cerium, forming a brown, pulverent mass. The tellurium and cerium combine vigorously.

Upon adding selenium to molten cerium, two products were formed. One was a powder and the other a metallic alloy which was apparently cerium selenide dissolved in molten cerium.

Lead and cerium combine with a violent action. The alloy is very soft and emits sparks of a reddish colour when filed. The alloy disintegrates slightly upon standing in the air.

Cerium and calcium unite quietly with the formation of a white alloy, harder than either of the constituents. It emits sparks when filed, and is apparently permanent in the air.

Sodium and cerium alloy quietly with the formation of a hard alloy that is slightly pyrophoric, and oxidises upon exposure to the air.

Aluminium alloys with cerium readily, and the alloy is hard and brittle. It disintegrates without oxidation, and is not pyrophoric.

When zinc and cerium alloy, there is a violent action, almost explosive. The alloy is hard and brittle. It is pyrophoric and remains unaltered in the air.

Cadmium combines with cerium with the same vigour as zinc. The alloy is hard, brittle, and pyrophoric. It oxidises upon exposure to the air, but does not disintegrate.

The chromium and cerium alloys are white in colour and hard and brittle, unaltered in the air, and somewhat pyrophoric.

Manganese combines with cerium, forming a hard and pyrophoric alloy permant upon standing.

The nickel and cerium alloys are somewhat softer than those of cerium and iron. The ones high in cerium were very pyrophoric.

The iron and cerium alloys are very interesting, as they were the first pyrophoric alloys known and were discovered by Dr. Auer von Welsbach. The alloys containing about 70 per cent. of cerium are hard and somewhat brittle. This is the alloy now used so extensively in self-igniting match-boxes and gas igniters. When filed, sparks are emitted which have the property of igniting easily inflammable substances such as gasoline or illuminating gas.

With tungsten a hard and brittle alloy was obtained that was pyrophoric.

Cerium forms amalgams with mercury readily and with a few per cent. they are brittle, but when a greater amount of cerium is used, they are solid. They oxidise easily in the air, and those containing 8 or 10 per cent. of cerium take fire in the air.

With magnesium highly pyrophoric alloys are formed. The alloy containing about 83 per cent. of cerium is highly pyrophoric. Most of these alloys are brittle and are readily pulverised. Excellent flash-light powders can be produced from the ones high in cerium.

Wireless Telegraphy. — An International Conference on Wireless Telegraphy, to which almost all the European nations will send official representatives, is to be held in London in June next. One of the chief objects will be to widen the scope of the Radio Telegraphic Convention which came into force in the summer of 1908. Great Britain has adopted the Marconi system. Germany has the Telefunken and its own regulations, and the United States again has a different system and regulations, so that co-operation is handicapped. It is hoped that many of the existing differences will be wiped away, and some effective scheme of international control agreed upon. The last international conference was held in Berlin in 1903, and marked a great step forward in the direction of international control.

INDUSTRIAL AND TRADE NOTES.

Wigan Coal and Iron Company.—The annual report of the Wigan Coal and Iron Company, which has a paid-up capital of nearly £2,000,000, shows a profit of £72,449 for the year 1911, and a total available of £119,419. The directors recommend a dividend of $2\frac{1}{2}$ per cent., making 4 per cent. for the year, free of income tax. The balance carried forward is £47,030.

Board of Trade Returns.—The returns for the month ended January 31st show that the value of goods imported during the month amounted to £67,002,582, against £62,693,421 in 1911, and £55,909,684 in 1910. Of foreign and colonial merchandise exported in the month the value was £9,594,626, against £8,641,472 in 1911, and £8,147,164 in 1910. The value of British and Irish produce and manufactures exported in the month was £40,416,812, against £37,730,831 in 1911, and £34,803,115 in 1910.

Ebbw Vale Steel Works Active.—A notable feature of the Welsh steel trade is the activity at the Ebbw Vale Works, which, after a long stoppage, are now working at high pressure. They contemplate extensions to their plant, including the erection of sheet mills on a site adjacent to the steelworks. It is understood that the Briton Ferry Steel Company and the Llanelly Steel Company are installing new plant to enable them to increase their output. The tinplate works are still experiencing an acute scarcity of steel, and each week the difficulty seems to get more and more pronounced.

Small Air Compressing Plant.—We have received from the Parsons Motor Company, Ltd., Southampton, a photo of a little combined paraffin engine and air-compressor plant, several of which they have supplied for compressing air for starting internal-combustion engines. The paraffin engine is of 7 h.p., running at about 800 revs. per minute, with a cylinder $4\frac{1}{2}$in. bore and a piston stroke of 6in. It is fitted with governor and pump for water cooling purposes. The compressor is of the single-cylinder type and water jacketed. This plant is designed to produce a compression pressure of 100lbs. per square inch.

Shipyard Discharge Note.—At the conclusion of the conference held at Edinburgh last week between the Executive of the Shipbuilding Employers' Federation and representatives of the men's unions, under the national shipyard agreement, for the consideration of the discharge note system, the following official communication was issued: It was agreed that the present system as regards discharge notes be discontinued pending the question of the non-completion of contracts by piece workers being remitted to the various employés' local associations and the local representatives of workmen with a view to devising a method which will meet such difficulties in a manner equitable to employers and workmen.

Exhibition of Internal-combustion Engines.—The Society of Motor Manufacturers and Traders will hold its usual show at Olympia this year, but will very probably hold a big exhibition in 1913, to include all types of internal-combustion engines. This would include Diesels and semi-Diesels as well as gas engines and marine motors of every known type, and reveal to the world at large marine uses of the oil engine, of which few people have any idea at present. In armoured warships Diesel electric light sets are now the rule. All the battleships of this year's programme are to be equipped in this way, and the contracts are keenly competed for. Nor is this practice confined to armoured ships. Even destroyers are to have Diesel electric light sets. The extension to their case is a new departure, and the first boats to be equipped in this way are those for which shipbuilders are now preparing tenders.

The National Gas Engine Company.—The present report of this company deals with the period from the 30th June (when the old company terminated its existence) to the end of 1911. After providing for depreciation the profit amounts to £43,368. The new company did not obtain its certificate to commence business until the 2nd September, and the directors are advised that the profits earned before that date (from the 30th June) cannot be legally disposed of in the way of dividend. It has therefore been decided that £8,800, being the estimated profit during the period mentioned, be placed to reserve account. This will leave £34,569 available for disposal. It is recommended that £6,000 be applied to the payment of a dividend at the rate of 5 per cent. per annum in respect of the preference shares and £22,500 in the payment of a dividend of 9d. per share on the ordinary £1 shares. These payments will, subject to directors' remuneration, leave £6,068 to be carried forward. The profit of £43,368 for the half-year compares with £52,806 by the old company in the whole of 1910, £41,682 in 1909, and £44,986 in 1908. The dividend paid on the capital of the old company was 20 per cent. for each of the last three years.

The Boilermakers' Society and Apprentices.—The following letter has been addressed to the Boilermakers' Society by the Shipbuilding Employers' Federation respecting the attitude of the society towards apprentices: "We are desired to formally refer to this question, which was raised during the Conference this afternoon between the Federation and the Shipyard Trades Agreement Standing Committee. The employers were surprised to learn from the public press this morning that your society was taking steps to bring under their control all apprentice iron workers in shipyards. There have been several conferences within recent months on certain proposed amendments of the existing apprentice agreement. Those negotiations are still pending, and the Federation is still waiting the further reply promised in the last communication received from your society. The apprentice agreement provides that 'an apprentice is not to belong to any trade society (except for the purposes of benefit) nor is he to be interfered with in any way by any trade society.' The action which has now been taken is directly contrary to this provision, and the employers, as was intimated at the conference to-day, most emphatically protest against this action, which they regard as provocative of trouble, and likely to bring about a grave crisis in the industry. They trust that advantage will be taken by your society of the adjournment of this Conference to take such steps as will relieve the present menace which overhangs the shipbuilding industry." The letter, it will be seen, is couched in firm tones, and it is feared, if an amicable arrangement is not soon arrived at, further trouble in the shipyards may arise.

Boilermakers and the National Shipyard Agreement. — Mr. John Hill, general secretary of the Boilermakers' Society in his February report, states that "the vote on the National Shipyard Agreement is altogether against a continuance of our present agreement, and is also against an amended agreement, either by ourselves or in conjunction with the joint trades." The members of the society were asked to vote on the following four questions: (1) Shall we continue the agreement as it is at present? (2) Shall we ask the employers to meet us in conference with the joint trades to have the present agreement amended? (3) Shall we, as a society, have an agreement ourselves with the employers? (4) Shall we notify the employers that we desire no agreement? The voting shows a very large majority against the renewal of the present agreement, a fair majority against endeavouring to obtain an amended agreement, a larger majority against an agreement of any kind between the society alone and the employers, and a large majority in favour of notifying the Employers' Federation that the members desire no agreement whatever. The total number of members voting was not large, but it is sufficiently decisive, and the result of the vote will be notified in due course to the Joint Trades' Standing Committee. That committee are taking a vote of all the other trades on the question of renewing the agreement, but even if this vote is favourable it seems clear that the Boilermakers' Society will not be a party to whatever new agreement is adjusted. The existing agreement formally terminates on March 9th of this year, but it continues in force for at least half a year longer, as six months' notice of its termination can be given only at the close of the period for which it was arranged three years ago.

Control of Pickets.—The Trade Disputes Act Reform League have drawn up a petition to both Houses of Parliament in support of Lord Claud Hamilton's Bill. The essential part of the document reads as follows: (1) Your petitioners crave leave to call the attention of your House to the disastrous effect of strikes to the nation as they are conducted under the Trades Disputes Act (1906). Loss of trade, with consequent loss to wage-earners, increased cost of the necessities of life consequent upon the paralysis of transport services, and general hardship and inconvenience to the community are only some of the results of these uncontrolled industrial disputes. Your petitioners hold the opinion that the interests of capital and labour, which are directly involved, are of secondary importance to those of the entire nation, which are adversely affected by this unregulated warfare. Under the existing Act such strikes are a constant menace to the welfare of millions of unoffending persons. (2) Your petitioners realise that industrial disputes must on occasion break out, but pray that they may be so regulated as to inflict a minimum of injury to all concerned, directly or indirectly, and that they may be conducted with the least possible infraction of the peace upon which the well being of the nation depends. The presence of large numbers of pickets, your petitioners hold, is in itself an incentive to law breaking while disputes are in progress, and they pray that the pickets may be controlled in the manner provided by the Bill promoted by the Trade Disputes Act Reform League. (3) Furthermore, your petitioners view with grave concern the loss of individual freedom which has resulted from the methods of inducement adopted by pickets, and which are brought into operation even at the homes of contented workers.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1910.

Safety cranking devices. Embleton. 29448.

1911.

Automatic turret lathes. Conradson. 1542.
Torsion meter and power recording apparatus. Scarff. 1579.
Mechanism for connecting the piston and crank shaft of internal combustion engines and pumps. Court. 1591.
Change speed gearing. Phillips & Allingham. 1790.
Means for heating by high pressure gas. Smith & Walter. 1872.
Internal combustion engines. Norman. 1905.
Nut-locks. Kirke. 1919.
Steam boiler furnaces. Jones. 2016.
Crank discs for internal combustion motors. Stuart Turner, Ltd., and Plint. 2213.
Turbine pumps. Page & Boultbee. 2223.
Oil engines. Aktieselkabet Volund. 2238.
Recuperative zinc furnaces. Folliet Mieusset. 2250.
Gas producers. Folliet-Mieusset. 2253.
Two-cycle internal combustion engines. Sears. 2272.
Ore concentration. Nutter, and Minerals Separation, Ltd. 2383.
Manufacture of air-gas. Pace. 2401.
Method of and means for re-making wire drawing dies. Horton. 2497 and 2503.
Holders for mining and boring drills. Thomas & Lewis. 2505.
Internal-combustion engines combined with pneumatic pressure apparatus. Kearton. 3005.
Heating of steam generators in connection with water gas producers. Thuman. 3024.
Apparatus for the removal of boiler incrustation. Van Devoorde. 3117.
Lubricators. Heenan & Froude, Ltd., and Walker & Coates. 3287.
Manufacture of crank-shafts. Overgaard & Aktielskabet Burmeister & Wains Maskin-og Skibsbyggeri. 3643.
Vacuum brake systems. Richardson. 3699.
Burner for liquid or gaseous fuel. Graddon & Blumenau. 3742.
Apparatus for reducing pressure, measuring volume, and regulating delivery of gases from vessels containing gases under pressure. Bayeux & Richard. 4187.
Processes for welding or cutting metals by means of the blow pipe flame. Knowles. 4487.
Carburetters for internal-combustion engines. Carter & Rivett. 5215.
Steam-generation. Fletcher. 5799.
Screw cutting machines. Sachsische Schrauben und Muttern fabrik Geb. Hubner. 6087.
Furnaces for boilers. Sturrock. 6231.
Feed-water heaters for boilers. Mejani. 6308.
Apparatus for the regulation of refrigerating machines. Pollard. 6414.
Gyroscopic transmission apparatus. Fieux. 6424.
High pressure gas burners for heating purposes. Smith & Walter. 6719.
Furnaces of the underfed type. Wills. 7119.
Grinding valves. Cotton. 7446.
Feeding and conveying apparatus for metal plate rolling mills. Gale & Whittle. 7717.
Mechanico-chemical process for the separation of ores. Compagnie d'Entreprises de Lavage de Minerais. 8154.
Regulating the travel of pump plungers. Wakefield. 8721.
Bearings for machinery. Hughes. 8755.
Screw propellers. Keitel. 8778.
Variable cut-off gear for locomotive engines. Baker. 8989.
Apparatus for regulating the supply of hydrocarbons to carburetting apparatus. Smith. 9144.
Flywheels. Bilitewski. 9643.
Means for treating smoke and fumes. Mercer & Mercer. 12791.
Hoisting apparatus. Garben. 13012.
Machines for grinding rollers of roller bearings. Hoffmann Manufacturing Company and Barrett. 13079.
Gasification of fine grained or pulverulent fuel. Kerpely. 13093.
Surface condensers. Reimers. 13569.
Engine governors. Sargent. 14047.
Frames of internal combustion engines. Kilburn. 14880.
Apparatus for charging open hearth furnaces. Babcock & Wilcox, Ltd., and Smith. 15258.
Process and apparatus for the combustion of refuse. Uhde. 16781.
Speed indicators and recorders. Beermann & Balzer. 16970.
Screw cutting stocks and dies. Frey. 18033.
Bolt and nut locks. Dietrich. 18111.
Engine starting apparatus. Justice. 18885.
Charging-apparatus for furnaces. Gmeindl. 19096.
Propeller for ships. Jamieson. 19354.
Elastic fluid turbines. London. 19622.
Fluid pressure actuated valves. Wagner. 19913.
Method for sinking a mine shaft in a water-bearing soil which is weak or porous. Gevers. 21788.
Broaches, drifts, and similar metal cutting tools. Maudslay Motor Company, Craig, and Greening. 22175.
Clutches. Bramley Moore. 22553.
Valves. Reader. 22893.
Thrust bearings. Emrick. 23503.
Fluid-actuated turbines. Boult. 23635.
Rotary two-stroke explosion-engines. Brivois. 26035.
Pneumatic starter for gas engines. Feeny. 26318.
Axle trucks for railway and tramway vehicles. Curwen. 27334.

1912.

Devices for regulating the threading tools of screw machines. Robertsen. 440.

ELECTRICAL, 1910.

Reproduction of sound by electric means. Brown. 29833.
Circuit breaking safety devices for electrical apparatus. Evershed and Vignoles, Ltd., and Evershed. 29980.

1911.

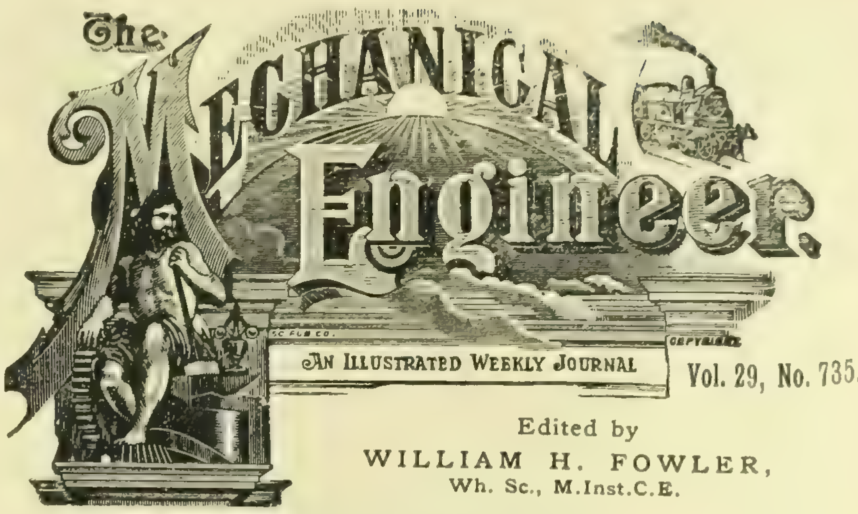
Arc lamps. Johnson. 1527.
Electric lighting of motor cars. Van Raden & Co., and Metz. 3549.
Incandescent electric lamps. "Z" Electric Lamp Manufacturing Company, and Hoge. 5061.
Control of electric motors. Allgemeine Elektricitats Ges. 6557.
Means for automatically controlling heat in electric heating apparatus. Nightingall. 15898.
Wind power electric storage installation. Perry. 17006.
Means for controlling and actuating apparatus by electro magnetic radiations. Wirth, Beck, & Knauss. 18879.
Excess current switches. Felten & Guilleaume Carlswerk Akt. Ges. 19392.
Insulation of electric conductors. British Westinghouse Electric and Manufacturing Company. 20659.
Regulatable electric resistances. Naumann. 20833.
Storage battery electrodes. Hubbell. 21783.
Electric switches. Bigge & Butt. 22547.
Arrangements for the working in parallel of synchronous and asynchronous alternating current generators. Siemens Bros. Dynamo Works, Ltd. 28263.

METAL QUOTATIONS.

TUESDAY, FEBRUARY 13TH.

Aluminium ingot	63/- per cwt.
" wire, according to sizes, &c. ......from	102/- "
" sheets " " ...... "	120/- "
Antimony ...... £27, 10/- to	£28/10/- per ton
Brass, rolled	7$\frac{3}{8}$d. per lb.
" tubes (brazed)	9$\frac{7}{8}$d. "
" " (solid drawn)	8d. "
" " wire	7$\frac{3}{4}$d. "
Copper, Standard	£62/10/- per ton.
Iron, Cleveland	48/10$\frac{1}{2}$ "
" Scotch	54/10$\frac{1}{2}$ "
Lead, English	£16/ - "
" Foreign (soft)	£15 15/- "
Mica (in original cases), small	6d. to 2/ per lb.
" " " medium	2/6 to 4/- "
" " " large	4/6 to 8/6 "
Quicksilver	£8/7/6 per bottle.
Silver	27$\frac{5}{8}$d. per oz.
Spelter	£26/15/- per ton.
Tin, block	£196 10 - "
Tin plates	13/6 "
Zinc sheets (Silesian)	£29/10/- "
" (Stettin; Vieille Montagne)	£30/-/- "

German Engineering Trade.—According to a continental contemporary, the position of the engineering and motor industries in Germany was not generally satisfactory during 1911, especially in Saxony. Prices of steam engines were low, agricultural machinery declined somewhat, and the machine tool trade was, as previously, unsatisfactory.



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Edited by
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The Coal Trouble and Oil Fuel.

THE contingency of a national coal strike and of the inconvenience which such an event would inevitably inflict upon all manufacturers who use coal for steam-raising purposes, gives a prominent, even if it be only a temporary, interest to the question of oil firing in boiler furnaces. The subject is one to which a good deal of attention has been given, and oil-burning installations are not only becoming pretty general for naval purposes, but in certain services where liquid fuel can be obtained at reasonable rates has been extensively adopted in the mercantile marine. The relative cost of oil and coal, however, in this country has hitherto prevented anything but the most limited application of oil to steam-raising purposes in land power installations. Its prohibitive cost is at once seen by the comparison of a few figures. Coal at 10s. a ton is, roughly, equivalent to 18lbs. for a penny, and the thermal value of this quantity in a boiler furnace is more than that which would be obtained from a gallon of petroleum oil; so that to compete on a similar evaporative basis its cost should not exceed one penny a gallon, and the price in this country is so much greater as to put it out of consideration except in cases of extreme urgency, notwithstanding the many incidental advantages in the way of storage and manipulation which a liquid fuel possesses. For naval purposes it is easy to understand that these advantages may be paramount, and hence its extensive adoption by the Admiralty. There are, of course, many power-plant services on land which must at all costs be maintained, and where a shortage of coal supply may necessitate a temporary resort to oil fuel, and to those responsible for their maintenance the principles governing the efficient burning of liquid fuel may be of interest. In the first attempts to burn crude petroleum oil it was mixed with absorbent substances and burnt in pans or grooved grates, but this, though simple and permitting of a quick interchange from coal firing, proved unsatisfactory owing to the imperfect and irregular character of the combustion and the excessive

quantities of smoke that were occasionally produced, though a modification of this method has been introduced recently in the Italian navy, the liquid fuel being fed into a series of grooved bars, on to which the air for combustion passing up and between the bars is deflected downwards by a series of T section bars, spaced alternatively with the troughs. It is not so simple as the method of spraying, and is not likely to come into general adoption. Another method tried in the early days was the vapourisation of the fuel in heated passages prior to its issue from the outlet jets, but such vaporising was found to lead to a deposition of solid carbon, which choked the passages, and in practice would not prove successful. Experience seems to show that the best method of burning oil is by atomising the spray injected into the furnaces, and the more efficiently the atomisation is effected the better is the combustion. This atomising is done in a variety of ways. In some cases it is effected by permitting the oil alone to escape under pressure with a revolving motion at the point of exit. In others the atomising is effected by combining the stream of oil with air or steam under pressure, so that the jet escapes as a fine spray. Opinions differ as to which method is the most effective. For simple atomising purposes air or steam is equally efficient, but the use of air demands a separate compressing plant, which means expense and complication. On the other hand steam does not supply oxygen as air does for combustion, while it absorbs about 4 to 5 per cent. of the total steam generated. The presence of steam in the waste gases also raises their specific heat and thus adds to the heat lost from the chimney. In either case, of course, the raising of steam in the first instance is a problem which presents difficulty, unless an air-compressing plant can be run from an independent power source such as a supply of electricity, or steam raised sufficient to work the fuel jets from a coal fire or in a supplementary boiler. For satisfactory oil burning, whatever the system of atomising, the air for combustion should, if possible, be heated before its introduction to the furnace, and further, the furnaces themselves should be of ample capacity. In an ordinary Lancashire or Cornish boiler oil cannot be burned satisfactorily by merely covering the firebars with firebricks and using the ordinary limits of the furnace. If the furnace is to be converted for oil burning the firebars should be completely removed and the furnace tube lined all round for some 5ft. or 6ft. with firebricks so as to secure a high temperature and complete combustion, while it is better also to set back the ordinary bridge wall 2ft. or 3ft. so as to give a large capacity to the furnace. It would be invidious to institute comparisons between the merits of the various types of burners, but there are a number of successful ones on the market both for steam and air spraying. Which is the best method is a matter steam users can only decide for themselves by reference to their individual circumstances. In any case the cost of raising steam in this way is so vastly greater than from coal fuel that it can only be regarded, in this country, at all events in land practice, as a temporary expedient created by stress of circumstances, and in the interests of the whole community it is to be trusted that the threatened trouble in the coal industry will not bring these about.

The Appointment of Engineers.

The Institution of Civil Engineers have taken a step which should prove of considerable assistance to its younger members in their efforts to secure professional employment. The importance of using every means to bring together those who require assistance and those who are wishful to render it is obvious, and with a view to facilitate this an organisation has been formed outside the institution, but with the special approval of the Council, to assist engineers and engineering assistants as far as may be practicable to obtain professional services or employment. The scope of this organisation is set forth in the following letter, which has been issued by the Board, comprising Sir Alexander Binnie, Past-Pres. Inst. C.E., Sir Alexander Kennedy, F.R.S., Past-Pres. Inst. C.E., Lord Cowdray, and Dr. J. H. T. Tudsberry, Sec. Inst. C.E., to the members.

> In view of existing difficulties in the way of many engineers, especially of junior rank, securing professional appointments, we have undertaken, at the request of the Council of the Institution of Civil Engineers, to form an organisation to assist such men to enter into communication with employers who are in need of the services of qualified engineering assistants.
>
> The Board formed with this object will be prepared to receive applications for engineering employment and also applications from employers for engineering assistants, and will endeavour to further the interests of both parties by placing them in communication in circumstances which may seem likely to lead to satisfactory results. Beyond this action the Board cannot undertake any responsibilities. At the outset its operations must necessarily be limited in extent, but it is hoped that these may develop in a manner that may be serviceable to the engineering profession.
>
> It appears to be impracticable for this business to be dealt with otherwise than by letter. Applications so made will receive prompt attention, and although correspondence on the subject must be strictly limited, those who apply may be assured that their wishes and requirements will at all times have careful consideration and attention.
>
> To facilitate the business, those who seek employment will be furnished with forms in which to state the particulars necessary to enable a judgment to be formed as to suitable quarters in which they may be advised to make enquiry. It is not intended to deal with testimonials, which should not be sent to the Board unless asked for, but to leave such details of special qualifications to be stated by the applicants individually to those with whom they may be put into communication.
>
> As the undertaking must be self-supporting, it will be necessary to charge some small fees to those who make use of it, and these will be indicated on the forms.
>
> We appeal especially to members of the Institution of Civil Engineers to assist our endeavours by communicating with the Board when they are in need of assistants, and shall be grateful for the support they may accord.

A BELGIAN DESIGN OF GAS PRODUCER.

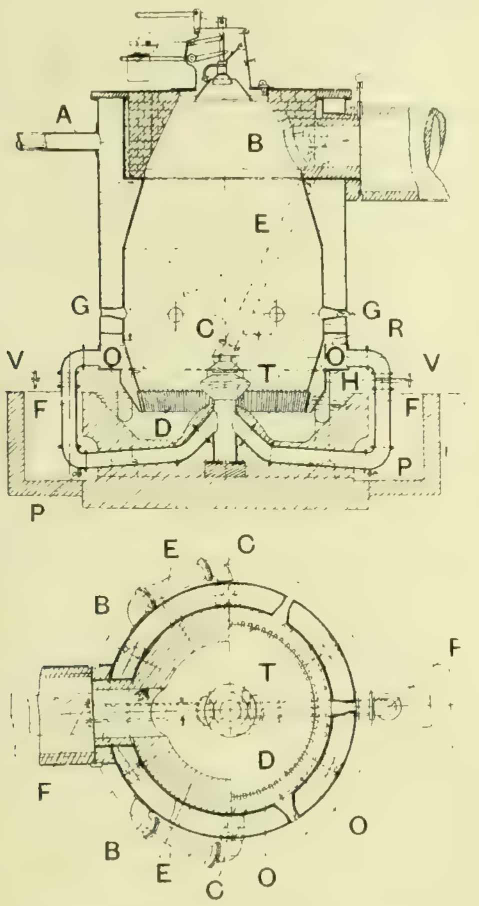
The gas producer illustrated herewith, the invention of A. Folliet-Mieusset, 28, Quai des Pecheurs, Liege, Belgium, has been designed with the object of obtaining a uniform and adjustable distribution of the primary air introduced at the base of the producer. Such a distribution is particularly necessary and also especially difficult to obtain in gas producers of large dimensions in which the air is introduced simultaneously at the centre and at the periphery of the zone of incandescent fuel.

The primary air forced by a blower is admitted through the conduit A, and enters the steam chamber situated at the upper part of the water jacket, where it becomes more or less saturated with steam, and thence passes through the two orifices B and the two inclined conduits E into the reheating chamber R at C. The inner wall of this annular chamber is in direct contact with exceedingly hot cinders, the lower part of the incandescent layer being limited to the level of the apertures G intended for the examination of the layer at the time of the daily cleaning. The outer wall of the chamber R is pierced at its lower part with openings arranged at 90° from the apertures C. These openings give access to the reheated mixture of primary air and steam into the central cone T through the conduits F. The bottom of the annular reheating chamber R is pierced throughout its entire periphery with apertures O, which likewise enable the mixture of primary air and steam (after reheating) to penetrate to a greater or less extent into the

annular space H comprised between the lower bell with hydraulic seal and the inner extension of the truncated cone of the producer. This inner part of the cone ends in a grating formed by an assemblage of half-round bars which are arranged very close together so as to retain the cinders, their flat portion being directed towards the interior D.

The mixture of air and steam which enters this annular space H passes through the layer of cinder over its entire periphery and proceeds progressively to the interior in rising and mixes with a similar mixture entering at the successive steps of the central cone. The valves V arranged in the conduits F are intended for regulating the proportion of primary air and steam passing through the cone and the apertures O, the partial closing of these valves increasing the admission at the periphery and reducing the admission at the central cone. The section of the conduits F is such that, if necessary, they can supply the whole of the primary air and steam after re-heating.

The apparatus is supported by the cast iron pillars in such a manner that the conical terminal bell is immersed in the water of the lower trough to an extent sufficient to



A BELGIAN DESIGN OF GAS PRODUCER.

enable the hydraulic seal to withstand the maximum pressure that can exist in the apparatus. The cocks P serve as purge cocks for the steam, which condenses when the apparatus is started for the first time until the normal course of the heating is attained. The fuel is introduced through the charging hopper at the top, which comprises a principal cone controlled by a lever with rolling counter-weight. When this lever is lifted the cone descends, carrying with it the hollow hemisphere which closes its upper orifice. This hemisphere can, however, be depressed alone by lifting its own lever, the suspension rod of the sphere being able to slide in a sleeve to which the principal cone is fixed. Owing to these two independent movements the fuel can be very readily distributed with great uniformity over the entire surface. A movable cover forming a hydraulic joint prevents any loss of gas when the fuel is allowed to fall into the producer.

Association of Mining Electrical Engineers.—Examinations for first-class, second-class, and service certificates in connection with this Association are to be held from March 16th to 23rd next. These examinations will be held simultaneously at Edinburgh, Glasgow, Newcastle-on-Tyne, Whitehaven, Sheffield, Manchester, Nottingham, Birmingham, and Cardiff. Application forms may be obtained from the secretary, Bank Chambers, London Road, Derby.

AUXILIARY MACHINERY FOR INTERNAL-COMBUSTION ENGINED VESSELS.

THE adjourned discussion on Mr. W. R. Cummins' paper on "Auxiliary Machinery for Internal-combustion Engined Vessels" was held at the Institute of Marine Engineers, Stratford, E., on Monday, February 5th. Mr. G. W. Newall (Member) presided.

A communication from Mr. Cummins in reply to the previous discussion was read by the hon. secretary. In the course of his reply, Mr. Cummins said he agreed with Mr. Timpson that British manufacturers of auxiliary machinery for the engine-room were as far advanced as their foreign competitors. There did not seem to be much doubt that compressed air, as a transmission system, was inferior to electricity in efficiency. In regard to Mr. Durtnall's proposal to generate at various voltages, he asked if the armature would be strong enough to stand the strain in cases of sudden stoppage of the winch. Auxiliary machinery on trawlers should be of the most robust description, and should be economical to run. For such small boats the use of electricity was not advisable. In reference to the remarks on compressed air, certain claims were made as to the vastly increased efficiency of the closed circuit system compared with that in which the air was compressed from atmospheric pressure.

In opening the discussion the chairman remarked that the subject was of peculiar interest, as the centenary of the passenger steamer had just been completed, and the comparison between the "Comet" and modern liners was an indication of the growth of the steam engine. It was now proposed to substitute the oil engine for the steam engine. There were many difficulties to be overcome, and he thought it would be many years before they could expect a high-class passenger vessel without steam.

Mr. E. Shackleton said the oil engine had ceased to be in the experimental stage. Only last week the "Zealandia," a 10,000-ton vessel, with three oil engines of a total power of 3,200 h.p., had passed her trials, and many other large vessels were in course of construction. The wreck of the "Romagna" was not an instance of failure on the part of the Diesel engines; in fact, it gave an example of how splendidly the engine worked under bad weather conditions.

Mr. W. P. Durtnall said the electric motor for auxiliaries, when first introduced on board ship, was not a mechanical engineering appliance, but to-day machines could be obtained, in the form of polyphase induction motors, that could stand comparison with any class of mechanical machinery. The main current was conveyed from the generators to all the stationary units. With regard to the variable voltage system and the possibility of sudden stoppage causing shock to the armature, the conditions could be met even on the constant voltage system, but it would mean that the engine would still be running on the full working current; but with continuous current and variable voltage the difficulty could be overcome economically.

Mr. William Walker considered it would be impracticable to have an oil engine for each independent unit, and while oil might be used for driving the main engine, other forms of power might be found to be better for the auxiliaries. He thought electricity, provided suitable machines could be obtained, would be best for deck purposes. He mentioned that in several London central power stations motor-driven pumps were being abandoned and steam was again being reverted to, in the form of a modification of the turbine and the Gwynn pump. It was evident, therefore, that there were conditions under which steam was still proved to be most efficient.

Mr. E. H. Evans cited instances where electrical machinery had been in use for many years in the Royal Navy.

The meeting closed with a vote of thanks to the chairman.

The Society of Engineers.—A meeting of this society will be held on Monday, March 4th, at the Institution of Electrical Engineers, Victoria Embankment, W.C., when a paper will be read on "The Trolley Vehicle System of Railless Traction" by Henry C. Adams, Assoc.M.Inst.C.E.

THE BALANCING OF LOCOMOTIVES.—I.

BY JAS. DUNLOP.

INTRODUCTORY.

A PERFECTLY-BALANCED locomotive may be defined as one in which the moving parts, whether revolving or reciprocating, move in such a manner at all times as to maintain the centre of gravity of the whole engine unaltered. The fact that the

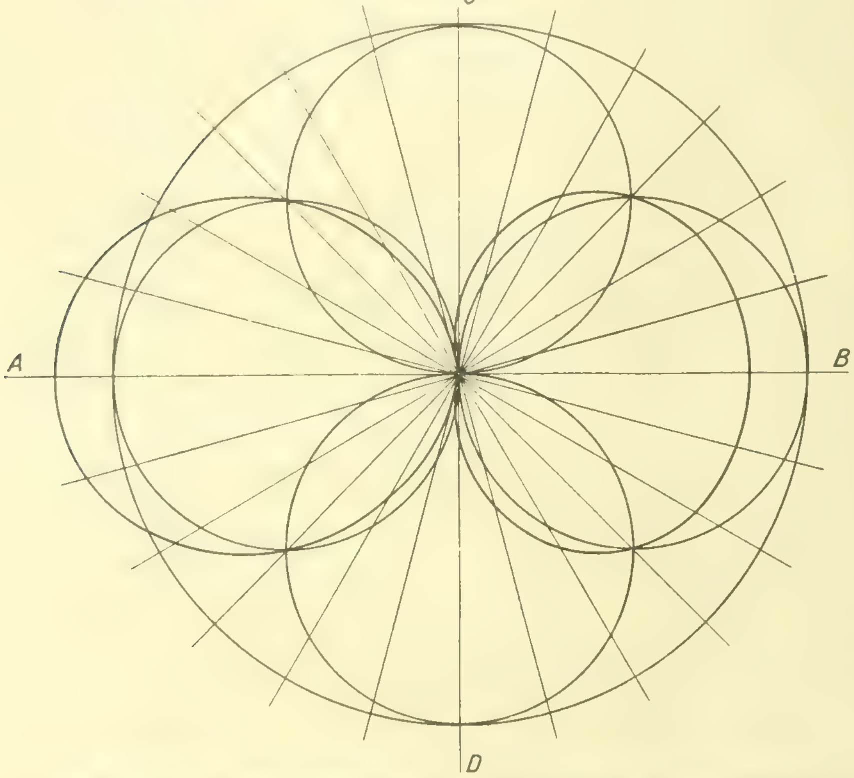


FIG. 1. SHOWING CENTRIFUGAL AND INERTIA EFFECTS OF EQUAL REVOLVING AND RECIPROCATING WEIGHTS, FOR 6 TO 1 RATIO OF CONNECTING-ROD TO CRANK, AND 15 DEGREE CRANK ANGLES.

great majority of the locomotives built have two cylinders only, the pistons of which are connected to cranks set at 90° apart, makes it practically impossible to have perfect balance in these engines.

So far as revolving parts are concerned, perfect balance can be attained in all cases by means of suitably placed balance weights in the wheels, the fact that the parts are revolving in a different plane to that in which the balance weights are revolving having no significance further than that of necessitating a rigid relation between the weight of the parts and the balance weights, along with a correspondingly definite angle between the balance weights in opposite wheels, *i.e.*, wheels on one and the same axle. In other words, by a suitable choice of balance weights and the angles between the weights, the revolving parts of a locomotive may be perfectly balanced around their centre of revolution and at the same time perfectly balanced in relation to the longitudinal centre plane of the engine.

The fact that the cylinders are placed on either side of the longitudinal centre plane of the engine horizontally, or approximately horizontally, results in the reciprocating parts producing alternating horizontal forces which act to turn the engine around a vertical centre in opposite directions alternately. The only means by which a reciprocating part can be perfectly balanced is by providing an equal reciprocating weight moving equal amounts in opposite directions in the same plane at all times. As this provision is not practicable in a 2-cylinder engine, it is usual to provide revolving weights in the wheels for the purpose of balancing as far as it is possible to balance the reciprocating parts by revolving weights. It is, of course, well enough known that a weight revolving around a centre produces a centrifugal force which acts radially and tends to pull the centre in whichever radial direction the weight happens to be at any given instant. By the well-known parallelogram of forces, the radial force may be resolved into two harmonic forces, maintaining the weight in its circular path. In the case of a weight in a locomotive wheel, these harmonic forces act horizontally and vertically respectively. As a reciprocating weight produces its unbalanced effect only in the direction in which it is guided—the horizontal in this case—the balance weight's horizontal force will more or less balance the effect of the reciprocating weight, but the vertical force of the balance weight will be an unbalanced force at all times. It is this latter fact which constitutes the greater part of the problem of balancing a locomotive.

The fact that the connecting rods are of definite lengths and have one end reciprocating with the piston rod crosshead while the other end revolves with the crank pin constitutes another considerable part of the problem—first, because of the definite lengths making the unbalanced reciprocating effect unequal at the ends of, and throughout, the two halves of the stroke, thus upsetting the balancing effect produced by the horizontal harmonic force of the revolving balance weight, and, second, because of the fact that these rods having neither a purely reciprocating or revolving motion cannot be perfectly balanced except by similar parts moving equal amounts in opposite directions in the same plane and around the same centre of revolution. As such a construction is practically an impossible one on a locomotive, it is usual to provide revolving weights in the wheels for the purpose of balancing as far as it is possible to balance the connecting rods by revolving weights. It will, of course, be understood that owing to the vertical pendulum action of the connecting rods the balance thus effected, although not perfect, is superior to that of the reciprocating parts, as some considerable proportion of the vertical harmonic force of the connecting rod balance weight will be counteracted by the pendulum action of the rod. The usual expression for centrifugal force is

$$C = \frac{W v^2}{g r'}$$

Where W = weight in pounds.
v = velocity in feet per second.
r' = radius in feet.
g = 32·2 = acceleration of gravity in feet per second.
C = centrifugal force in pounds.

To convert this into a form making use of dimensions in

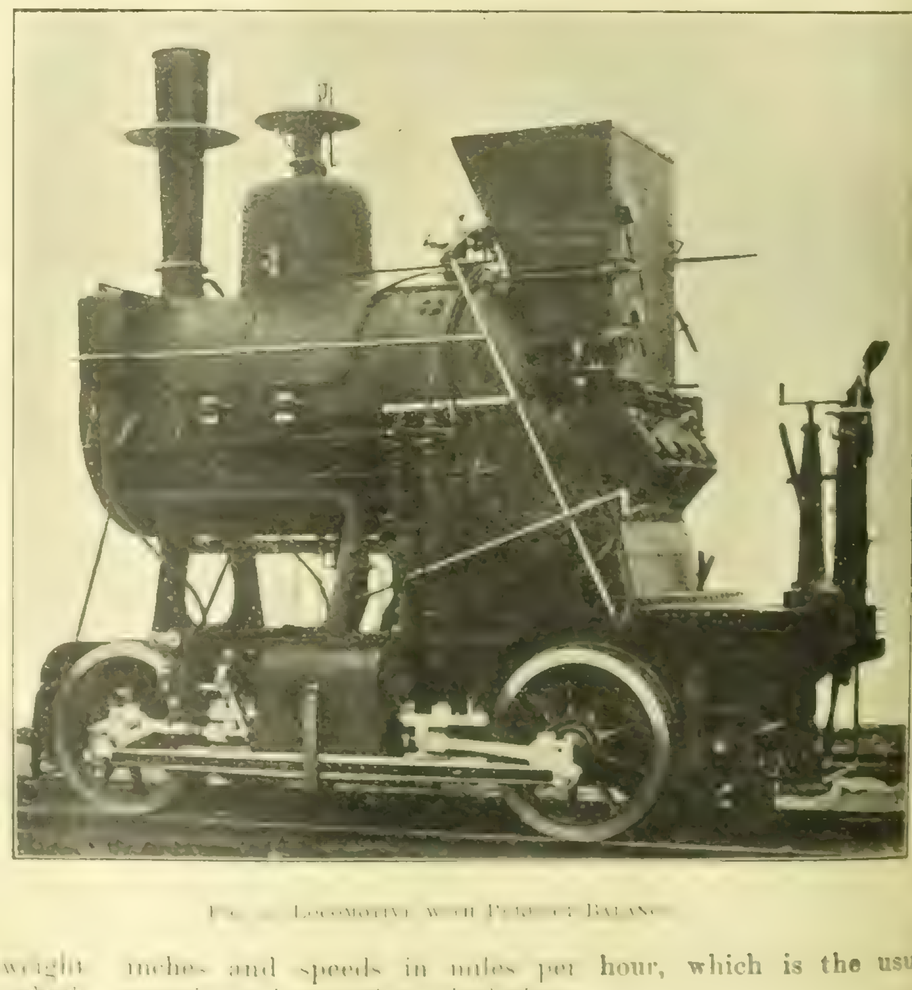


FIG. 2.—LOCOMOTIVE WITH PERFECT BALANCE.

inches and speeds in miles per hour, which is the usual practice in locomotive calculations.

Let M = speed in miles per hour.
D = diameter of wheel in inches.

r'' = radius in inches of crank or of centre of gravity of balance weight,

$$\text{then} \quad C = \frac{W\left(\dfrac{2 \times 3{\cdot}1416 \times r' \times 336\, M}{60 \times D}\right)^2}{32{\cdot}2 \times r' \times 12}$$

$$= 3{\cdot}2\ W r'' \left(\frac{M}{D}\right)^2$$

From this expression the centrifugal force of a revolving weight can be found for any given speed, and it is to be

FIG. 3.—LOCOMOTIVE WITH WORSE-THAN-NO-BALANCE.

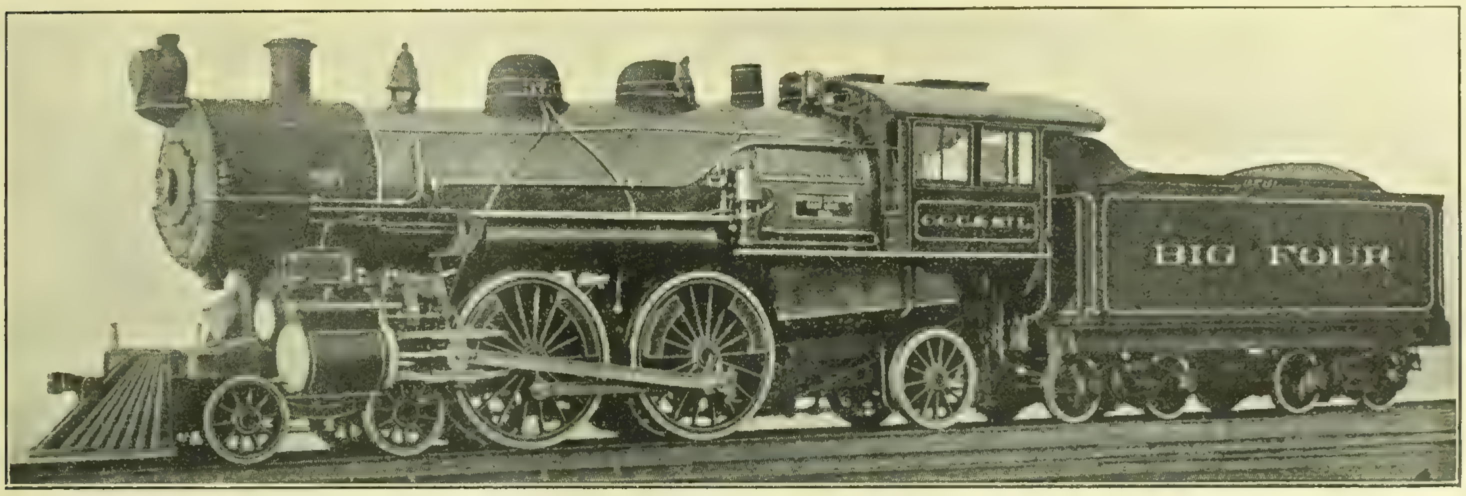


FIG. 4.—LOCOMOTIVE WITH INORDINATE BALANCE.

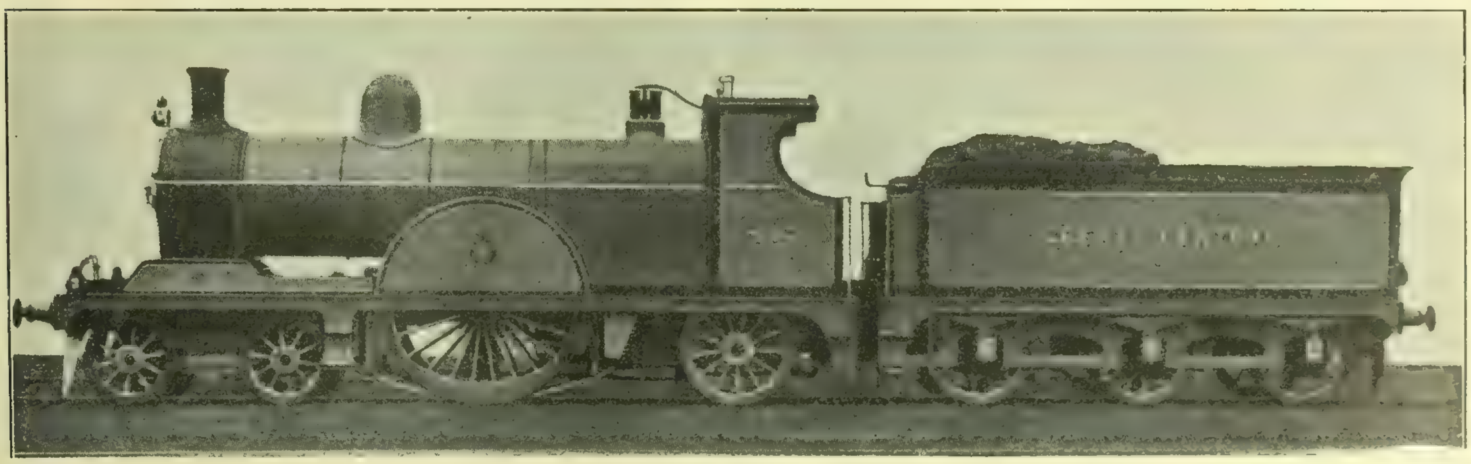


FIG. 5.—INSIDE "SINGLE DRIVER" LOCOMOTIVE.

noted the unbalanced or inertia effect of a reciprocating weight is simply this expression multiplied by an expression of the connecting rod effect. The combined expression is

$$Q \doteq 3{\cdot}2\ W r'' \left(\frac{M}{D}\right)^2 \left(\cos a \pm \frac{r''}{l''} \cos 2a\right)$$

Where a = angle through which the crank has moved for any position of the piston,

l'' = length of connecting rod in inches,

W = weight of reciprocating parts in pounds,

Q = inertia effect of reciprocating parts in pounds,

and other factors have the values already given.

The $(-)$ sign is to be taken for the forward stroke and the $(+)$ sign for the backward stroke.

Values of Q calculated for handy use are given in Tables I. and II., the value of $3{\cdot}2\ W r'' \left(\dfrac{M}{D}\right)^2$ being equal to 1.

Fig. 1 illustrates graphically the centrifugal and inertia effects of equal revolving and reciprocating weights. If the radius of the circle A B C D represents to any scale the centrifugal (radial) force of the revolving weight, then the polar circles on the horizontal semi-diameters give the horizontal harmonic forces, and the polar circles on the vertical semi-diameters give the vertical harmonic forces, which, as before noted, are entirely unbalanced forces. The elliptical shaped figures plotted on the horizontal centre give the horizontal inertia effect of the reciprocating weight. All the quantities are measured radially from the centre O to the circumferences of the polar circles and the elliptical figures. It may be noted when the crank is at 45° above or below the horizontal centre, or forward or backward of the vertical centre, the inertia effect of the reciprocating weight is equal to the horizontal effect of the revolving weight, so that at these four positions the revolving weight perfectly balances the reciprocating weight, but at no other positions. At these four positions the vertical effect of the revolving weight is, of course, equal to the horizontal effect.

A very noticeable point is that the connecting rod causes the inertia effect to be greater than the centrifugal effect at the forward centre and less than it at the backward centre. This difference is dependent on the ratio of connecting rod to crank, and is shown for a 6 to 1 ratio. That is to say, in Fig. 1 the inertia effect is one-sixth greater than the centri-

Table I.—*Inertia Effect of Reciprocating Weights at various Crank Angles.*

Crank angle.	0°	15°	30°	45	60°	75°	90°	105	120	135	150°	165°	180°	Backward Stroke ⟶
$l'' = 4r''$	1·250	1·1824	·9910	·7071	·3750	·0423	–·250	–·4753	–·6250	–·7071	–·7410	–·7494	–·7500	$l'' = 4r''$
$l'' = 5r''$	1·200	1·1391	·9660	·7071	·4000	·0858	–·200	–·4320	–·6000	–·7071	–·7660	–·7927	–·8000	$l'' = 5r''$
$l'' = 6r''$	1·1666	1·1102	·9493	·7071	·4167	·1148	–·1666	–·4028	–·5833	–·7071	–·7827	–·8216	–·8333	$l'' = 6r''$
$l'' = 7r''$	1·1428	1·0896	·9374	·7071	·4286	·1351	–·1428	–·3825	–·5714	–·7071	–·7946	·8422	–·8572	$l'' = 7r''$
$l'' = 8r''$	1·1250	1·0741	·9285	·7071	·4375	·1506	–·1250	–·3670	–·5625	–·7071	–·8035	–·8567	–·8750	$l'' = 8r''$
Crank angle.	360°	345°	330°	315°	300°	285°	270°	255°	240°	225°	210°	195°	180°	Forward ⟵ stroke.

Table II.—*Inertia Effect of Reciprocating Weights at various Piston Positions.*

Piston Position.	0	·1	·2	·3	·4	·5	·6	·7	·8	·9	1·0	Backward stroke.⟶
$l'' = 4r''$	1·250	·9382	·6437	·3682	·1137	–·1172	·3210	–·4932	–·6279	–·7172	–·7500	$l'' = 4r''$
$l'' = 5r''$	1·200	·9073	·6299	·3691	·1265	·0960	–·2960	–·4706	·6161	–·7278	–·8000	$l'' = 5r''$
$l'' = 6r''$	1·1666	·8875	·6220	·3708	·1364	–·0810	–·2793	–·4566	·6099	–·7368	–·8333	$l'' = 6r''$
$l'' = 7r''$	1·1428	·8737	·6169	·3732	·1438	–·0704	–·2678	·4472	–·6065	·7441	–·8572	$l'' = 7r''$
$l'' = 8r''$	1·1250	·8637	·6136	·3754	·1500	–·0678	–·2589	·4402	–·6044	–·7499	–·8750	$l'' = 8r''$
Piston Position.	1·0	·9	·8	·7	·6	·5	·4	·3	·2	·1	0	Forward ⟵stroke

fugal effect at the forward centre and one-sixth less at the backward centre. The perfect balance shown at the 45° positions is not an accidental effect for this particular ratio of connecting rod, but is actually a constant occurrence with any ratio of connecting rod as may be noted from Table I. For that reason it would appear that in all cases the whole of the reciprocating parts of a locomotive should be balanced, but owing to the disturbing effect produced by the unbalanced vertical harmonic force of the balance weight it is found necessary in modern practice to balance only about two-thirds of the weight of the reciprocating parts. The alternate upward and downward action of this force tends to rock the locomotive on its springs, with the result that at times the momentum of the rocking locomotive assists the downward action to such an extent that a pressure is imposed on the rail considerably in excess of both the normal wheel load and the downward centrifugal force. This excess of pressure has at times made its existence so manifest as to have earned for itself the descriptive title of "hammer blow." Another effect more or less assisted by the momentum of the rocking locomotive and the upward centrifugal action is the tendency to lifting of the wheel from the rail, resulting in "slipping," with corresponding wearing of "flats" on the tyres. By balancing only about two-thirds of the reciprocating weights it is found that at the high speeds of modern locomotive operation the engines ride comparatively easy on their springs. The increased length of modern locomotives to some extent counteracts the deficiency in horizontal balance.

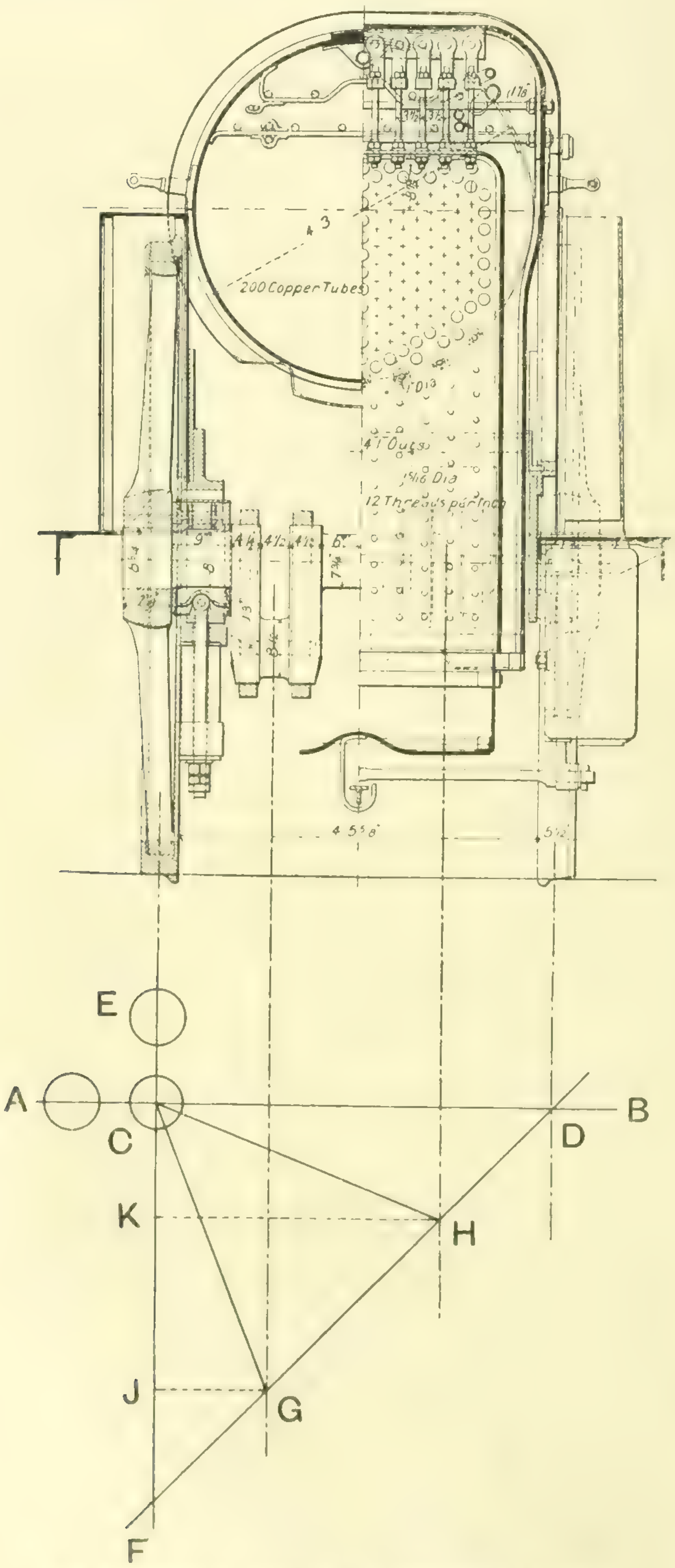


Fig. [illegible] Balancing Diagram: Inside [illegible] Single Driver Locomotive.

For balancing purposes the reciprocating weights consist of the piston, the piston rod, the piston-rod crosshead, and half the weight of the connecting rod, the other half of the connecting rod weight being taken as revolving weight.

Before proceeding to demonstrate how these weights should be dealt with in balancing a locomotive it will be interesting to notice the arrangements made for balancing the nearest approach to a perfectly balanced locomotive ever built along with some examples of how balance weights should not be dealt with.

Fig. 2 illustrates the nearest approach to perfect balance so far attained in locomotive construction. The engine was built to operate a motor coach service on the Bavarian State Railways. It is of the four-wheel coupled type, with outside cylinders placed midway between the driving wheels on either side. There are two pistons in each cylinder, connected front and back to the driving crank pins, each by the usual piston rod, crosshead, and connecting rod. The steam acts alternately between and on the outer faces of the pistons, producing the effect of what is practically a four-cylinder engine. The coupling rods are jointed to overhung cranks, the pins of which on the front and back wheels are behind and in advance of the main crank pins respectively. By this means it is ensured that the pistons will move equal amounts in opposite directions in the same plane at all times. The reciprocating parts, therefore, are perfectly balanced without the necessity of using any balance weight whatever in the wheels for that purpose. The overhung cranks and the coupling rods, being purely revolving parts, are completely balanced by the balance weights shown in the wheels, the only point in which the engine falls short of perfect balance being the fact that the connecting rods cannot be completely balanced by revolving

weights. The difference between the vertical effect of the pendulum action of the connecting rods and that of the revolving weights provided to counteract it is so insignificant, however, that "hammer blow" may be said to be non-existent with this engine. It may be pointed out that even without connecting-rod balance weights there would be no longitudinal unbalanced forces. It is not pretended that this construction of locomotive is suitable for other than the class of work it is applied to, the whole object of the construction being to obtain an extremely short wheel base engine with no forces acting to rotate the engine around a vertical centre.

Fig. 3 illustrates what is probably the worst balanced locomotive ever built. The engine is an inside cylinder "consolidation" type, and in six out of its eight coupled wheels the balance weights are placed in almost exactly the opposite side of the wheels to that in which they should be placed. The driving wheels are the third coupled pair from the front of the engine, and as the inside cranks are placed opposite the outside cranks in the wheels the balance weights on the driving wheels might be considered to have some pretence to correctness of position, but no sane theory of balancing can account for actually adding to the unbalanced revolving weights attached to the two leading and the trailing pairs of coupled wheels. This, it will be noticed, has purposely been done by the slab form given to the coupling pin bosses. The wheels are of welded wrought iron construction, and the only lightening in a space enclosed by a three-spoke interval is that of the two drilled holes clearly shown in the trailing wheels. It is more than probable that "hammer blow" effects were a pronounced feature in the running of this engine at any considerable speed. It is not at all probable that the inside moving parts could be of such weight as to require any additional outside balance such as shown, even with the whole of the reciprocating weights taken into account, and the intention had been to ensure extreme steadiness longitudinally.

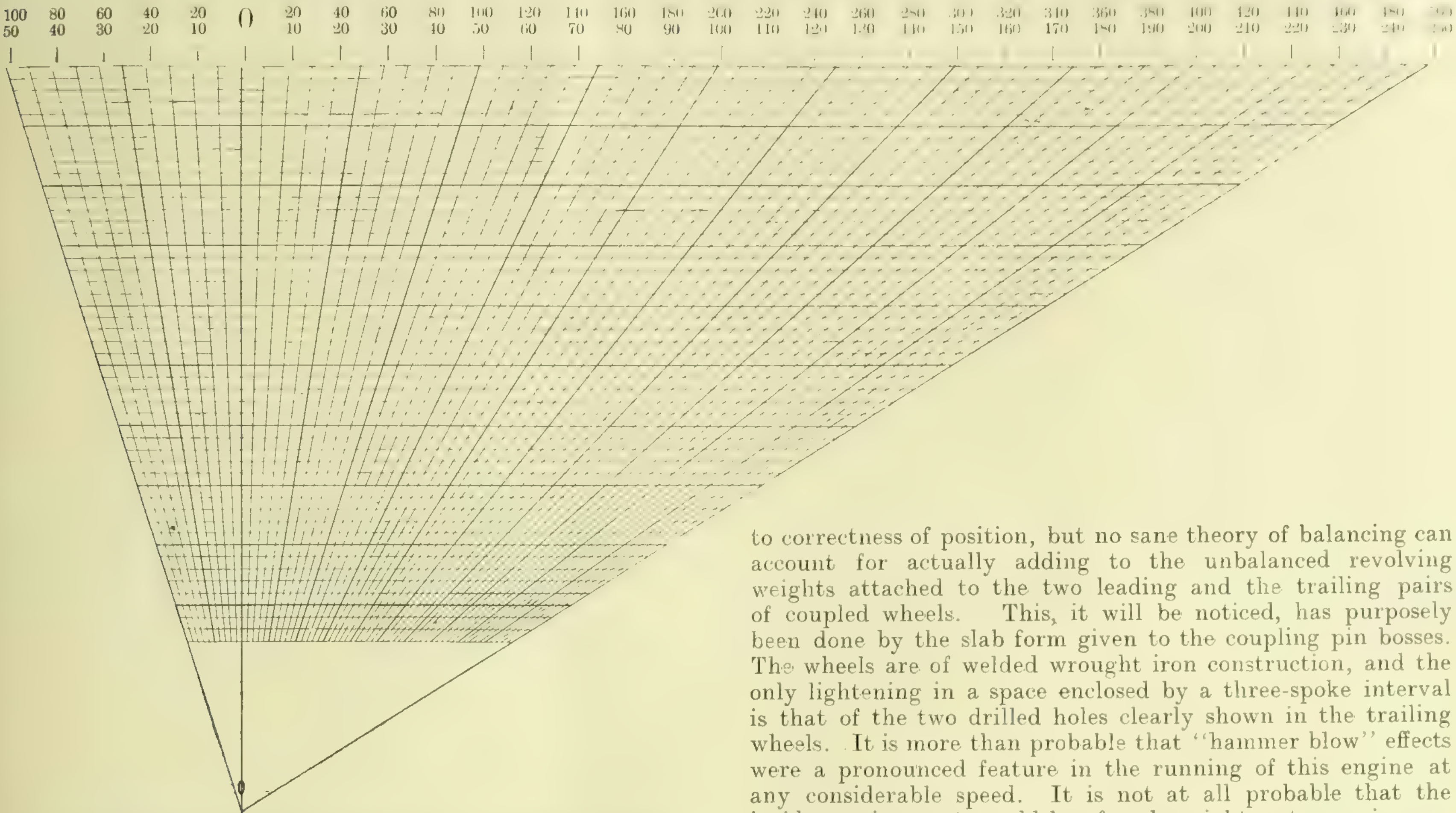


FIG. 7.—SCALE FOR DETERMINING LOCOMOTIVE COUNTER-BALANCE WEIGHTS.

Fig. 4 illustrates a locomotive balanced on a system controlled by the Davis Locomotive Wheel Company under the patent of Mr. P. Z. Davis, of Lometa, Texas, and it is claimed that by arranging the balance weights in the fashion shown, viz., in two separate parts, making an angle of 120° between each part and the crank, "the revolving and reciprocating parts of the locomotive are perfectly balanced for any speed from point of contact with rail, whatever that may mean. It is also claimed that "the hammer blow on the rail is entirely avoided." As regards balancing a reciprocating

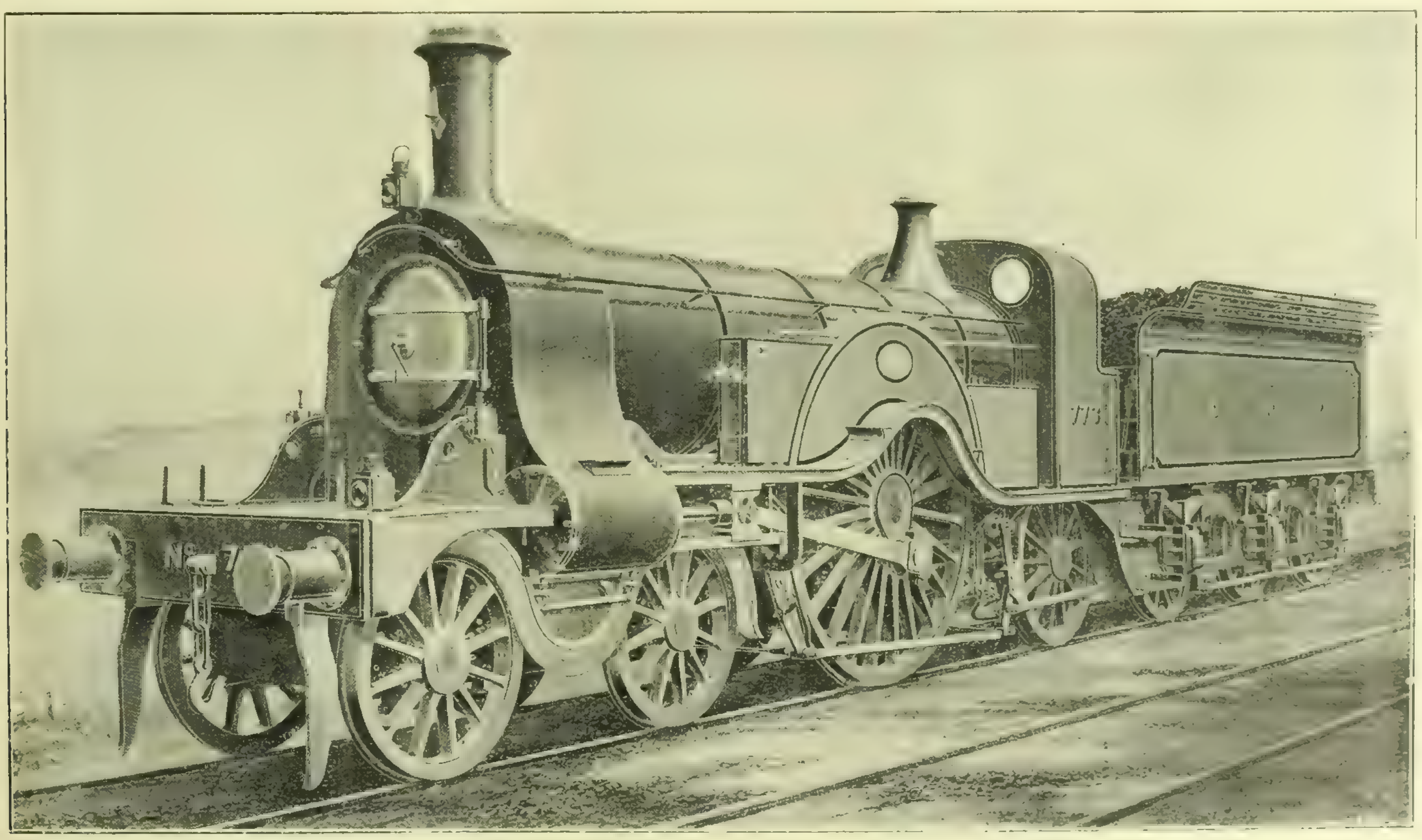


FIG. 8.—OUTSIDE "SINGLE DRIVER" LOCOMOTIVE.

part by a revolving weight, it has already been seen from Fig. 1 what the possibilities are in that direction, while as regards the separation of the balance weight into two parts, and the particular angle at which they are placed, it may be accepted that for all practical purposes a locomotive wheel is a rigid structure. It is quite immaterial, therefore, so far as balancing effect is concerned, whether one or two weights are used so long as the necessary effect of weight multiplied by radius is obtained. Consequently the most that can be said

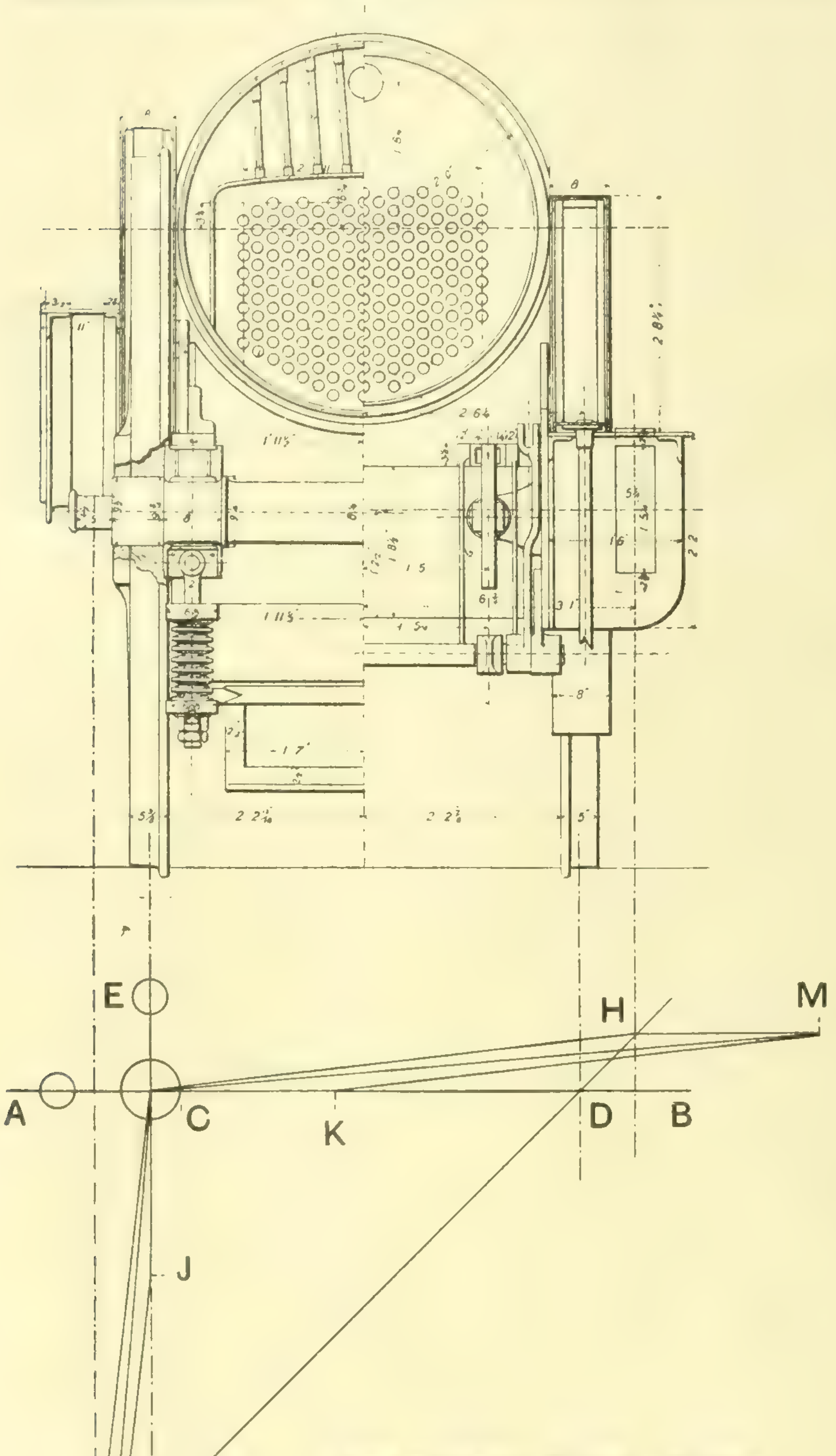


Fig. 9 Balancing Diagram Outside Single Driver Locomotive

for the arrangement illustrated is that it is very symmetrical. At its worst it employs just twice the amount of balance weight that would be used under ordinary circumstances to effect the required balance, and consequently unnecessarily increases the rail load to that extent.

Single Driver Engines.

The simplest case of balancing in an ordinary type of locomotive is that of an inside cylinder single driver engine, such as illustrated in Fig. 5. Under stress of modern conditions of railway operation this type of locomotive is rapidly becoming obsolete, but the cross section of the engine illustrated in Fig. 6 will demonstrate to locomotive draughtsmen a probably hitherto unsuspected virtue in their 45° set squares. To find the amount and the position of the balance weights for this engine project downwards, from the cross section drawing, the centre lines of the cylinders and of the centres of gravity at which the balance weights are intended to be placed in the wheel rims. At right angles across these lines draw the line A B, cutting the balance weight centres at C and D. With C as centre describe a small circle to indicate the crank axle. Also at A and E describe small circles to indicate the crank pins at right angles. Through D draw D F at an angle of 45°, cutting the cylinder centres at G and H. Join C G and C H. Then if C D—the distance between the centres of gravity of the balance weights—represents to any scale the amount of weight to be balanced at each crank pin, the lengths C G and C H represent to the same scale the amounts of the balance weights required. Also the angles they make with each other and with the crank positions indicated are the angles at which they must be placed in the driving wheels. The construction just described is complete, but as an indication of its accuracy the lines J G and K H show that the weights C G and C H are in reality each a combination of two weights at right angles to each other, and at the same time indicate that the weights C G and C H ensure transverse as well as rotational balance.

It may be noticed that, having given the vertical centres, anyone familiar with the construction would simply draw the three lines C D-D H and C H, and from them understand all that the complete construction conveys. For this type of engine the construction shows certain points very clearly.

1. The angles at which the balance weights are placed depend entirely on the cylinder and balance weight centres, and have nothing whatever to do with the amount of the weights to be balanced.

2. The angle between the balance weights is always less than a right angle.

3. For inside 2-cylinder engines the amount of balance weight is always considerably less than the amount of weight to be balanced.

Ascertaining the amount of weight represented by the lines C G or C H (which, of course, are equal) involves at the most a simple proportion sum, but even this labour may be avoided by means of a proportional scale such as illustrated in Fig. 7. If the draughtsman prepared such a scale on tracing cloth he will be able to move it up or down on his drawing until the lines representing the amount of weight to be balanced fall on the points C and D. Then by swinging the scale on the point C he can read the value of C G or C H direct. Other uses of the scale will be made evident later.

Fig. 8 illustrates an outside cylinder type of single-driver locomotive, of which quite a number are still in use, but of which no further examples are now being built. As an example of balancing it serves the double purpose of showing the application of the graphic method of balance weight determination to outside cylinder engines, and in doing so introduces an extension of the method that is applicable to all coupled engines. The cross-section of the engine is illustrated in Fig 9. To find the amount and the position of the balance weights for this engine project downwards, from the cross-section drawing, the centre lines of the cylinders and of the centres of gravity at which the balance weights are intended to be placed in the wheel rims. At right angles across these lines draw the line A B, cutting the balance weight centres at C and D. With C as centre describe a small circle to indicate the driving axle. Also at A and E describe small circles to indicate the crank pins at right angles. Through D draw D F at an angle of 45°, cutting the cylinder centres at G and H. Join C G and C H. Then if C D—the distance between the centres of gravity of the balance weights—represents to any scale the amount of weight to be balanced at each crank pin, the lengths C G and C H represent to the same scale the amounts of the balance weights required. As outside cylinder engines have crank arms formed in the driving wheels, it is necessary to balance these. Opposite each crank, as indicated, to the same scale as C D, set off the requisite amounts C J and C K. With C H and C K, also with C G and C J, draw the parallelograms C H M K and C G L J. Join C L and C M. Then C L and C M are the actual amounts of balance weights required, and the angles they make with each other and with the crank positions indicated are the angles at which they must be placed in the driving wheels.

Two points clearly brought out by this construction are:—

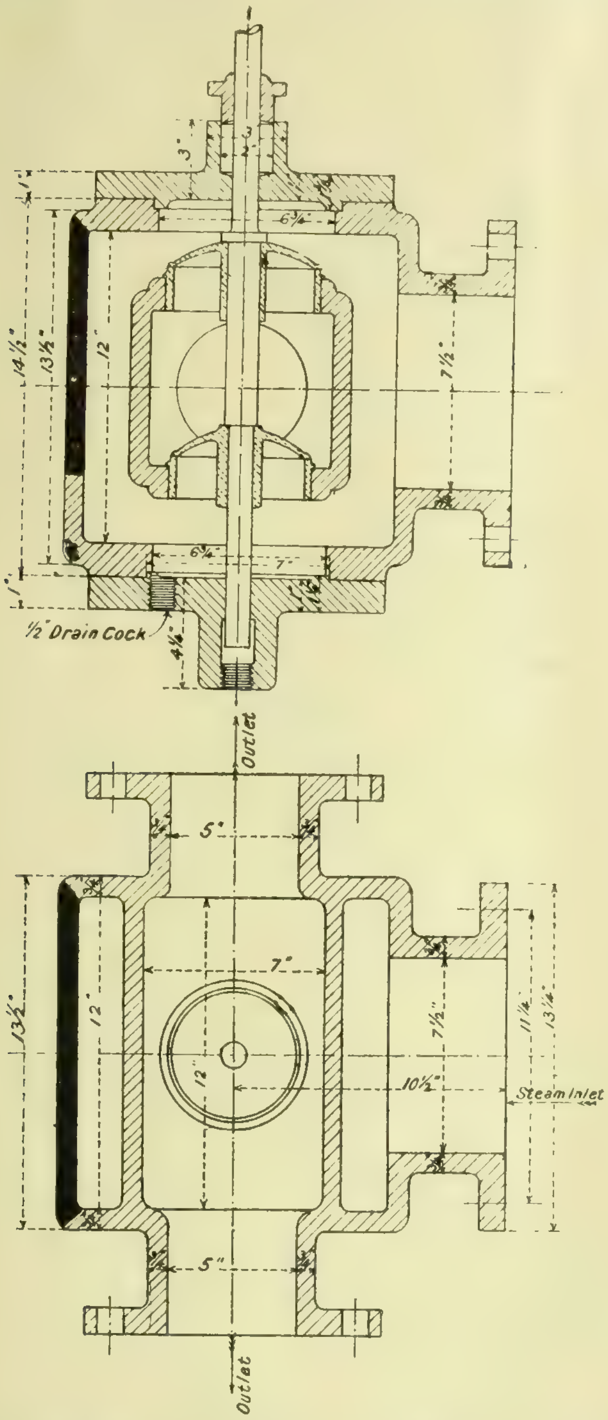
(1) The angle between the balance weights is always greater than a right angle.

(2) For outside 2-cylinder engines the amount of balance weight is always considerably more than the amount of weight to be balanced.

As in the case of Fig. 6, the proportional scale, such as illustrated in Fig. 7, may be used to ascertain the actual values of the various weights.

STEAM PIPE FAILURES AND "WATER-HAMMER."

FAILURES of steam pipes and stop valves as a result of "water-hammer" have been so often discussed that it would seem almost unnecessary to refer to them again, but a number of failures recorded in recent Board of Trade Reports show that the lessons of past failures are slowly learned by men in charge of steam power plants, for a large percentage of recent ones are directly traceable to this cause. The first of the batch of failures under notice, Report No. 2,062, arose because those in charge attempted to drain water from a range of pipes while they were in open communication with the boilers. The risk of this proceeding, especially with cast-iron pipes, has been repeatedly illustrated. If water is known to exist in a length of steam piping the stop valve controlling steam admission should be shut, or if the pressure in the pipes is not sufficient to drive out the water the valve should be eased in the gentlest manner possible until the water is all drained away and the pipes heated up. During this proceeding the risk of "water-hammer" should be recognised, and someone should stand by the valve to shut it instantly if need be.



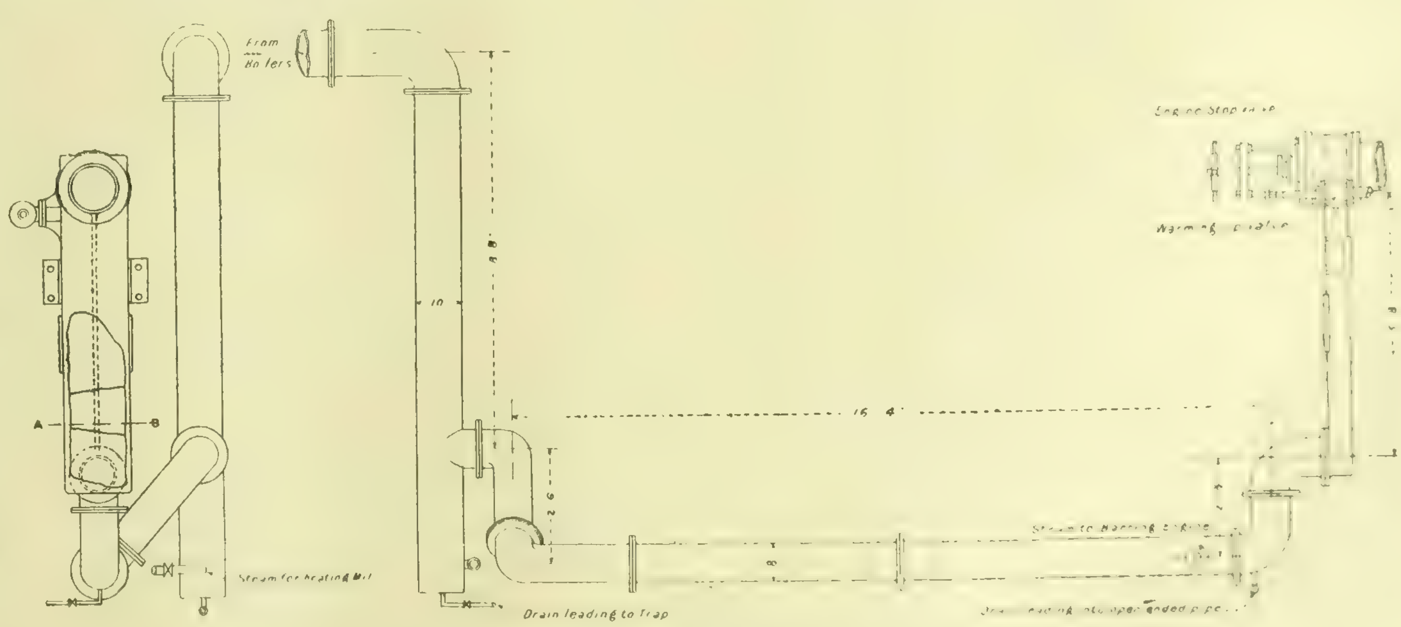
REPORT NO. 2,062.—SECTIONAL ELEVATION AND SECTIONAL PLAN OF THROTTLE VALVE. THE BLACK PORTION SHOWS THE PART THAT WAS BLOWN OUT.

In the case of Report No. 2,081, which occurred at a textile mill at Wigan on September 4th last, the "water-hammer" was brought about by opening a stop valve when there was an accumulation of water in the pipes, resulting from condensation during a week-end's stoppage, and which defective drainage had failed to relieve. This plug of water was then driven forward, and burst a rectangular and weak section of the pipes just below the engine stop valve. The moral of this case is that attendants should make sure before turning steam into pipes that the drain taps are in working order, and that no accumulation of water exists.

In the third case, No. 2,063, in which the cast-iron boiler stop valve was fractured, it is not clear how the "water-hammer" was brought about, but the evidence of the attendant as to what he did immediately before the accident, and by which he was scalded, is not, according to the report, far from doubt. The boiler was fitted with a superheater, consisting of a number of vertical tubes hung in the down-take of a Lancashire boiler, and it is suggested that under certain conditions the water may have been driven out of these into the steam pipes as steam was being raised, and so led to "water-hammer." It would seem, therefore, that in the working of superheaters in which any accumulated water has to be boiled away before it is in proper operation, care needs to be exercised.

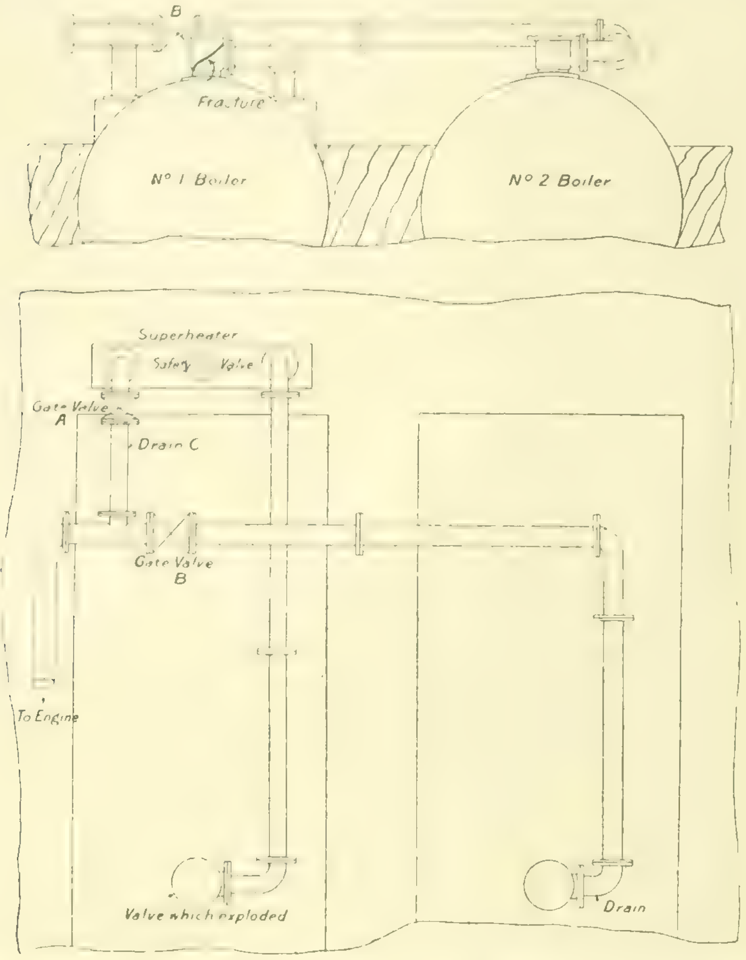
Of two other steam-pipe failures recorded, one (Report No. 2,088) occurred in a steam ship, as a result of excessive vibration owing to bad weather, coupled with slackness in the riveting of the engine seat and the holding-down bolts. This developed a circumferential fracture in a solid-drawn copper steam pipe, close to the flange uniting it to the engine stop valve. The failure in itself was slight, but it partially disabled the vessel, which in consequence was compelled to return to port for repairs. The second (No. 2,090) occurred at an engine works at Patricroft, and was due to the failure of a 6in. steel pipe where it was screwed into a cast-iron flange, owing to corrosion, which had eaten away the thread until it was incapable of withstanding the working pressure. It is of interest to note that in none of the above cases was the steam piping arrangements inspected by independent authorities, though in several instances the boilers were insured; it appears desirable, therefore, to point out to steam users that the ordinary policy of insurance only extends to the boiler stop valve, and that if owners wish periodical supervision of their steam pipe systems it is necessary to make special arrangements with the insuring company.

Convenient reference may here be made to the failure at Stoke-on-Trent, on October 22nd, of a cast-iron branch pipe connecting the bottom of a Lancashire boiler to the blow-off



REPORT NO. 2,081.—END AND SIDE ELEVATIONS OF STEAM PIPE RANGE.

valve. The fracture was due to an objectionable, but not uncommon, defect in blow-off waste pipes, viz., lack of freedom of movement, the pipe being cemented fast in a cross wall through which it passed on its way to the sump, into which the end discharged. As a result of this, severe



REPORT No. 2,063. VIEWS SHOWING ARRANGEMENT OF STEAM PIPING AND POSITION OF FRACTURED STOP VALVE.

stresses were induced in the pipe, and it fractured all the way round at one of the flanges when the contents of the boiler escaped at a pressure of 180lbs. on the inch, and severely scalded the boiler attendant.

THE JUNIOR INSTITUTION OF ENGINEERS.

THE annual dinner of the above Institution, which was held on Saturday last at the Hotel Cecil, proved a great success; the President of the Institution, Commendatore G. Marconi, D.Sc., LL.D., being in the chair, and amongst the other guests may be mentioned Vice-Admiral Sir H. B. Jackson (commanding the Royal Naval War College), Engineer Vice-Admiral Sir Henry J. Oram, Sir George Greenhill, Mr. G. C. Horsley (President of the Architectural Association), Prof. John Perry, Count Albiz (managing director of the Spanish Marconi Company), Mr. G. C. Isaacs (managing director of Marconi's Wireless Telegraph Company, Ltd.), Major H. B. Strange, Prof. H. J. Spooner, Mr. W. B. Bryan (Engineer to the Metropolitan Water Board), and Mr. T. E. Gatehouse.

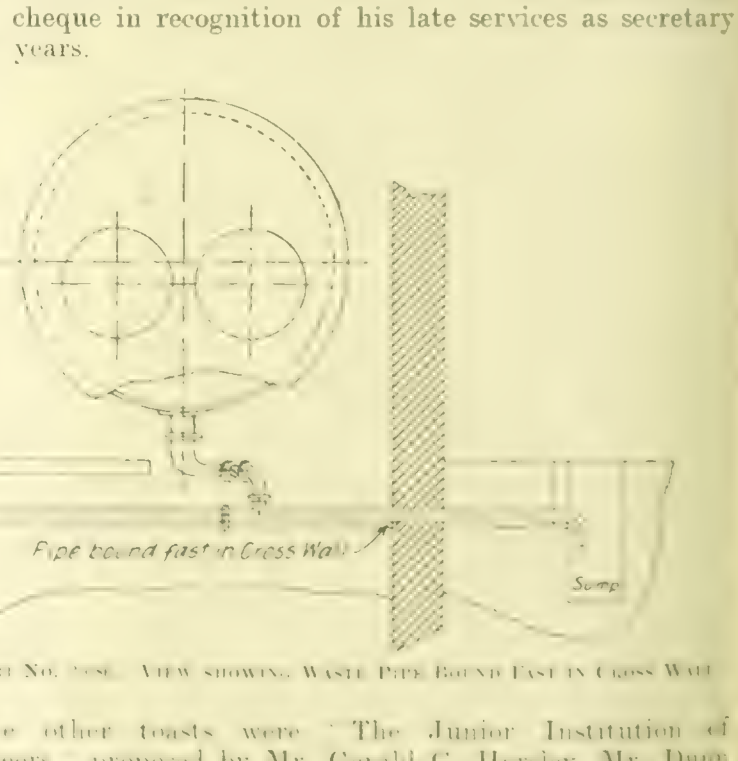
The toast of the evening was "Electrical Intercommunication," submitted by Prof. John Perry, who in the course of his remarks said that wireless telegraphy had, taking into consideration the fact that it was still a little known subject, made great progress, and showed promise of future rapid development. Cable work had advanced by leaps and bounds, and he would call attention to the cable from the Azores to America, which could send 220 letters a minute, or each way 110 letters a minute. Across the Atlantic, by means of its eleven cables, four newspaper columns could be sent in ten minutes. Messages at halfpenny a word had been talked about by Sir Henniker Heaton, but the difficulty of speeding up the cables was not realised by the general public. In a very short time, he was told, they would be able to telephone from New York to San Francisco, and from London to any part of the British Isles, but perhaps before many years had passed the inhabitants of Teheran, Persia, would be able to enjoy a Covent Garden opera. It is interesting to note that in the United States there were 7,000,000 telephones in use.

The President, in responding to this toast, said wireless telegraphy had travelled a long way in distance covered, practicability, reliability, and efficiency since he read his first paper before the Institution of Electrical Engineers. The introduction of high-speed apparatus enables radio-telegraphy to successfully compete, as regards speed, with long distance cables. Wireless telegraphy, he thought, could make use of the improvement introduced in cable working, and wireless telegraphic speed was more or less a mechanical problem. Atmospheric electricity difficulties had been gradually but surely overcome, and improvements in the receiver, and the effective utilisation of a larger amount of energy in the transmitters had been made. The natural effects did not have the same pull as they used to have, owing to the impulse at the receiving stations being so much stronger than formerly at a given distance, and in ship work interference due to atmospheric conditions was very small. These new improvements made frequent communication possible, and in the tropics, overland stations for a distance of 1,000 miles were often in touch with one another.

Mutual interference, although they had only one ether, he thought would be minimised, as had been done in ships; and a larger number of high-power stations in England and Ireland had proved possible without mutual interference. The ease with which the number of stations could be worked efficiently without interference will determine the extent of the use of wireless communication. The International Convention had fixed the wave lengths, and in his opinion this caused some of the interference which took place. This could be overcome if a third and longer wave was authorised.

The number of ships equipped with radio-telegraphy was very large as compared with three years ago, and the receipts for messages, both in finance and commerce, also showed a much greater increase. This could not have been obtained if the interference had increased with the number of installations in use. His experience taught him that the wave lengths at present available ranged from 6in. to 30,000ft., and this fact should be borne in mind. With a wave length of 6in., communications for several miles could be obtained, but longer waves are necessary for long transatlantic distances. Mutual interference was being overcome, too, by the wave-group tuning and directive systems available. Waves did not go all round and become a nuisance to people who would rather be without them, even though they spread a bit, as the result of oscillation. These and many other improvements with which he was in touch convinced him that the new method of communication was destined throughout the world to be of the greatest importance in facilitating communication.

Another interesting feature of the evening was the presentation to Mr. Walter T. Dunn of an illuminated address and a cheque in recognition of his late services as secretary for 27 years.



REPORT No. [illegible]. VIEW SHOWING WASTE PIPE BOUND FAST IN CROSS WALL

The other toasts were "The Junior Institution of Engineers," proposed by Mr Gerald C. Horsley, Mr Dunn responding; and "The President," proposed by Mr S. Bylander.

ELECTRICITY IN COAL-MINING OPERATIONS.

At a recent meeting of the West of Scotland Branch of the Association of Mining Electrical Engineers, Mr. W. H. Telfer, of Glasgow, delivered an interesting address on "Electricity in Coal-mining Operations, with Special Reference to Safety and Reliability." Mr. Telfer said that in Lanarkshire they had been able to work very thin seams of coal in competition with the thick seams, and the success of this had been due in great part to the adoption of electric power for coal-cutting and coal-face conveyers. The commercial success of working these thin seams was of vital importance in view of the fact that the thick and favourably-situated seams were being rapidly exhausted. For the various operations underground, it was, he stated, generally admitted that in the majority of cases electricity was the most economical and the simplest form of power to install and distribute. There were, however, both cases and places in which the older systems of transmission of power by compressed air, steam, or wire ropes were more economical and in certain places safer. It was well that both electrical and mining engineers should recognise this, and not apply electricity indiscriminately.

A great deal had been heard recently about the use of electricity in mines from the point of view of safety. Electrical apparatus, cables, &c., were, he observed, like many other things, not free from danger if improperly installed or used. Reliability would, he considered, be increased and danger reduced to a minimum if the following important points were observed with regard to all electrical apparatus in use in mines. They should be strongly constructed, of good design, with the best material and first-class workmanship. All electrical apparatus should be of ample capacity for its work, and all motors should work well under their rated power. It might be argued that to put in a motor of 20 h.p. where 16 h.p. was the normal load was bad policy from the point of view of economy, but it was the very opposite in practical working. Any extra capital cost or small extra consumption of current would be easily outbalanced in more reliable and safer working and longer life of the machine. The same remarks were applicable to switchgear, which should be of ample current-carrying capacity.

Mr. Telfer said the three principal sources of danger from the use of electricity in mines were: (1) Shock; (2) fire; (3) ignition of gas or coal dust. As most of the accidents in connection with electricity had hitherto been due to shock, it followed that insulation was most important. This should be as perfect as possible, and all dangerous and live parts should be well guarded. Cables should be of ample section for the current, and material used for insulation should be of good quality and subject to little deterioration. Dampness and electrical machinery did not agree at all. A dry situation was the best, and where this was not possible means must be taken to keep at least the electrical parts free from moisture.

One of the greatest dangers attending the use of electricity was, he continued, the risk of fire with its attendant consequences to life and property. This risk could, he said, be pretty well eliminated by adopting the following rules: All generators, motors, switchgear, and fuse boxes should be put in houses or places of wholly fireproof construction, or at least so constructed in the immediate vicinity of the generators, &c. Portable motors should have flame-tight casings. Proper fuses or other means for automatically cutting out the current should be inserted in every circuit. All joints in cables, or of cables to terminals, should be mechanically and electrically sound. Electrical plant and everything in connection with it must be well maintained. Rough slipshod work or repairs which might for a time in other classes of mining machinery do the turn, were no use in electrical work, if good results and safety were desired. If originally well constructed, of ample capacity and intelligently used, there was no class of machinery more easily maintained in good and safe condition. One of the simplest but one of the most important points with regard to its maintenance was perfect cleanliness. Dirt accounted for a good many of the failures of electrical machines.

The intelligent use of all electrical machinery and apparatus was of the greatest importance. In every mine in which electricity was used to any extent there should, he said, be a competent person in charge of all electrical work. The efficient and safe working of the plant greatly depended on his skill and the interest and care he devoted to his work. But more than this was necessary. Every official of the mine and every person who was working electrical plant should have some knowledge of electricity, electrical apparatus, and electrical rules. The knowledge necessary would vary according to the position they occupied, but it should be as much at least as would ensure the working and maintenance of all electrical plant with safety and efficiency. This knowledge could be acquired in various ways. In many cases the colliery electrician could teach motor attendants all that was necessary, but there were also opportunities offered them in science and other classes of learning more.

FACTORY AND WORKSHOP ACT, 1901.

PARTICULARS OF WORK AND WAGES IN SHIPBUILDING YARDS.

The following is the draft of an Order which the Secretary of State proposes to make under Section 116 of the above Act, in substitution for the provisions relating to shipbuilding yards in the Order of 30th December, 1909. The effect is to require particulars in shipbuilding yards so far as concerns the work of all persons employed in the building or repairing of a ship who are paid by the piece; the corresponding words in the Order of 1909 being platers, riveters, and caulkers. Any communication relating to the draft Order should be addressed, before 1st April, 1912, to The Under Secretary of State, Home Office, London, S.W.

The said section shall be modified so as to read as follows:

(1.) The occupier or contractor shall, for the purpose of enabling each worker who is paid by the piece to compute the total amount of wages payable to him in respect of his work, cause to be published particulars of the work and rate of wages applicable thereto, as follows:

(*a*) He shall furnish every worker with written particulars of the rate of wages applicable to the work done by him at or before the time of his first employment on the work and on every subsequent occasion when the rates are fixed or altered; or he shall exhibit such particulars on a placard in the factory or workshop. Provided that if the rates are not ascertainable before the work is given out, the particulars shall be furnished to the worker in writing when the work is completed.

(*b*) Such particulars of the work done as affect the amount of wages payable to each worker shall be furnished to him in writing when the work is completed.

(2.) Where the work is done in common by a gang of workers it shall be sufficient if the particulars of the work done by the gang and of the rate of wages applicable thereto are furnished to the member of the gang to whom the wages of the gang are paid by the employer.

(3.) The particulars, either as to rate of wages or as to work, shall not be expressed by means of symbols.

(4.) Any placard exhibited in pursuance of the foregoing provisions shall contain no other matter than particulars of rates of wages, and shall be affixed in such a position as to be easily read by all persons to whose work the particulars relate.

(5.) If the occupier or contractor fails to comply with the requirements of this section, he shall be liable for each offence to a fine of not more than £10, and, in the case of a second or subsequent conviction within two years from the last conviction for that offence, not less than £1.

(6.) If anyone engaged as a worker in the aforesaid class of work, having received such particulars, whether they are furnished directly to him or to a fellow workman, discloses the particulars for the purpose of divulging a trade secret, he shall be liable to a fine not exceeding £10.

(7.) If anyone for the purpose of obtaining knowledge of or divulging a trade secret, solicits, or procures a person so engaged to disclose such particulars, or with that object pays or rewards any such person, or causes any person to be paid or rewarded for so disclosing such particulars, he shall be liable to a fine not exceding £10.

(8.) The Order of the 30th December, 1909, relating to Shipbuilding Yards so far as concerns the work of platers, riveters, and caulkers is hereby repealed.

SOME GENERAL PRINCIPLES INVOLVED IN THE ELECTRICAL DRIVING OF ROLLING MILLS.*

BY C. ANTONY ABLETT, B.SC.

THE power which is required to drive a rolling mill generally varies rapidly between wide limits, while the condition that power should be generated cheaply is that the demand made for power on the generating plant should be maintained steadily at the full capacity of that generating plant. To ensure that the working costs of a rolling mill should be low, means must be found for reducing the fluctuations in the power required to drive the mill, care being taken in doing this that the capital cost of the plant is not unduly increased nor the possible output reduced. Any reduction of the possible output is equivalent to an increase in the working cost, as the capital charges per ton are increased.

The variations in power are reduced by employing a flywheel in conjunction with the electric motor which is used to drive the rolling mill, and by providing some device for reducing the speed of the motor and flywheel to enable the flywheel to give out some of its stored energy when the demand for power is great, so as to reduce the power which has to be furnished by the motor. When the demand for power is small the motor will speed up the flywheel, thereby replacing its stored energy; this increases the power which the motor has to supply when the demand made by the mill is small, and therefore reduces the total variation in power.

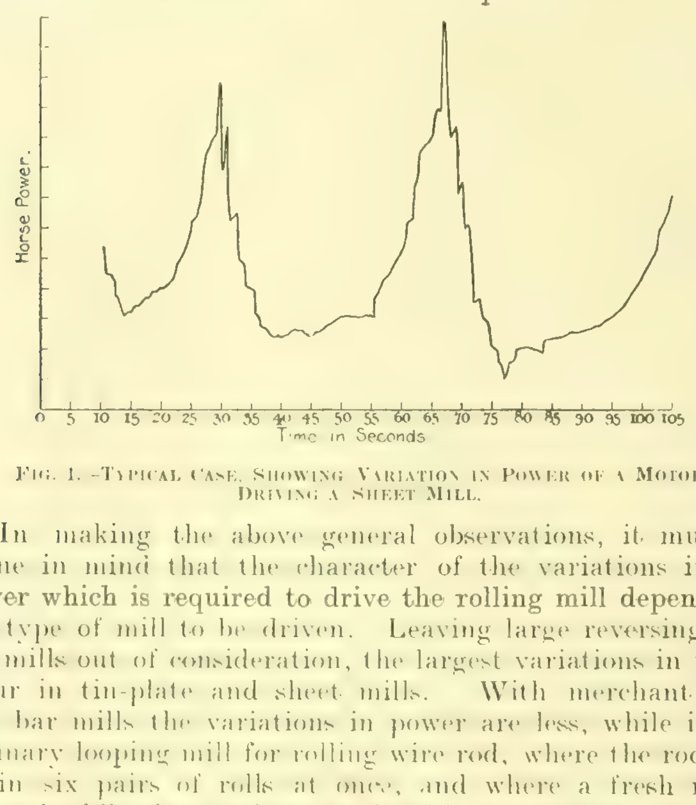


FIG. 1.—TYPICAL CASE, SHOWING VARIATION IN POWER OF A MOTOR DRIVING A SHEET MILL.

In making the above general observations, it must be borne in mind that the character of the variations in the power which is required to drive the rolling mill depends on the type of mill to be driven. Leaving large reversing rolling mills out of consideration, the largest variations in power occur in tin-plate and sheet mills. With merchant mills and bar mills the variations in power are less, while in the ordinary looping mill for rolling wire rod, where the rod may be in six pairs of rolls at once, and where a fresh rod is entered while the previous one is still in the rolls, the power required to drive the mill does not vary much. A special case is that of a tyre mill, where the variations in power are considerable, but where the power demand remains pretty steady for nearly a minute, so that a flywheel would not prove of much benefit in reducing the fluctuations in power unless it were very heavy indeed.

The remarks about power generation apply to the case of a works generating its own power. Where power is being bought from a power company the system of charging may considerably modify the arrangement of the drive to be adopted, in order to obtain the cheapest possible working costs. This point is entered into more fully later on.

Action of Motor and Flywheel.—It is stated above that in using a flywheel in conjunction with an electric motor some device must be adopted for reducing the speed when the demand for power is great. This point requires a little consideration. The ordinary direct current shunt-wound motor, or 3-phase induction motor running at light load, will fall in speed by, say, 2 per cent. when it is required to give its full power. The stored energy of the flywheel varies as the square of the speed at which it is running, so that if a flywheel were used in conjunction with this motor it would only give up 4 per cent. of its stored energy as the power increases from light load to the full power of the motor. Continuing this argument further, suppose that the rolling mill required during a pass a power equivalent to four times the normal full-load power of the motor for a few seconds. Commercial motors will not give more than twice the normal full-load power for a few seconds without being liable to injury, and to prevent this the circuit breaker is usually set to open at the current corresponding to this power. The flywheel, therefore, has to furnish the power which is in excess of that which the motor can give.

* Paper read before the Institution of Electrical Engineers.

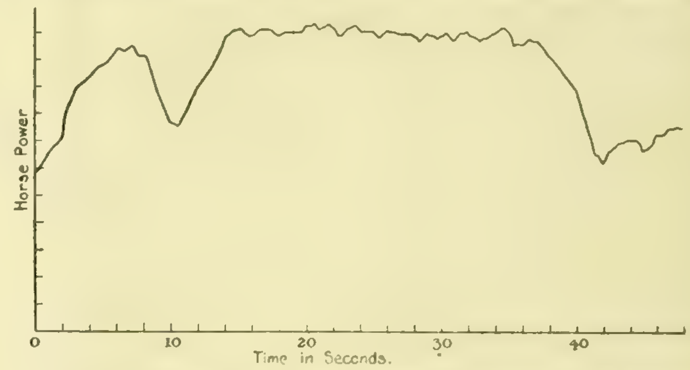


FIG. 2.—TYPICAL CASE, SHOWING VARIATION IN POWER OF A MOTOR DRIVING A LOOPING MILL.

In the case considered, the motor would fall perhaps 5 or 6 per cent. in speed when the power increased from light load to double full-load power, so that the flywheel would only give up 10 or 12 per cent. of its stored energy. The flywheel would, therefore, have to be abnormally heavy, or else if a flywheel of a weight within the bounds of commercial possibility were adopted, the combination would be unable to cope with this demand for power, and the motor power would increase until the circuit breaker opened.

It is therefore necessary artificially to increase the fall in speed of the motor as the power which it has to give increases. If the speed falls by, say, 10 per cent. as the power increases from zero to full load, and, say, by 22 per cent. as the power increases to the double full-load power, the flywheel would have given up 39 per cent. of its stored energy by the time that the motor was giving double its normal full-load power, instead of from 10 to 12 per cent. A flywheel, therefore, of moderate weight would materially assist the motor in overcoming heavy demands for power which last for a short time only.

In practice the maximum power given by the motor would seldom be as much as double the normal power, nor would the motor power sink to zero, as even when nothing was being rolled the motor would still have to provide the power for overcoming the friction of the mill, which is considerable. There are two possible devices for artificially increasing the

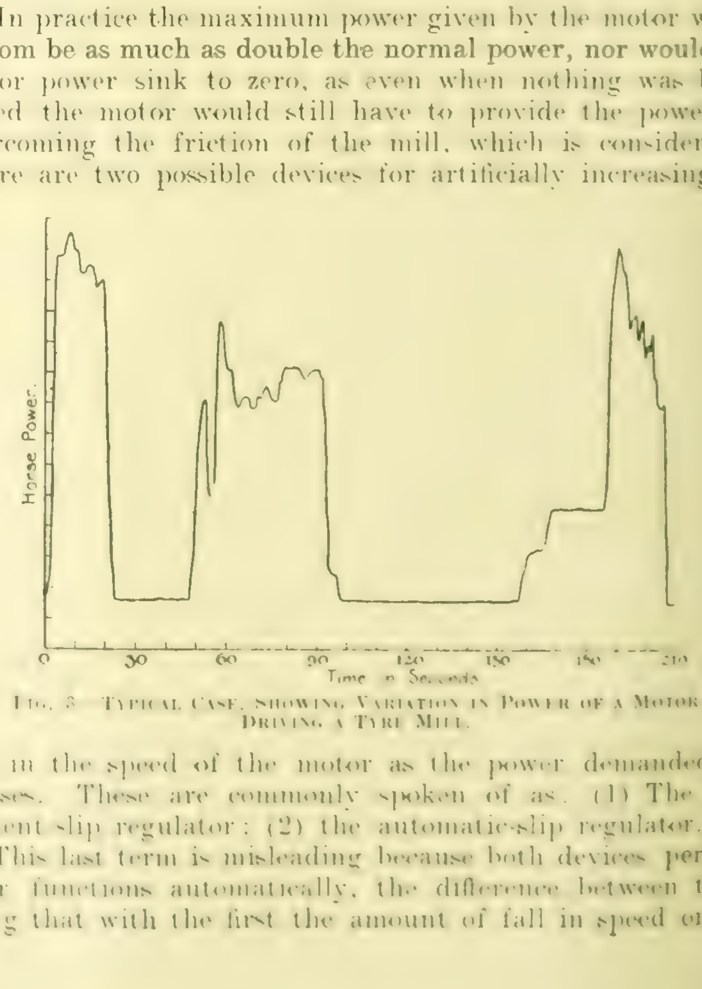


FIG. 3.—TYPICAL CASE, SHOWING VARIATION IN POWER OF A MOTOR DRIVING A TYRE MILL.

fall in the speed of the motor as the power demanded increases. These are commonly spoken of as (1) The permanent slip regulator; (2) the automatic-slip regulator.

This last term is misleading because both devices perform their functions automatically, the difference between them being that with the first the amount of fall in speed or the

slip steadily increases as the power increases, while with the latter the fall in speed increases suddenly after a definite power is attained. It would therefore be better to call these devices: (1) The continuous-slip regulator; (2) the intermittent-slip regulator. For reasons explained later on, the continuous-slip regulator is the device which is more commonly used in practice. It should be explained that in the case of the direct-current motor the continuous-slip regulator consists of an ordinary compound winding provided for the field-poles, while the intermittent-slip regulator consists of a system of relays which successively short circuit resistances in series with the shunt field winding, thus increasing the field and causing the speed to fall when the power has reached a certain predetermined point.

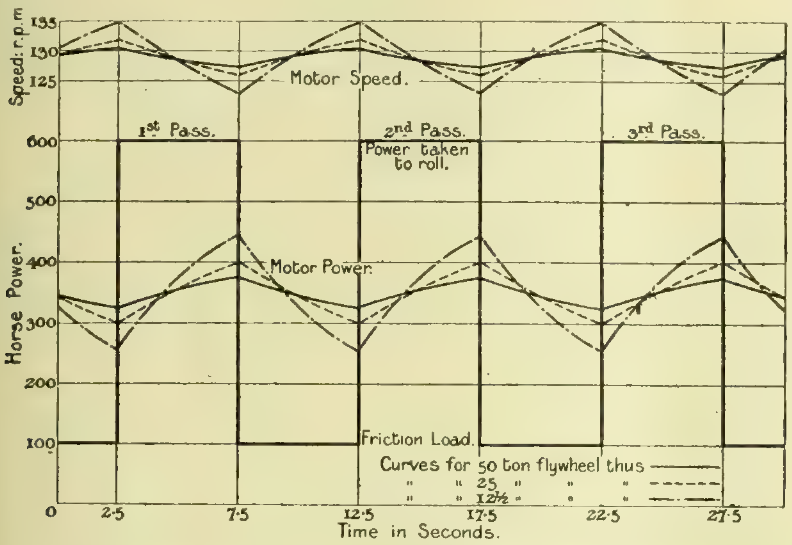


FIG. 4.—CURVES SHOWING VARIATION OF MOTOR POWER AND SPEED FOR 50, 25, AND 12½ TON FLYWHEELS.
Pass, 5 seconds; interval, 5 seconds.

In the case of the 3-phase motor, the continuous-slip regulator consists of a resistance, liquid or metallic, permanently inserted in the rotor circuit, while the intermittent-slip regulator may consist either of a liquid resistance, the moving plates of which are controlled by a motor relay, so that the plates are raised and the rotor resistance increases when the current has reached a predetermined point, or a metallic resistance which has its various sections short-circuited by a series of relays, so arranged that these relays cut the resistance into the rotor circuit when the current has reached the predetermined limit. As the continuous and intermittent-slip regulators are essentially different in their action, it is desirable to consider the action of each in detail.

Continuous-slip Regulator.—For the sake of simplicity, it is assumed that the fall in speed of the motor or slip below no-load speed is proportional to the power which the motor is giving. This is not strictly true, but the modification of the results which this slightly erroneous assumption introduces will be considered later on. Within the limits of fall in speed or slip of the motor it can be assumed that the stored energy given up by the flywheel is proportional to the slip, without involving any large error, therefore the power given by the flywheel is proportional to the rate of change of the slip—that is, to the rate of change of the motor power. It will thus be seen that if a sudden increase of load is imposed on the motor and flywheel by entering a bar between the rolls, and a curve is constructed showing the increase of motor power with the time, this curve will be a logarithm curve; while if the power required by the mill suddenly decreases owing to the bar leaving the rolls, the motor power decreases according to a logarithm curve. The curves showing the rise and fall in speed of the motor and flywheel are also corresponding logarithm curves.

After the bar leaves the rolls the power which the motor gives while decreasing to the value corresponding to the friction goes to increase the speed of the flywheel, and so replaces its stored energy. These curves are quite analogous to those for the heating and cooling of electrical machinery; the power of the motor, however, rises to practically its full value in a few seconds, while the temperature of an electrical machine takes a number of hours to reach approximately its full value. We may illustrate this reasoning by mathematical symbols as follows:—

Let—

P = power required to drive rolling mill when bar is between rolls.
K_{s1} = full-load power of motor.
s_1 = slip of motor at full load.
v_o = speed of motor at no load.
v = speed at which motor is running at any particular time.
s = corresponding slip.
I = moment of inertia of flywheel.

$$\text{Stored energy of flywheel} = \frac{I\,v^2}{2};$$

supposing speed of flywheel is reduced from v_o to v.

$$\text{Stored energy given up} = \frac{I\,(v_o^2 - v^2)}{2}$$

or—

$$\frac{I}{2}(v_o + v)\,(v_o - v);$$

$v_o - v$ is the slip s, and $v_o + v$ may be put equal to $2\,v$ without making much error.

Stored energy given up by the flywheel is—

$$I\,v\,s;$$

that is, the stored energy which has been given up is proportional to the slip.

The sum of the power given by the motor and the flywheel must be equal to the power required to drive the rolling mill. We can express this by the linear differential equation—

$$I\,v\,\frac{\delta s}{\delta t} + K_s = P,$$

the solution of which is—

$$\text{Motor power } K_s = P\left(1 - \epsilon^{-\frac{K\,t}{I\,v}}\right)$$

showing that the motor power increases according to a logarithm curve.

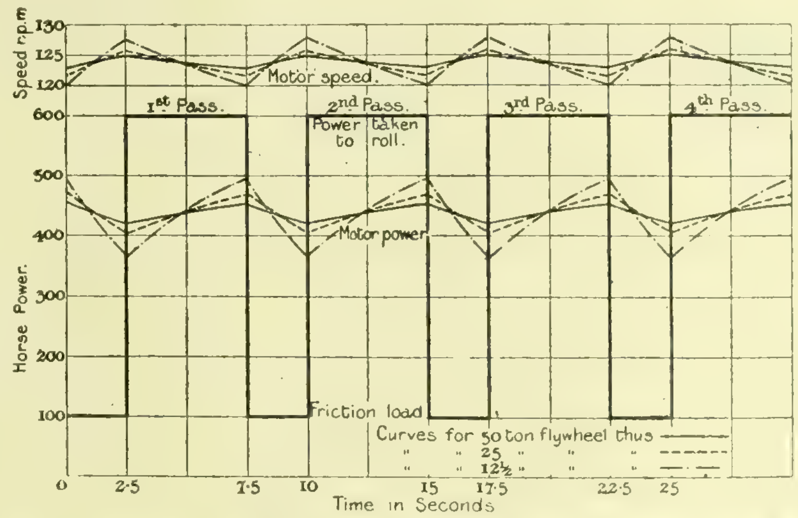


FIG. 5.—CURVES SHOWING VARIATION OF MOTOR POWER AND SPEED FOR 50, 25, AND 12½ TON FLYWHEELS.
Pass, 5 seconds; interval, 2½ seconds.

Similarly, when the bar is out of the rolls the motor power is equal to the power taken to speed up the flywheel, thereby restoring its stored energy, or—

$$I\,v\,\frac{\delta s}{\delta t} + K_s = 0;$$

the solution of this is—

$$\text{Motor power } K_s = P\,\epsilon^{\frac{K\,t}{I\,v}}$$

showing that when bar is out of the rolls the motor power decreases also according to a logarithm curve.

The friction of the mill has been left out of these calculations for the sake of simplicity, but it can be very easily taken account of in drawing the curves by shifting the zero line.

The expression $\frac{I\,v}{K}$ expressing the relation of motor power to flywheel capacity is the "time constant" in this case and is

exactly analogous to the "time constant" in the case of the heating or cooling of electrical machinery. The value of the time constant for a motor and flywheel, however, does not usually exceed about 33 seconds. The value of the time constant to be selected naturally depends on the type of mill. In a sheet mill where the duration of the passes is very short the time constant need not be so big as in the case of a bar mill, where the finishing passes may take a considerable time. The greatest time constants are found in the case of motor and flywheel for the motor-generator set of an Ilgner electrically driven reversing rolling mill.

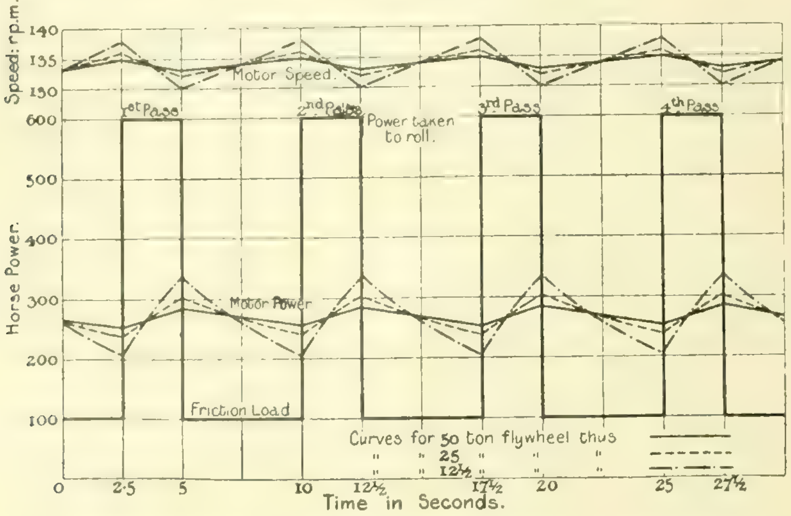


FIG. 6.—CURVES SHOWING VARIATION OF MOTOR POWER AND SPEED FOR 50, 25, AND 12½ TON FLYWHEELS.
Pass, 2½ seconds; interval, 5 seconds.

Figs. 4, 5, 6, and 7 are drawn to show the rise and fall of the power of a motor provided with a continuous-slip regulator and used in conjunction with a flywheel, and to show how this variation of power changes as the respective times of the pass and interval change. In each case it is supposed that during each pass 500 h.p. is required to roll the bar and 100 h.p. to overcome the friction of the mill, so that a total of 600 h.p. is required during the pass, and the power falls to the friction load, namely 100 h.p., during the interval.

Fig. 4 shows the case where the pass lasts 5 seconds and is succeeded by an interval lasting 5 seconds. Fig. 5 shows the case where the pass lasts 5 seconds and is succeeded by an interval lasting 2½ seconds. Fig. 6 shows the case where the pass lasts 2½ seconds and is succeeded by an interval lasting 5 seconds. Fig. 7 shows the case where the pass lasts 15 seconds and is succeeded by an interval lasting 15 seconds. In each Fig. three curves are shown, the first supposing a flywheel weight of 50 tons, the second a weight of 25 tons, and the third 12½ tons, it being assumed that the continuous-slip regulator remains unaltered in each case.

Since the energy which is taken from the flywheel during the pass is replaced again in the interval between passes, the average power for any particular figure remains the same whatever weight of flywheel is used, but the percentage variation of power and speed is less with the heavy wheel than with the light wheel. When the relation of the time of the pass to the time of the interval is changed the average power naturally changes, the average being less where the interval is long, and greater where the interval is short. The following table shows how the percentage variation in power changes with different weights of flywheel and with various durations of pass and interval.

	Average power.	Percentage variation of power.		
		50-ton wheel.	25-ton wheel.	12½-ton wheel.
	h.p.	Per cent.	Per cent.	Per cent.
Fig. 4 (pass 5 seconds, interval 5 seconds)	350	14·2	28·2	54·5
Fig. 5 (pass 5 seconds, interval 2½ seconds)	433	7·7	15·3	30·0
Fig. 6 (pass 2½ seconds, interval 5 seconds)	267	12·6	25·0	48·5
Fig. 7 (pass 15 seconds, interval 15 seconds)....	350	41·8	76·0	120·0

In this table the percentage variation is expressed with relation to the average power. It is thus possible to obtain variations greater than 100 per cent. The table shows that the percentage variation of the power increases as the weight and consequently the stored energy of the flywheel decreases, but that this increase is not proportional to the decrease of stored energy, but increases at a slower rate than the stored energy decreases.

Although for each particular figure the average power remains the same whether a light or a heavy flywheel is employed, a somewhat larger motor would be required with the light flywheel than with the heavy wheel, because the motor size is settled by the root mean square current and not by the average current, and where the variation of power is great the root mean square value is naturally greater than where the variation is small. In the curves shown in Fig. 7 the average power is 350 h.p.

Where a 12½-ton wheel is used, the root mean square power is 379 h.p., so that a motor of this power would have to be installed. Where a 25-ton wheel is used the root mean square power is 360 h.p. Where a 50-ton wheel is used the root mean square power is 354 h.p. If no flywheel at all were used the root mean square power would be 430 h.p.

Comparing the case where no flywheel at all is used with the case where a 25-ton flywheel is used, it will be seen that in the former the motor would have to be 20 per cent. larger. It should be noticed that the speed of the motor and flywheel rises and falls in accordance with the logarithm curves which vary inversely as the power.

If Figs. 5 and 6 are compared, it will be seen that in each case the actual amount by which the power varies is the same, but in Fig. 6 the percentage variation of power is much greater because the mean power is less. It will also be noticed that the power curves in Fig. 6 are exactly similar to those in Fig. 5, but they are turned upside down. This is merely a coincidence, because in one case the duration of the pass is twice the interval, while in the other case the duration of the interval is twice that of the pass, so that one case may be said to be the inverse of the other. If the slip of the motor were plotted instead of the speed of the motor, the curves for increase and decrease of slip would be exactly similar to the power curves.

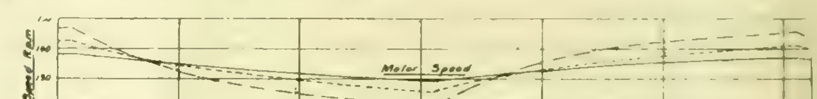


FIG. 7.—CURVES SHOWING VARIATION OF MOTOR POWER AND SPEED FOR 50, 25 AND 12½ TON FLYWHEELS.
Pass, 15 seconds, interval, 15 seconds.

Alarm is raised from time to time in cases where work is being carried on very rapidly so that there is only a very short interval between passes, to the effect that the flywheel may not have time to recover itself between the intervals and passes. Such alarm is entirely without foundation, and this is illustrated by Fig. 5. If the intervals are short, then naturally the average power increases, while the percentage variation of power is reduced. As the average power is increased the motor is supplying greater power to the flywheel during the interval, and although this interval may be short it is able to restore the stored energy of the flywheel.

Fig. 7 shows that where the passes are long the flywheels are less effective in reducing variations of power than where the passes are short, because the time constant of the motor

and flywheel become comparable with the length of the pass, so that the motor is giving nearly the full power required by the rolling mill towards the end of the pass, and the flywheel is not giving out much power. In such cases heavy flywheels are required if the percentage variation in power is to be kept small.

The following general conclusions may be drawn from these curves, namely: (1) If the time during which the pass lasts is short, and the interval is also short, light flywheels will reduce the percentage variation in power to a small value, while if the time of passes is long, and the intervals are also long, heavy flywheels are required; (2) where the time of the interval is short compared with the time of the pass a light flywheel will enable the percentage variation of power to be kept moderate, but if the time of the interval is long compared with the time of the pass, the heavier flywheels must be used.

In practice the question is not so simple because, as is pointed out later on, the various passes in rolling down a billet to a definite section require widely differing powers, while the time of the passes and of the intervals also differ widely.

The effect of the errors introduced by the assumption made in the above theoretical considerations may now be considered. To simplify calculations, it was assumed that the stored energy given up by the flywheel is—

$$I \, v \, s,$$

and not—

$$\tfrac{1}{2} I \, (v_0 + v) \, s;$$

that is to say, the stored energy given up by the flywheel has been assumed to be rather too large, so that the variation of power will actually be somewhat larger than the calculated value. An error introduced in this way may be about 7 per cent. at the most.

It has also been assumed that the decrease in speed of the motor is proportional to the power which the motor is giving—this also is not quite correct. In the case of a direct-current motor having a continuous-slip regulator, that is to say, a compound wound motor, the speed-power curve begins to approach that of a series motor, and as the load increases from light load the speed falls more rapidly at first than it does later on. The effect of this is to flatten the logarithm power curves for the rise and fall of power, making these curves approach more towards straight lines, and, in the case of passes of short duration, actually to reduce the variations of power. This effect becomes more marked as the compounding of the motor is increased.

With a 3-phase motor having a continuous-slip regulator —that is, a resistance connected permanently in the rotor circuit—the speed falls less rapidly at first, when the power increases from light load, than it does later on. The effect of this is to increase the curvature of the logarithm power curves and to increase the variations of power in the case of passes of short duration. The consequence of this is that in certain cases a heavier flywheel must be used in conjunction with a 3-phase motor than with a direct-current motor, in order to obtain the same results.

Figs. 4, 5, 6, and 7 will serve to illustrate the conditions of rise and fall of power entailed by the use of a continuous-slip regulator, but they do not in any way represent the conditions obtaining in a rolling mill. In any mill the bar is elongated in each pass so that each successive pass taken in the same pair of rolls takes a longer time than the previous pass. Frequently less draught is taken in each succeeding pass than in the previous pass, so that the tendency is for the power diagram to consist in the earlier passes of large powers lasting for a short time, and for the power gradually to diminish and the time to become longer as the later passes are reached. There are many exceptions to this, too numerous to be discussed here, but mention may be made of such cases as those where the bar cools rapidly, owing to the shape of its section being such as to present a large area in proportion to its weight, so that considerable powers are required for the later passes, or where heavy draughts must be taken in certain passes, so as properly to form the section, as, for instance, in the rolling of wagon spokes, or in the case of a sheet or plate mill where the plate is turned at right angles after a few passes in order to broaden it, thus requiring a greater turning moment and thus a greater power, owing to the increased width of plate presented to the rolls.

Fig. 8 is an illustration of a practical case, being a series of curves obtained for a bar mill, and this serves to show the sort of variation of power and speed to be found in practice. It may be mentioned that the bar mill for which these curves were drawn had two stands of rolls, a roughing stand and a finishing stand, and as bars may be in both stands at the same time, account has to be taken of the power required when two passes come simultaneously.

The plain rectangles show the powers required by the passes in the roughing mill, the dot-shaded rectangles show the powers required by the passes in the finishing mill, and the shaded rectangles show the amount by which the total power is increased by adding the powers taken by the roughing mill passes to the powers taken by the finishing mill passes.

The curved lines show the motor power which reaches 620 h.p. as a maximum, although in one case, where two bars are in the rolls together, the mill requires 1,220 h.p., while the minimum value is 295 h.p. As the mean horse-power is 424, the percentage variation is 76 per cent. If no flywheel were used the percentage variation would be 267 per cent. This practical example illustrates the benefit of the flywheel in a striking manner.

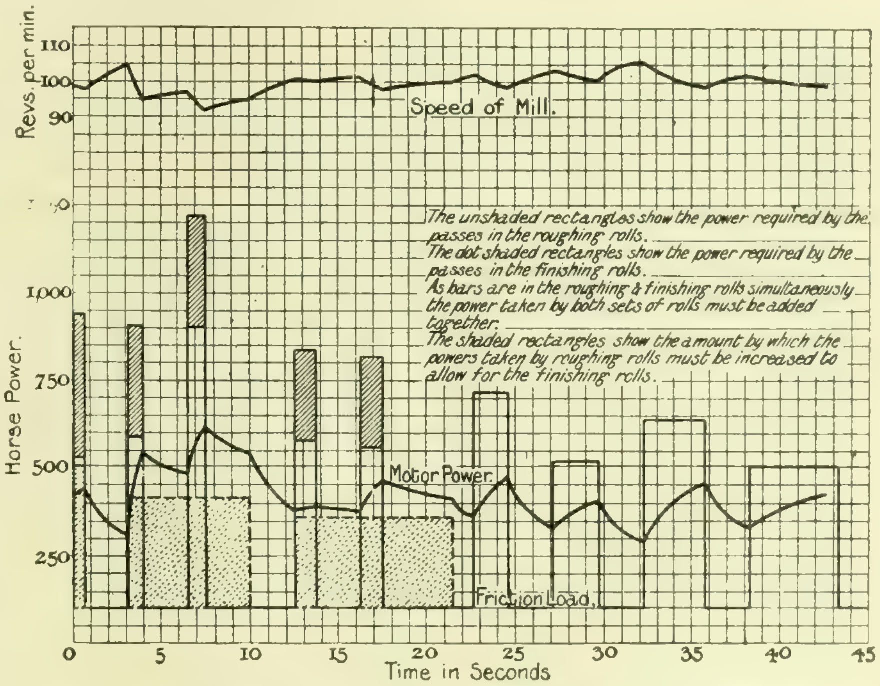


FIG. 8.—TYPICAL EXAMPLE OF THE VARIATION OF THE POWER AND SPEED OF A ROLLING MILL MOTOR UNDER PRACTICAL CONDITIONS.

Speed variations of 22 per cent. between no load and double full load have been mentioned above, but a little inspection of the curves on Figs. 4, 5, 6, 7, and 8 will show that no such speed variations may be expected in practice where the work at the mill is being carried out fairly steadily, because with steady working the power never comes down to no load, neither does it reach double full load except in very exceptional conditions, so that if the speed variation were 22 per cent. between no load and double full load a much less speed variation would take place when working under practical conditions. In the case of Fig. 8 the speed variation of the motor is 20 per cent. between no load and full load, but in the curve the speed variation does not exceed 11·2 per cent.

(To be continued.)

Another Aviator Killed.—While flying from Brooklands to the Old Deer Park at Richmond shortly before noon on Saturday morning last, Mr. Graham Gilmour, one of the youngest of English aviators, met with an accident in mid-air, and his machine crashing to the earth from an estimated distance of about 300ft. resulted in his instant death. It appears that Mr. Gilmour was steering a new type of monoplane of a French design, and had started from Brooklands with the idea of testing the machine with a view to it being entered for the forthcoming War Office competition in March.

BRASS: ITS MANUFACTURE AND PRACTICAL APPLICATIONS.*

BY J. J. EDWARES.

Brass, an alloy of copper and zinc, was in use for casting purposes centuries before one of its constituents—zinc—was a recognised article of commerce. It was found that metal, having a golden colour, could be prepared by melting copper with a mineral known as calamine, which contained zinc in the form of carbonate. Doubtless, good brass castings were turned out in those early days, but it must have been very difficult to ensure anything approaching uniformity of product. Excellent examples of early brass castings can be seen in many collections—notably in the British Museum—tributes to the skill of the early founders, and eloquent in proclaiming, by their age and excellent preservation, the capacity of brass for resisting the conditions in the earth, and in the atmosphere, which make for corrosion. Copper in the metallic state, and known as native copper, is fairly plentiful in some parts of the world; and it is possible that the early brassfounders prepared their metal by fusing native copper with calamine in the presence of charcoal, the zinc being reduced by the charcoal used as fuel, and, alloying with the copper, produced a metal of golden colour that could be readily cast into articles for personal adornment or for use. The direct fusion of the two metals—copper and zinc—for the preparation of brass is said to have been first carried out in England about the year 1781.

Nominally, brass should consist only of the two metals copper and zinc, but many varieties contain small amounts of iron, tin, arsenic, or lead. Bismuth and antimony are also sometimes present, but even in small percentages both of these elements are usually considered to be very undesirable intruders, particularly in brass to be used for rolled sheet or drawn bars. Iron, tin, arsenic, or lead are not particularly harmful if present only in small amount; in fact, either or all of them are sometimes purposely added with a view to imparting some special property to brass, such as strength, solidity or improved machining qualities. The impurities named are chiefly derived from the raw materials, copper and zinc used, and they vary in amount according to the source or origin of the ingots and the care that has been exercised in the selection of the ore and fuel used in their production. It was formerly the practice to purchase brands of copper and zinc on the basis of their reputation or of their proved suitability; it is however now quite common practice to purchase to specifications which define the nature and the amount of permissible impurities.

Copper and zinc ingot of excellent quality, comparatively free from impurities, and admirably suited to meet general foundry requirements can be readily obtained from the metal market at recognised current prices, and less pure materials at slightly lower rates are used for less exacting purposes. In recent years, the refining of copper and zinc electrolytically has been so perfected that both metals can be obtained of 9·99 per cent. purity, and their price does not exceed that of the best of the old approved brands. Electro deposited copper is known as cathode copper, and it is usually melted in a furnace and brought to the condition known as tough pitch, before being cast into ingots for use in the foundry. These pure materials are a boon to foundries engaged in the preparation of brass for critical purposes. Electrolytic copper is much used by electrical engineers, on account of its high electrical conductivity.

Copper and zinc may be alloyed in almost any proportions, and a useful purpose can be found for most of the resultant metal. Zinc being invariably cheaper than copper, there is a tendency to use, in the preparation of brass, as high a proportion of zinc as is consistent with the purpose for which the metal is intended. The three most useful copper-zinc alloys are those consisting of copper 70, zinc 30; copper 60, zinc 40; and copper 80, zinc 20.

70 and 30 brass is extensively used for sheet, tubing, rod and wire. It works well cold, but cannot be satisfactorily forged or manipulated in the hot state. It has a very wide range of usefulness, depending chiefly upon the facility with which it may be rolled into sheets, or drawn into rods, and afterwards manipulated or machined into almost any form or section. It is very sensitive to work put upon it by rolling or hammering, and also to heat treatment. Great variation in hardness, toughness, and strength, can be obtained from it as the result of the judicious application of work, and by careful annealing.

60 and 40 brass is used extensively for castings made in sand moulds, as it gives sharp and clean castings, with the advantage of being cheap as well as good. It forges well in the hot state, and lends itself to the production of drop forgings, and it may also be rolled hot or cold. In a semi-fluid condition it may be extruded under pressure, through dies having the section of the bar or rod required. The extruding process is carried out in a manner analogous to the familiar method for squirting lead tubing and rod. The extruded brass is very strong, and, possessing good machining qualities, it is in demand for the stock bars used on automatic and capstan lathes. For this purpose the metal usually contains lead up to about 2 per cent, which imparts good machining qualities.

80 and 20 brass is employed when a material softer than either of the foregoing types is desired. It works well in the cold state, but cannot be manipulated in the hot state. In quality and constitution it very much resembles the 70 and 30 alloy. It is not much in request, probably owing to its high cost.

All three types of brass are in use for war material, and instances are known where similar articles have been supplied by different makers from brass of each of the three types mentioned.

Brass enters largely into the construction of scientific apparatus, small parts of machinery, steam engines and boilers, electrical plant and apparatus, and even in the construction of motor cars, where aluminium alloys are so much in demand on account of their lightness—the condenser tubes are of brass.

Brass is usually melted in plumbago crucibles, heated in coke fired furnaces of the ordinary vertical type, having a flue connected with a stack sufficiently high to induce the draught required to burn the hard coke used as fuel at a rate such as to generate the necessary temperature. Crucible furnace melting is generally preferred for brass, on account of the facilities for covering the pot and obviating the volatilisation of zinc or the entrance of foreign matter. The metal may also be readily stirred to ensure uniformity of composition. Melting in small quantities is also very convenient for brass work, as it enables a number of small moulds to be filled while the metal is at a fairly uniform temperature. Other types of furnace such as the reverberatory, and the cupola, are sometimes used, particularly when heavy castings are being made, or when melting scrap or stock metal for foundry use.

The art of founding has been described as making a hole in sand and filling it with molten metal—this definition is certainly graphic, but it lacks detail. Perhaps the following will be more acceptable. "A mould is a quantity of sand rammed into a flask round a pattern so as to leave a perfect imprint of the pattern." The essentials of a good mould are a sand that is fine enough to take an imprint of all the sharp lines of the pattern, and yet open enough to allow gases to escape freely.

Patterns of required castings are made of well-seasoned wood, usually pine or mahogany. Where necessary, patterns have attached to them prints which define the position, and provide a seating for any cores required to form recesses or perforations in the casting. Moulding boxes commonly consist of two parts, with a convenient contrivance for coupling. The portion of the pattern that is intended to be in the lower part of the box is rammed up first and the surface at the parting level is smoothed. The other part of the box is then superimposed and rammed. The upper half of the mould may then be lifted off, leaving—thanks to the virtues of parting sand—a plain surface on the face of both halves. A slight taper on the pattern, assisted perhaps by a rap from the moulder's trowel, enables the pattern to be readily withdrawn. Arrangements are made for runner and riser, and the mould may be closed and prepared to receive metal for a green sand job, or may go into the stove to be fitted for a dried sand casting.

Castings of intricate section, having bosses or projections in more than one plane, often need boxes of several or many parts, and may render it necessary for the pattern to be made in sections, or with detachable parts. Brass or gun metal

*Lecture delivered before the London and District Branch of the British Foundrymen's Association.

patterns are frequently used for small articles required in considerable numbers. Metal patterns are also used on moulding machines. Great care is taken in the fitting and finish of metal patterns, but their cost is justified by their durability, and the superior quality of the castings. It is obvious that to allow for shrinkage of the metal in cooling from the liquid to the solid state, patterns must be made larger than the casting dimensions. To ensure solidity in brass castings, the deadheads should be on the generous side. The section, rather than the weight, should be the determining factor for the amount and position of deadheads. Cores are stoved. Cores of large size are often built up on perforated tubular spindles, which receive a thick course of hay band or wood fibre, covered with a coating of loam or other suitable material. This weak core obviates undue strain on the metal while cooling, and provides efficient ventilation.

In the manufacture and utilisation of brass, a large amount of scrap is made in the form of deadheads, risers, crop ends, and trimmings, and, as it is desirable to utilise this metal, it is exceptional for crucible charges to consist wholly of virgin copper and zinc, this course being pursued only for experimental or special purposes. The proportion of virgin material for the charge having been decided upon, it is weighed up; a small percentage of zinc being allowed to make good the loss occasioned by volatilisation. Brass scrap to make up the total weight completes the charge. The copper and as much of the scrap as the crucible will hold is put in the crucible, and when this has fused and sunk sufficiently in the pot, the remainder of the scrap is added. When, from stirring, and observation, it is assured that the whole charge is melted, the zinc is added. When the fireman or person supervising the melting is satisfied that the metal is in fit condition, the crucible is withdrawn from the furnace, skimmed, and the metal is poured into the moulds. A little flux is generally used; borax, common salt, sodium sulphate, lime and ground glass, are among the materials used. They each tend to remove occluded slaggy matter by increasing its fluidity and so causing it to rise to the surface of the metal and facilitate its removal by skimming before the metal is poured.

Mechanical Tests of Brass.

Tensile, Yield, and Shearing are in Tons per Square Inch.

Type.	Treatment.	Tensile Stress.	Yield Point.	Elongation Per Cent.	Shearing Stress.	Brinell's Hardness Number.	Contraction of Area Per Cent.
70-30	Hard rolled strip ...	53·6	40·2	9·5	28·2	143·0	—
	Very soft strip	21·4	6·7	91·0	14·8	45·0	—
	Strip annealed 450 C.	23·65	10·77	54·1	—	54·8	60·3
	,, ,, 650 C.	20·95	8·02	65·8	—	41·0	64·4
	,, ,, 850 C.	19·25	6·05	73·8	—	31·9	56·9
	Drawn rod..............	28·5	24·1	41·5	—	—	—
	Annealed drawn rod...	21·6	6·6	82·0	—	—	—
	Chill casting	16·25	—	80·0	—	—	—
60-40	Strip annealed 600 C.	24·4	—	52·0	—	—	—
	,, ,, 700 C.	25·2	—	49·7	—	—	—
	,, ,, 800 C.	25·0	—	52·0	—	—	—
	,, ,, 850 C.	24·5	—	52·0	—	—	—
	Cast in chill	26·0	8·0	46·0	—	—	—
80-20	Chill casting	16·25	4·0	82·5	—	—	—
	Strip annealed	19·95	—	55·33	—	—	—

Brass that is intended for sheet or rod is poured into cast-iron moulds which are usually in two parts, cramped together, so as to admit of ready removal of the ingot when solidified. The ingots are usually of plain rectangular section, but they may be of any form that will permit of ready removal from the mould. Before use, it is necessary for cast-iron moulds to be heated to a suitable temperature, and coated with some substance which will not permit heat to be conducted too quickly away, and which experience has proved will conduce to the production of clean and sound castings having a good surface or skin. Plumbago, tallow, lime, resin, oil, soap, or a combination of two or more of these are used. A dressing which answers well with one alloy is not necessarily suitable for another. Great care is necessary in pouring metal into iron moulds, the rate of pouring being governed by the section of mould, the temperature of the metal, and its composition.

Chill castings are made much thicker than that of the required strip. This allows for work to be put upon it by a series of passings through a rolling mill, by which it is much improved in quality, reduced in thickness and greatly increased in length. Brass castings are in a soft condition whether allowed to cool out gradually or quenched from a red heat in water, hence the casting, after trimming and removal of the deadhead may be repeatedly passed through the rolls, receiving a reduction in thickness each time, until it has received such a reduction in thickness, and has acquired such a condition of hardness, as to suggest the desirability of annealing before further reduction by rolling is carried out. Annealings and series of rolling are alternated until the desired section has been reached, and then the strip may be left in the hard condition in which it leaves the rolls, or be passed to the annealing furnace to be annealed to any extent desired.

The amount of reduction that may be given in one passage through the rolls is dependent on the thickness of the metal, its condition as to relative hardness and the power of the rolling mill. A strong mill will take a casting 2in. thick, and reduce it to 1in. thick in five passes—the metal would then receive the first annealing. The second series of rollings would then reduce its thickness to ·5in. in four passes, when the second annealing would be given. The third series of rollings—three passes—would reduce it to ·25in., when it would receive its third annealing, and be returned to the mill for the fourth series of rollings (4 passes) and be finished at ·1in. thickness, and either be retained in its hard rolled condition, or go into the furnace again to receive any desired extent of annealing.

Annealing can be most economically carried out—taking time occupied and fuel consumed into consideration—with a furnace temperature of from 600 to 700 degrees Centigrade. The higher temperature may only be considered quite safe when the passage of the brass through the annealing furnace is controlled automatically and uniformity assured of the time during which any part of the brass is exposed to the furnace temperature. In practice it is well to aim at the mean of these figures, viz., 650.

Pyrometers by measuring and indicating temperatures greatly help to make furnace processes more exact, and although there is not yet any practical instrument that will indicate the temperature of molten brass, owing to the obscuring effect of volatilised zinc, yet pyrometry is of real service in the important process of annealing, and greatly aids in attaining and maintaining uniformity in results.

The microscope affords welcome aid in the examination of brass, revealing defects and irregularities, and is a most useful help in determining the fitness of metal for the purpose to which it is proposed to apply it, and for ensuring comparative uniformity in articles made in quantity, and which it is desired should as nearly as possible be equal in every way.

Chemical and microscopic analysis should be welcomed in the workshops, because by their help the inner life and constitution of metal is revealed, and light is thrown on the effects produced by various combinations of the constituent metals in alloys, which greatly adds to the value of the results of mechanical tests obtained from specimens of the alloys under consideration, and afford indications for modifications in the composition or the treatment of the metal to enable specifications and requirements to be met.

The intelligent use of the results of chemical and microscopic analysis, combined with experience and sound judgment in coming to right conclusions as to the inferences to be drawn frequently clears up difficulties that would otherwise remain unsolved. Analysis detects injurious impurities, locates and measures losses, and determines whether correct proportions of constituents have been attained in alloys. It points out inaccuracies and enables mixtures of metals to be standardised, and reveals the exact composition of any metal submitted for reproduction. Let us gladly welcome in our workshops all the assistance that science and scientific apparatus can afford, as an aid rather than as a substitute for experience and discretion, for the full exercise of which there will always be ample scope.

TWO NOVEL DESIGNS OF STEAM TURBINES.

Two novel and compact designs of steam turbines have recently been developed in the United States. The one shown in Figs. is what may be termed a bladeless turbine, the blades being replaced by plain discs. This turbine has been designed and patented by Mr. Nikola Tesla, and we are indebted for the following particulars and illustrations showing the principle of the design to the "Engineering News." Fig. 1 shows, more or less diagrammatically, a Tesla rotary pump in which a series of smooth, flat discs revolve in a casing, with a volute delivery passage. The discs are fastened to a driving shaft, but have central openings which serve as inlets for the fluid. On rotating the shaft and discs, the

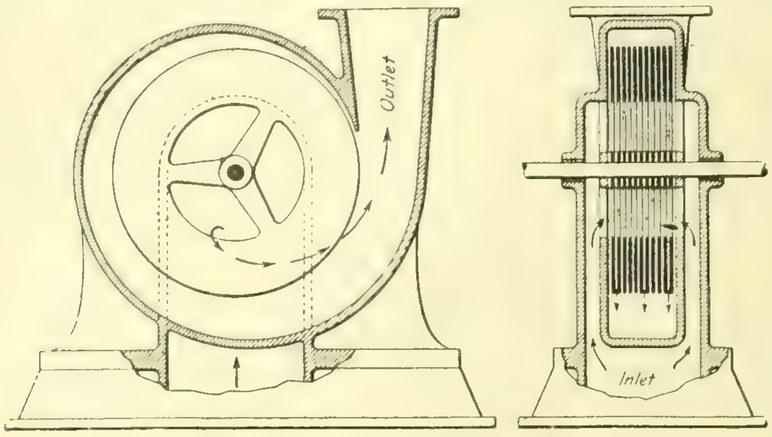


FIG. 1.—TESLA DISC IMPELLER PUMP.

fluid film in contact with the discs is set in motion, even with perfectly smooth discs, on account of the molecular adhesion between disc and fluid. The fluid between discs is also dragged along by the molecular attraction between particles of the fluid (viscosity). The motion of each point of the disc being circular, it is evident that the particles of fluid receive impelling forces which are always tangential to the circular paths. The successive points on the disc that impel given particles of fluid are at increasing distances from the centre. The fluid being mechanically unconstrained by walls or vanes except in an axial direction is free to travel in spiral paths from the axis to the periphery.

The fluid, in traversing the space from inlet to periphery, may follow a long spiral of several turns or a short one of part of a turn, depending on the quantity of fluid that is allowed to escape from the outlet. With unrestricted flow from the casing, there is little resistance to flow in a radial

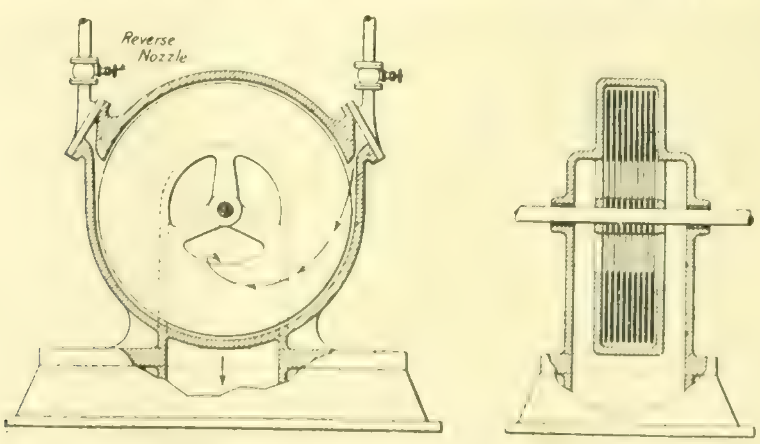


FIG. 2—TESLA DISC WHEEL IN A STEAM TURBINE.

direction (that is from the backing up and development of pressure), and the tangential slip between disc and fluid is large. The pressure in the casing depends on the velocity with which the particles of fluid leave the periphery of the disc; the maximum pressure with the exit throttled is then proportional to the speed of the discs, the velocity head being converted to pressure head in the volute passage of the casing. The power absorbed is proportional to the square of the slip

To one seeing such a piece of apparatus in action for the first time, the capacity of a small machine is surprising, especially in the absence of all vanes and projections of every sort which have heretofore been deemed necessary to force the fluid along. A moment's consideration, however, shows that the whole surface of each disc is effective in impelling the fluid along (solely by molecular drag), and the useful surfaces may be made very great in a machine of modest dimensions, in direct contrast with other analogous apparatus where only the relatively small area of buckets, blades, or other projections is effective.

Consideration also shows that any buckets or projecting parts that a disc might carry would constrain the fluid to travel in paths less natural or free, with the consequent development of impact and eddy friction which may be expected to decrease the efficiency over that of simple discs depending for their hold on the fluid only on natural molecular forces. In the case of the Tesla discs, the particles of fluid may be mentally pictured as rolling along on their spiral paths in orderly procession, held to the discs by some gravitation or force; whereas in the case of a disc with projections, the fluid would be pushed and crowded along by impact, with consequent disturbances.

It has been found, as theory would indicate, that the quantity of fluid discharged off the discs is proportional to the area of the discs; that is, the capacity of such machines increases nearly directly with their length along the shaft and about as the square of their diameter, the discrepancies

FIG. 3.—VIEW OF TESLA 110 H.P. TURBINE, GIVING AN IDEA OF THE SIZE.

arising naturally from the casing not having impelling surface but adding to the diameter and length of the machine.

The spacing of the discs in such a machine would depend on the conditions under which it had to operate increasing with the viscosity and diameter and decreasing with the allowable slip. The aim of the designer would be to deliver the fluid from the discs at not much below peripheral speed under normal load conditions. When limitations of practical design would prevent the securing of desired pressures with one simple set of discs, the multiplication of stages is easily accomplished. The fluid then would pass from the exit passages of one stage to the inlet of a second, and so on.

The operations of a pump, as above described, are in general reversible for the production of power from a fluid moving with considerable velocity or under pressure. If a fluid under pressure, but of low velocity, enters the casing of the device shown in Fig. 1 in order to flow along the volute of decreasing cross section and through the inter-disc spaces to what is now the outlet, it must constantly accelerate, converting its pressure head to velocity head. This moving fluid will exert a pull on the discs on account of molecular adhesion and viscosity If the shaft were blocked so that it could not

rotate, the particles of fluid would take short spiral paths from the volute to the outlet.

If the discs are allowed to rotate, however, the particles of fluid in contact with the discs would be subjected to a force preventing travel along the shortest spirals to the outlet. The resultant of the centrifugal force exerted by the disc and that coming from the velocity of the steam constrains the fluid then to follow a longer spiral path. This reminds one of the counter electromotive force developed in the armature windings of an electric motor opposing the impressed voltage.

It is evident that the torque developed by the disc increases with the difference in peripheral velocity of the disc and of the fluid in contact. As in the analogous case of the pump, the torque rises as the square of the slip. When the shaft runs free, without load, the speed rises and the centrifugal counter force on the fluid, travelling in very long spirals (almost concentric circles), would cause the casing pressure to rise nearly to the supply pressure, the difference being only that required to do the work of supplying energy losses.

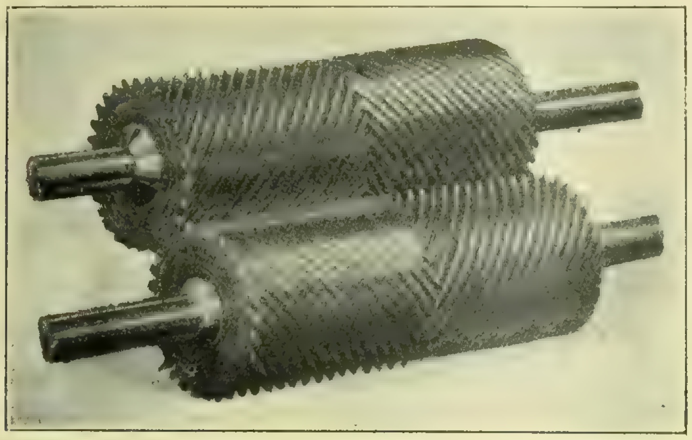


FIG. 4.—"SPIRO" ENGINE WITH ROTORS REMOVED FROM CASING.

Such a prime mover would give its maximum output at about 50 per cent. average slip, but the maximum efficiency would come with a comparatively small slip, the actual figure depending upon the fluid employed, on the working conditions, and on the mechanical limitations of design.

The greatest interest in the Tesla design, as outlined above, probably centres in its application to a heat motor, such as the Tesla steam turbine. While a device like Fig. 1 would operate with steam, it probably would be advisable for obvious reasons to modify the mechanical features—for instance, to suppress the volute passage in the casing, coming down to the simple construction indicated in Fig. 2.

If the steam is expanded in a diverging nozzle, it may be expanded over any of the usual ranges of pressure drop, the heat energy then being converted into kinetic energy. The high velocity steam escaping from the nozzle is caused to impinge tangentially on the edges of the discs. In order to escape, it has to take a spiral path from the periphery of the discs to the centre openings. The velocity energy of the steam is utilised through the molecular drag on the surface of the discs. With such a nozzle it is seen that the machine is essentially of the so-called "impulse" type of turbine. The arrangement shown in Fig. 2 has a very simple and convenient means of reversing, it merely being necessary to provide a duplicate nozzle discharging against the opposite diameter of the discs and in the opposite direction. When the machine is at rest or running slowly, as in starting, the steam takes a short path from the nozzle to the exhaust and develops a comparatively large torque, since this would be proportional to the square of the difference in velocity of steam and disc. As the machine speeds up, the difference in velocity between steam and discs decreases and the centrifugal forces tend to lengthen the spiral path, so that a given quantity of steam may make several revolutions before finally passing to the exhaust.

It is not necessary, however, to expand the steam before it reaches the discs, and in place of the nozzles shown there may be simple ports. The machine then apparently will operate as a reaction type of turbine, the steam expanding as it flows in its path from port to exhaust. The expanding steam might develop a slight reactive thrust against the disc, but it would depend probably more for its influence on the peculiar action of increasing the velocity of the steam in small increments as it flows along; and absorbing the kinetic energy as fast as developed, in driving the disc.

A Tesla steam turbine was tested at the Waterside Station of the New York Edison Company. The rotor of this turbine consists of 25 discs, 18in. diam. The assembled unit occupies a floor space some 20in. by 35in., and it stands some 5ft. high. With steam at 125lbs. gauge and exhausting to atmosphere, 200 horse-power was developed with a speed of 9,000 revs. per minute. The steam consumption under these conditions was about 38lbs. per horse-power hour. Mr. Tesla states that with moderate superheat and the degree of vacuum ordinarily obtainable in a turbine plant, the consumption can be reduced to 10 or 12lbs. per horse-power hour. The weight of the unit is about 400lbs., giving a unit weight of 2lbs. per horse-power. Through refinements in design, in addition to the increase of capacity secured with superheat and vacuum, Mr. Tesla expects that the weight may be reduced to as little as $\frac{1}{4}$lb. per horse-power capacity and still allow of designs which will have rotational speeds low enough for direct connecting to the majority of services.

One of the interesting possibilities of the design of turbine shown is that of self-regulation. It has already been shown how the counter pressure due to the rotation of the discs amounted nearly to that of the impressed fluid when running idle. Since the centrifugal head increases as the square of the number of revolutions, and as with available materials great peripheral velocities of the discs are possible, a turbine may be designed which will not run away, the peripheral speed being limited to that value which corresponds to the maximum velocity of the fluid which can be developed.

The main principle of design may be used for an internal-combustion motor. The small machine shown in Fig. 3 has been operated with gaseous fuel burned in an auxiliary chamber and the products of combustion cooled by injecting steam or water spray. This gives a mixture of superheated steam and gases which leave the combustion chamber under high pressure, but reduced in temperature so that they may be led directly to the discs, serving in the place of steam from a boiler. The machine shown developed 110 horse-power, and it is stated that only the small-sized shaft prevented pushing the load higher. The products of combustion, instead of being cooled by the formation of superheated steam, may be expanded in an insulated nozzle, the temperature falling with the reduction in pressure and the increase in velocity. At the exit of the nozzle, the temperature could be sufficiently reduced so that the gases could be caused to impinge on the discs without injuring them.

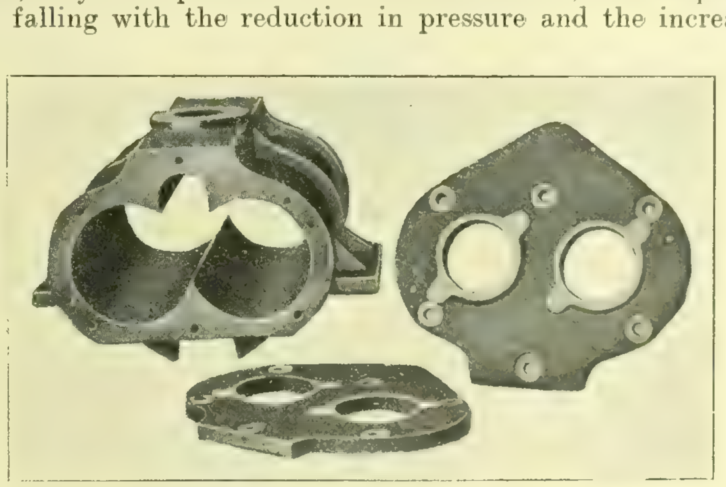


FIG. 5.—"SPIRO" ENGINE CYLINDER AND CYLINDER HEADS.

In the design shown in Figs. 4—7, which has been invented by John H. Van Deventer, Superintendent of the Buffalo Forge Company, Buffalo, N.Y., herringbone gear rotors are employed. We are indebted to the same contemporary for the following particulars:

The turbine consists simply of two herringbone gear wheels meshing together and revolving in a close-fitting casing. A pair of the gears, or rotors, and their casing is shown in Figs. 4 and 5. It is notable that the herringbone rotors are much longer axially in proportion to their diameter than ordinary herringbone gears for power transmission

would be. Steam is admitted at mid-length of the rotors, at the point where the teeth of opposite spirals meet. Thus the steam occupies the space between two adjacent teeth, and this space is closed at the tooth points by the closely-fitting casing. As the rotor turns, the tooth-space occupied by the steam increases in length and the steam expands. Finally the steam escapes when the outer ends of the teeth pass the line of contact of the two rotors. The increase in length of the tooth-space from the time when steam is first admitted until the exhaust occurs is shown by the diagram, Fig. 6.

The inlet-port openings, as indicated in the diagrammatic sectional view, are situated one on each side of the central rib, shown inside the casing at the bottom in Fig. 5, which divides the casing into two partly-closed cylinders. The ends of these cylinders are covered by the heads which are shown removed in Fig. 5, but no effort is made to have a steam-tight contact between the heads and the ends of the rotors. In

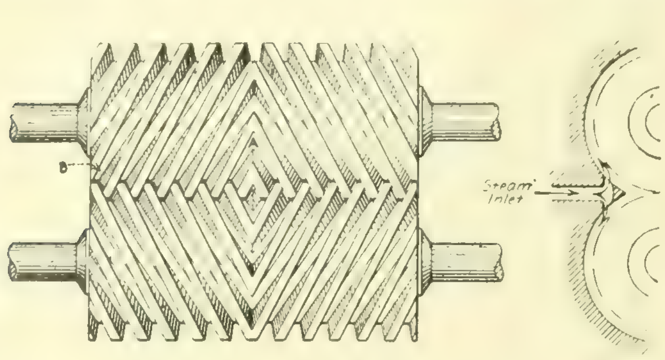


FIG. 6.—DIAGRAMMATIC SKETCH OF "SPIRO" TURBINE TO SHOW STEAM ACTION.

fact, space is left between the rotor end and cylinder head for the passage of the exhaust steam. The steam passes from these end spaces to the exhaust port shown at the top of the casing in Fig. 5, which communicates with the exhaust pipe.

The rotors are mounted on shafts turning in long bearings which are either attached directly to the cylinder heads or bolted to the base casting. On small units ball bearings are used, while the larger sizes have bearings so designed that each bearing acts as an individual oil pump to circulate oil between the shaft and bushing with a positive pressure.

This engine, under the trade name of the "Spiro turbine," is now being made in sizes up to 60 horse-power. The 185 horse-power unit shown in Fig 7 has been in use for three years by the Buffalo Forge Company, driving fans, gas scrubbers, and other apparatus requiring a running test. It has never been taken apart nor needed a single adjustment in that time. The following results of non-condensing tests with units developing 25 and 150 horse-power, are given out by the makers:

	Test 1.	Test 2.
Boiler pressure, by gauge, lbs.	120	130
Initial pressure, by gauge, lbs.	101.5	115
Horse-power	25.3	151
Speed, revs. per minute	2450	2710
Water per b. h.-p.-hr., lbs.	53.2	31.8

In tracing the analogy between this so-called "Spiro turbine" and the reciprocating engine, the tooth-space to which steam is admitted takes the place of the cylinder, the tooth ahead becomes the piston, and the abutment against which the steam pressure reacts is formed by the tooth of the other rotor, which closes the end of the tooth-space at the line of the rotor contact.

In Fig 6, the tooth space marked A is about in the position where steam is first admitted. A glance at the diagram shows how this space increases in length until the position B is reached (after about half a revolution of the rotor) When the end of the tooth space is no longer closed the exhaust occurs

The time of cutoff depends on the axial length of the inlet port. The intersections of each tooth space with the line of rotor contact move from the mid length of the rotors toward the ends, when the engine is running; and as each tooth space passes in this way beyond the end of the port its steam supply is cut off by the tooth behind In the units already built, the number of expansions, that is, the ratio of the tooth space length at cutoff to the total length at beginning of exhaust, has been made from $3\frac{1}{2}$ to 6

A cutoff governor, which operates by varying the length of inlet port, has been designed. A throttling governor could be equally well applied.

The power in foot-pounds which should be developed by each tooth-space is found by multiplying together the mean effective steam pressure, length of tooth, right sectional area of tooth-space and revolutions per minute. In other words, we have for the horse-power the familiar formula

$$Hp. = \frac{PLAN}{33,000}$$

the only change being that L is now the length of tooth-space instead of length of stroke. To get the total combined horse-power of both rotors, we must multiply by twice the number of teeth on each one.

A rough computation in this way of the horse-power of a unit with rotors 3in. diam. by 7in. long with 20 teeth, an initial steam pressure of 100lbs. and 2,000 revs. per minute, gives about 3 or 4 horse-power. This corresponds fairly well with the rating given by the makers, the Buffalo Forge Company, of Buffalo, N.Y. The engine rated at 1 to 3 horse-power has a length of casing of $8\frac{3}{4}$in., and the width is $8\frac{1}{4}$in. The total length over bearings is $16\frac{3}{4}$in., and the weight is 100lbs.

The great problem of steam leakage in rotary engines is simplified in this design by the fact that the exhaust steam escapes at the ends of the rotors. No packing, therefore, is needed there. The rotors and casing can be made with a very slight clearance, a few thousandths of an inch perhaps, between them. Moreover, the pressure difference between adjacent tooth-spaces is small, and this tends to minimise the leakage over the tooth points.

The greatest loss of steam by leakage, then, will be mostly at the line of contact of the pitch cylinders of the two rotors, where the teeth are in mesh. Here we have pressures in the several tooth-spaces ranging from the initial

FIG. 7.—VIEW OF "SPIRO" 185 H.P. TURBINE, GIVING AN IDEA OF THE SIZE

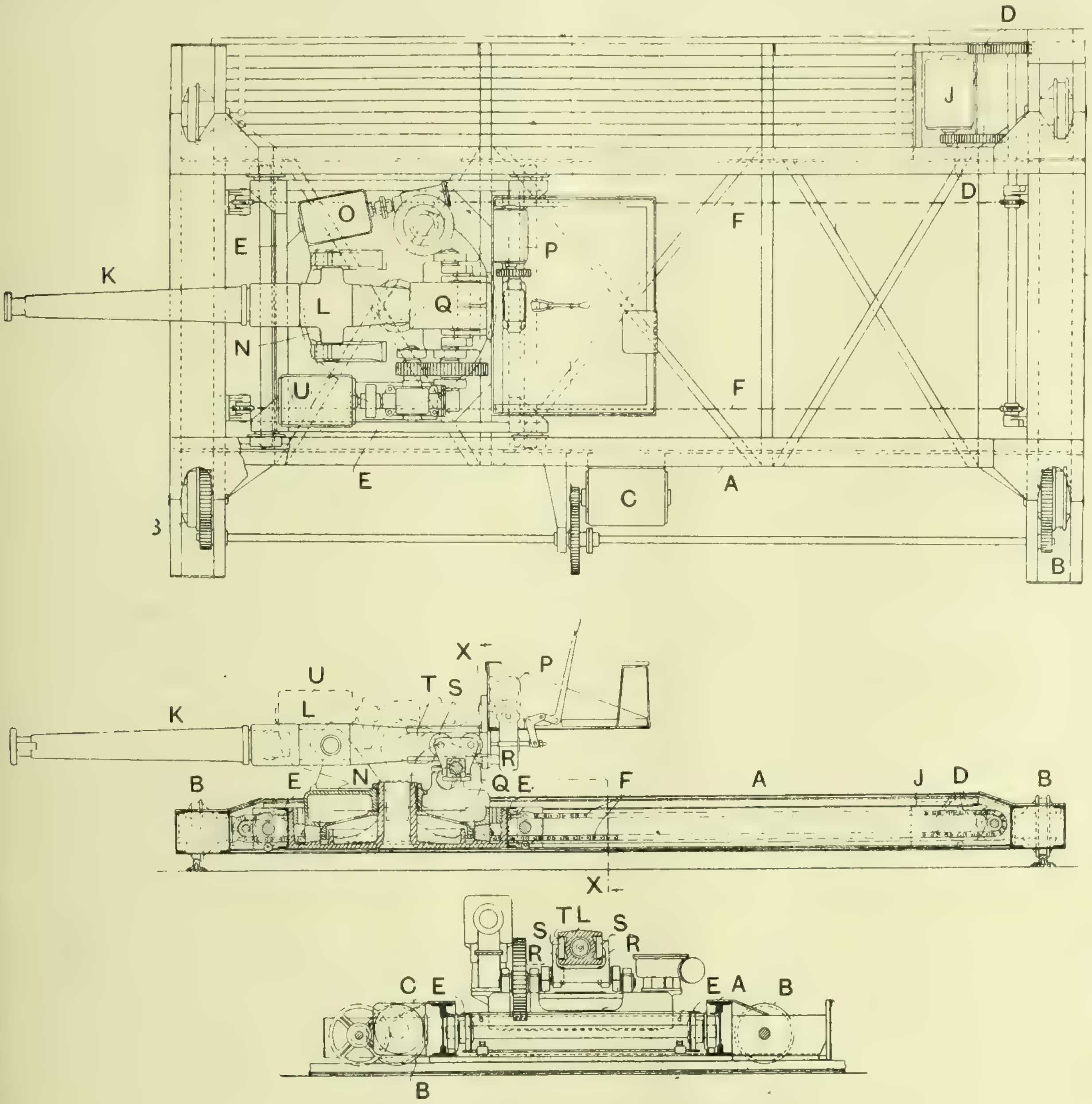
to the exhaust pressure, on the inlet side; and the exhaust pressure all the way across on the other. There must be some clearance between the teeth, at least at the points, and it appears that some leakage must occur The leakage here may be reduced, however, owing to the high speed of the meshing teeth in a direction opposite to that of the leaking steam, below what would otherwise be expected From the economic results claimed, it appears that the leakage is not great enough to seriously affect the engine's performance

The only point of wear, beside the bearings of the rotor shafts, is at the contact of the teeth. As already noted the rotors are much longer axially than power transmission gears would be, and the larger number of teeth in contact reduces the tooth pressure. The tooth pressure in the engines as built, we are informed, is only about 5lbs. per square inch, making the wear very slight

APPARATUS FOR CHARGING OPEN-HEARTH FURNACES

THE accompanying illustrations show a construction of machine for charging open-hearth or similar furnaces, the invention of Messrs. Babcock & Wilcox, Ltd., Oriel House, 30, Farringdon Street, London, and James Smith. The machine is of the kind including a movable structure on which runs a trolley carrying a platform rotatable on a vertical axis and on which is mounted a charging arm or bar adapted to be tilted on a transverse horizontal axis and to be rotated or oscillated on a longitudinal axis.

Referring to the illustrations, the apparatus comprises a main travelling structure A made up of braced I-beams resting on wheels B adapted to be rotated, through the intermediary of suitable gearing, from an electric motor C, whereby the structure may be traversed along stationary rails disposed parallel to the furnace front. Mounted to run



APPARATUS FOR CHARGING OPEN-HEARTH FURNACES.

on the structure A in a direction perpendicular to the line of movement of the structure, *i.e.*, towards or away from the furnace opening, is a trolley E, to which are connected the ends of sprocket chains F, led around sprocket wheels driven through the intermediary of gearing D, from an electric motor J, the gearing and motor J being located to one side of and at the rear of the structure A, so that the component parts thereof are readily accessible and out of the dangerous heat from the furnace. The motor J and gearing D participate in the movement of the structure but do not participate in the movement of the trolley towards and from the furnace; the gearing, chain connections, &c., acting positively to traverse the trolley.

The charging arm K is rotatably mounted within a hollow member L adapted to tilt on a horizontal transverse axis, the member L having journals fitted in brackets mounted on a turntable N which is carried by the trolley E and is adapted to be operated by gearing from an electric motor O; the charging arm being adapted to be rotated within the member L by means of gearing operated by an electric motor P. The member L is adapted to be tilted by means of a crank Q secured to a shaft located beneath the member L and mounted on turntable N, and to which crank are connected arms R provided with rollers S engaging guides T on the rear portion of the member L, the crank shaft being driven through gearing from an electric motor U, the gearing being kept as low as possible relatively to the charging arm at one side thereof, so as to afford an uninterrupted view of the charging arm and the load carried thereby, when the furnace is being charged. The devices for tilting the charging arm operate on the same from below.

DINNER IN HONOUR OF PROF. UNWIN, F.R.S.

ON Saturday, February 10th, Prof. W. Cawthorne Unwin, LL.D., F.R.S., was entertained by about two hundred of his past students at the Criterion Restaurant, Piccadilly. The dinner was organised by the Old Students' Association of the City and Guilds Central Technical College, with the intention of celebrating their late Professor's year of office as president of the Institution of Civil Engineers, a position which has never before been held by an engineer who has devoted practically all his life to the teaching side of the profession.

The chair was taken by the President of the Association, Mr. W. Duddell, F.R.S., who proposed the toast of the evening and showed the phenomenal growth of the college under Professor Unwin by stating that in 1885, when the college was opened, there were only 35 students, whereas in 1904, the year in which Prof. Unwin retired from actual teaching, the roll of students was 349. The chairman proceeded to speak about the Professor's personal influence on his students, and evidently expressed the general feeling of the meeting when he said that all had regarded him as a second father, and that he was beloved accordingly. Mr. H. A. Humphrey, one of Prof. Unwin's original students, warmly seconded the chairman's proposal.

Prof. Unwin said that he was very much touched by the expression of his old students' respect for their professor, and having given a short but very interesting autobiography, he gave particulars as to the distinguished careers of several of his past students, now scattered all over the globe. Since the opening of the college 175 students had become Associate Members of the Institution of Civil Engineers, while 16 had been elected to full membership, and 157 had taken the new degree in engineering of the London University. Prof. Unwin hoped that soon his old college would have three distinct departments for Civil, Mechanical, and Electrical Engineering respectively. The meeting was a great success, and the association presented Prof. Unwin with a cigar cabinet as a tangible souvenir of the evening.

Fatal Crane Accident.—On the 15th inst. a man employed at the works of Messrs. Ruston, Proctor & Co., Lincoln, was guiding timber from an electric crane into a truck, when the chain gave way, and the whole lot, weighing about 2½ tons, fell and struck him on the head, killing him instantly.

A STUDY OF THE PROPERTIES OF ALLOYS AT HIGH TEMPERATURES.*

BY. G. D. BENGOUGH, M.A.

(*Continued from page 195.*)

Preliminary Experiments. — All the bars used in the research could be broken in the machine at the ordinary temperature, with the exception of the ½in. cast bars. Except where the contrary is stated, all the tests were carried out on ½in. round bars turned down parallel to a ¼in. diam. over a length of 2½in., in the case of all the rolled bars. The cast bars were 1in. diam. turned down to ½in. for 2½in.

One of the difficulties of the research was to find a suitable method of marking the bars for the purpose of measuring elongation. The ordinary method of punch marks was quite unsuitable for small bars at high temperatures, and localised the fracture at once. In any case it would have been useless owing to oxidation. A large number of alternative methods were tried, and from them the following were selected as giving the best results under the conditions stated.

1. **Marks of Graphite.**—These were suitable for brass alloys up to a temperature of about 600° C. They were

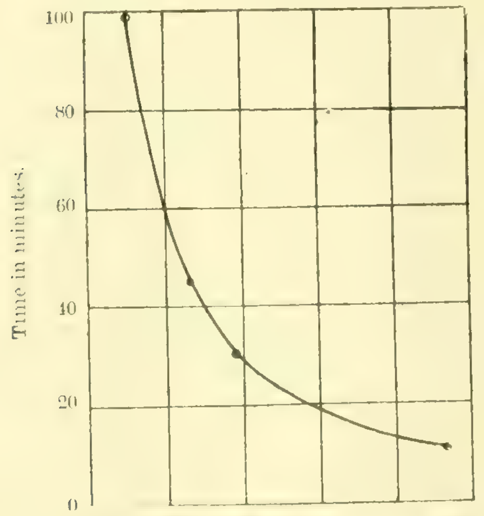


Fig. 4.—70 : 30 Brass. Temperature, 590° C. (Wire).

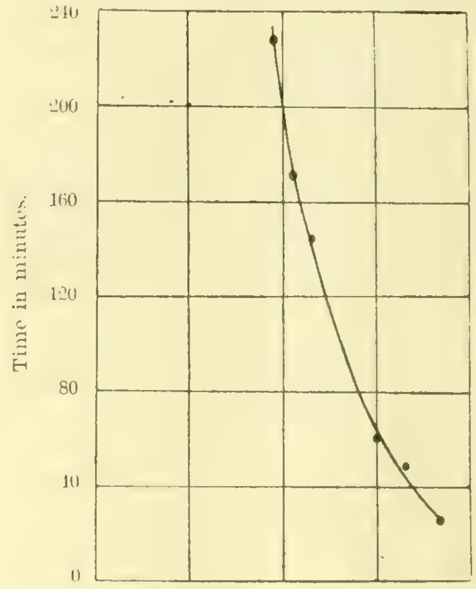


Fig. 5—70 : 30 Brass. Temperature 735° C. (1in. Cast Bar.)

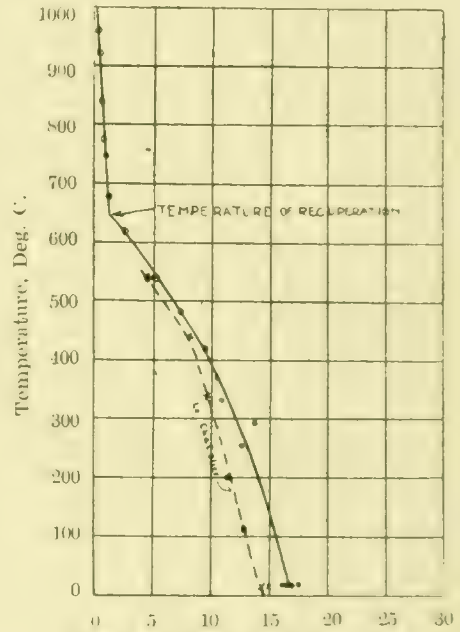


Fig. 6.—Copper.

sufficient for all the aluminium bars. In the case of copper and copper-nickel bars they were only suitable for comparatively low temperatures. It may be mentioned that some kinds of copying pencil give remarkably good results for moderate temperatures. In some cases a complete ring of deposit was made round the bar and for some distance outside the gauge length towards the shoulder, with the object of limiting oxidation. The junction between the oxidised and protected parts could then be clearly seen.

2. **Heavily Gold-plated Marks.** — The bars were plated from shoulder to shoulder with a thick deposit of gold. The middle 2in. of the parallel portion was then "buffed" free of gold. The gold prevented the oxidation of the bar beneath it, and a sharp line of demarcation was obtained between the plated and the oxidised surfaces. This method was useful for brass up to a temperature of nearly 800° C. It was not so satisfactory for the copper nickel bars, which scaled so heavily that the plating flaked off in an irregular manner at the edges. These bars were the most difficult to mark, as the scaling was even worse than with pure copper except at the highest temperatures.

3. **Method of Fireclay Wedges.** — This method was based on a chance observation that fine tinned copper wire used for tying the thermocouples on to the test piece held very tightly to the fine grained fireclay tube by which the wires of the couple were insulated from each other. This appeared to be due to the formation of a trace of silicate of tin, but the cause was not investigated in detail. The method of marking based on this observation consisted in making two little fireclay wedges and tying them on to the specimen with the tinned wire; the wedges pointed towards the centre of the bar, as this was the most likely direction of slip in the case of a drawn-out bar. The friction due to the oxidation of the test-bar kept the little wedges in position, and the distance between the wire ties was measured before and after the experiment. This method failed in the case of metals which drew out very greatly, as, for instance, in the case of certain complex brass bars which gave elongations up to 165 per cent.

4. **Method of Shoulder Measurement.** — In cases in which all the above methods failed, resort was had to the method of shoulder measurement. This method is admittedly only approximate. It consisted in making a test-bar of such a form that exactly 2in. of it were parallel; beyond this the diameter was gradually increased up to the shoulder, which was ½in. beyond the parallel portion on each side. The total elongation between the two shoulders (which were 3in. apart) was then measured, and the total elongation calculated on to the 2in. length, the assumption being made that no elongation took place over the gradually enlarged part of the bar. This is probably true in most cases, and the author believes that the errors of this method consist in the fact that the near neighbourhood of the enlarged shoulder diminishes the total elongation of the 2in. length. Errors due to this cause may amount to 6 per cent. of the values given; thus, where an elongation is given as 66 per cent. the true value may be as low as 64 per cent. or as high as 68 per cent. Thus the values obtained in this way are only approximate.

A very slight acquaintance with the tensile properties at high temperatures was sufficient to indicate the importance of the time under load. Two typical curves are given to illustrate the phenomenon. Fig. 4 is for a wire ¼in. diam., and Fig. 5 for a 1in. cast bar; in each case the alloy used was 70/30 brass. These cases have been selected as representing the extreme cases of a highly stressed thin specimen and a thick cast bar. Similar phenomena were noticed with all the alloys used, and became increasingly important as the temperature was raised. Below about 400° C. the effect was only slight, even if it existed at all. Precautions were taken to remove any error due to this phenomenon, and it was not investigated in any detail at temperatures below 500° C.

The method adopted for avoiding these errors was to keep the total time for which the specimen was under test approximately constant. The test period selected was twenty minutes. In actual practice it was possible to keep within the limits of 15 minutes and 25 minutes, except in the case of great loads at low temperatures; here, however, the factor was not important.

In order to keep within the limits a rough idea of the properties of each specimen was required, so that an approximately correct rate of loading could be adopted. For this

* Paper read before the Institute of Metals, January, 1912.

purpose preliminary tests were made for each alloy, but these tests have been omitted from the tables and curves now presented. To save expense they were made on thin, straight bars $\frac{1}{4}$in. diam., although they were not turned down at the centre, they always broke within an inch of it owing to the distribution of temperature along the bar.

Materials Used in the Main Research.—It was desired to obtain typical curves representing the relations of stress and strain to temperature for the following classes of materials:

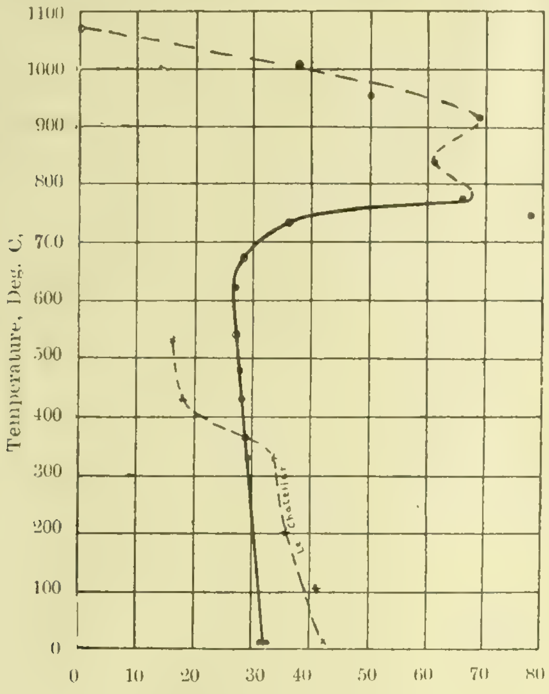


Fig. 7.—Copper.

(*a*) Ordinary pure metals of commerce. (*b*) Alloys consisting of a single simple solid solution, with no critical points beneath the solidus. (*c*) Alloys consisting of two solid solutions or other phases. This class is very large, and many types are possible in it.

In each case both cast and worked materials were studied. In class (*a*) copper and aluminium were the materials selected. In class (*b*) a copper-nickel alloy was chosen, the reason being that this series of alloys consists throughout of simple solid solution of nickel in copper, and no doubt can be entertained as to their simple character. Further to represent this class two specimens of 70/30 brass have been used, though it is possible the constitution of this alloy may not be quite so simple. In class (*c*) various types of brass have been selected. Analyses and descriptions of all the materials used in the research are given in Table II.

Details of the Main Series of Experiments.—The materials as received were cut up into 12in. lengths, and screwed at each end for $\frac{3}{4}$in. The rolled $\frac{1}{2}$in. round bars were turned down to $\frac{1}{4}$in. diam., parallel for $2\frac{1}{2}$in.; the cast 1in. bars were turned down to $\frac{1}{2}$in. over $2\frac{1}{2}$in. They were then marked by one of the methods already described. The thermojunctions were next wired on to points between the gauge marks, and the whole placed in the furnace, and left till equilibrium had been obtained. It was very desirable that this should be reached as quickly as possible, and that the time occupied in reaching it should be nearly the same for all the bars of each series, since in this way the effects of annealing could be to some extent eliminated. By never allowing the furnace to cool, and by bringing it to a temperature a little above that required before the introduction of the bar, it was found that the $\frac{1}{2}$in. bars could be brought to a practically constant temperature in about one hour for all but the highest temperatures. The total interval of time from the introduction of the bar to the instant of fracture was usually about $1\frac{1}{2}$ hours. For the larger bars this period was about two hours. The temperature readings were taken at the instant of fracture, and are accurate to $\pm 4°$ C.

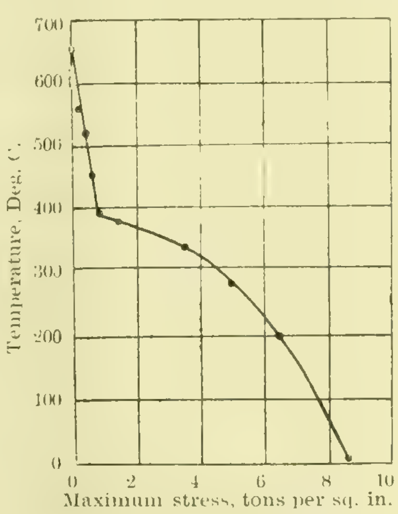


Fig. 8.—Aluminium.

The rate of loading the bars was adjusted so that the total time under test should be approximately the same for all bars of the same series. It was, in consequence, rapid with large loads and slow with small loads. In the case of the stronger bars, at temperatures below 350 C., it was not possible to load rapidly enough to obtain fracture in twenty minutes, and in some instances nearly double this period was required for a single test. No appreciable error is thereby introduced, since at these low temperatures the time effect is small.

Experimental Results.—These will now be dealt with separately for each series, beginning with the simplest cases of the pure metals, and leading up to the more complex cases of the 2-phase systems. The whole of the results will then be summarised and discussed, and some general suggestions and conclusions proposed.

Table III. (Series I).—*Copper (Rolled)*.

Temperature of test, degrees Centigrade.	Maximum Stress. Lbs.	Maximum Stress. Tons per square inch.	Elongation per cent. on 2in.	Contraction of area, per cent.
17	O.T.*	16·5	31·5	
17	O.T.	17·5	32·0	
17	1800	16·3	32·5	
17	1843	16·7	32·0	
252	1393	12·7	28·0	
290	1505	13·7	29·3	
330	1197	11·0	29·6	
370	1153	10·5	29·0	
420	1043	9·5	28·0	
480	823	7·5	27·5	
540	570	5·1	27·0	
620	287	2·6	27·0	
675	169	1·3	28·4	
736	141	1·2	36·0	
740	141	1·2	78·0	
775	111	1·0	66·0	
840	105	0·96	61·0	
920	60	0·50	69·0	
960	36	0·30	50·0	
1010	21	0·16	38·0	

*The letters "O.T." in the tables mean that the corresponding tests were carried out in the ordinary testing machine.

Series I.—*Copper*.—The stress-temperature results are given in Table III., and the corresponding curve is shown in Fig. 6. Le Chatelier's results are also given in Fig. 6; so far as they go, the two sets agree remarkably well. Unfortunately both Unwin and Le Chatelier stopped their work on copper before the most interesting range of temperature was reached. It will be noticed that at 650° C. the stress curve undergoes an abrupt change of direction. The upper part of the curve, which extends from the melting-point (1,065° C. oxidising atmosphere) to 650° C., is a straight line. From 650° to the ordinary temperature the curve is convex upwards. Theoretically these two portions of the curve must merge gradually into one another so as to mask the exact transition point from one to the other, and whenever a con-

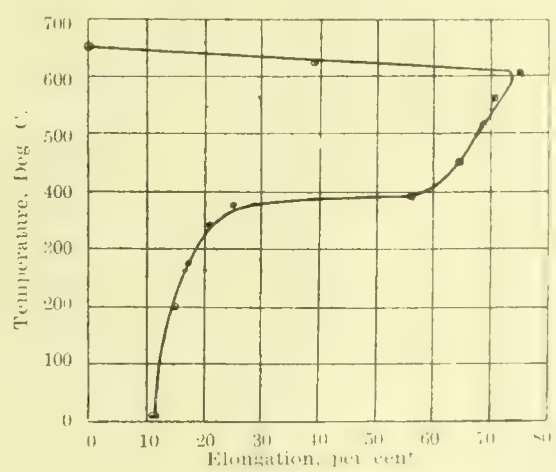


Fig. 9.—Aluminium.

Table II.—*Analyses of Materials.*

	Series I.	Series II. and III.		Series IV.	Series V.	Series VI.	Series VII.	Series VIII.	Series IX.	Series X.
	Copper.	Aluminium.		Copper-Nickel.	Brass A.	Brass B.	Muntz Metal A.	Muntz Metal B.	Brass C.	Complex Brass.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Copper	99.84	Trace		79.99	69.88	69.4	60.52	59.52	56.75	55.1
Aluminium	—	99.56		—		—	—	—	—	0.07
Nickel	—	—		19.60	0.05	—	—	0.39	—	0.28
Zinc	—			—	27.49	30.44	38.80	39.43	43.20	41.89
Tin	—			—	—	—	—	—	—	0.77
Lead	—	—		—	0.64	0.005	0.40	0.74	0.10	0.52
Iron	Trace	0.22		0.41	—	0.15	—	—	Trace	0.84
Arsenic	0.05	—		—	—	—	—	—	—	—
Sulphur	0.005	—		—		—		—	—	—
Silicon	—	0.22		—				—	—	—
Manganese	0.08 (Oxygen)	—		—	—	—	—	—	—	0.36
Physical condition	Rolled	Rolled	Cast	Rolled	Cast.	Wiredrawn	Rolled	Rolled	Cast	Extruded
Constitution	Pure metal	Pure metal	Pure metal	Single solid solution (α)	Single solid solution (α)	Single solid solution (α)	Two solid solutions ($\alpha + \beta$)			

siderable number of observations have been made in similar ranges the experiments have confirmed the theory. An exact transition point can be obtained by extrapolation of the two parts of the curve, so that they meet. This transition point is called briefly by the author the "temperature of recuperation," but the full title should be the "limiting temperature of complete recuperation." The reason for adopting these terms will be stated later when the whole of the experimental results are being reviewed. Every tensile curve studied may be considered to exhibit a definite temperature of recuperation which can be deduced from the experimental curve by extrapolation; in most cases the curves have been drawn so as to indicate these temperatures.

Attention may be called to a single result obtained at a temperature of 295°, for which the author is unable to account; also to another at 740°, which appears to lie well off the curve. The differences between these two results and the values that might be expected for them from the general form of the curves are far beyond the possible errors of experiment.

Series II.—*Aluminium (Rolled).* The stress-temperature curve (Fig. 8, Table IV.) is of precisely similar form to that obtained for copper. The temperature of recuperation is 395° C. The strain-temperature curve (Fig. 9) is rather different, in that the elongation increases slowly up to about 390°, *i.e.*, a little below the temperature of recuperation, and then undergoes a rapid and large increase. Above 400 the increase becomes slower till a temperature of rather over 600 is reached, when a rapid fall takes place, due probably to loss of cohesion.

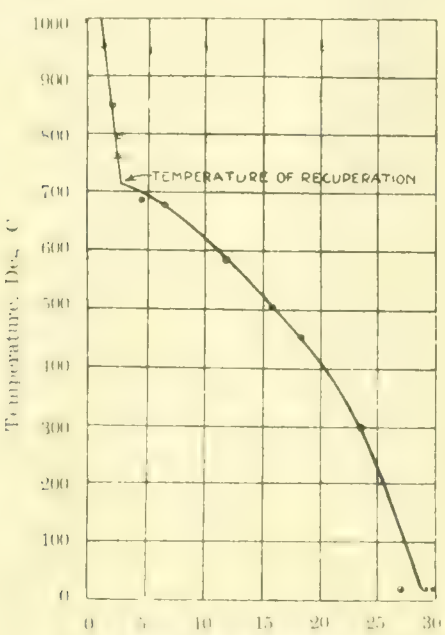


Fig. 10.—Copper Nickel (α Solution)

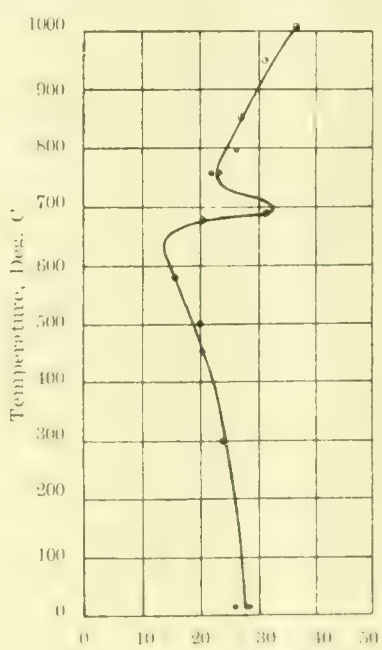


Fig. 11.—Copper Nickel.

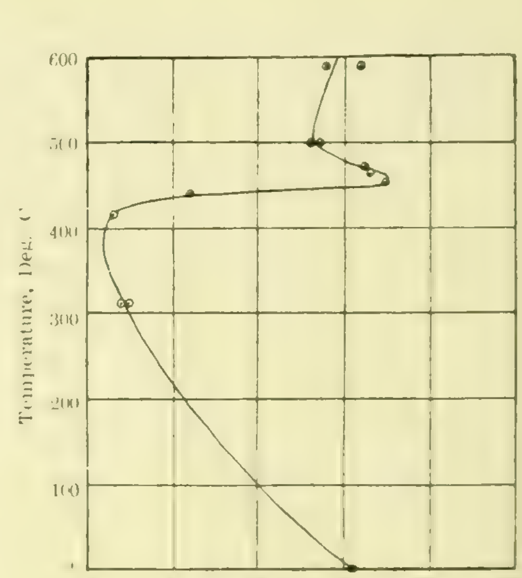


Fig. 12. (Bengough & Hudson).

The strain temperature, or elongation temperature, curve is shown in Fig. 7. Contrary to what might have been expected, the elongation falls off slightly as the temperature is raised till 650° C. is reached. The elongation then increases at first slowly and then very rapidly; at about 920° C. it falls rapidly, the fall being due probably to almost complete loss of cohesion, and reaches zero at the melting point. It is uncertain whether or not a re-entrant angle really occurs in the curve at a temperature of 840°, since the single result shown in that range is not sufficient to establish it. For this reason the curve in the region of this temperature has been dotted in to indicate that it has not been satisfactorily determined. The important fact shown by the curve as a whole is that a decided change in direction occurs at 650° C., and that at temperatures over 700 and below 900 the metal exhibits ductility of quite a different order from the rest of the temperature range.

Points to be noticed especially in the curves for copper and aluminium are: (1) The well-marked change in direction of the stress-temperature curves at 650 and 395. (2) The well-marked change of direction in the strain-temperature curves at approximately the same, but rather lower, temperatures.

Series IV.—*Copper-Nickel Alloy.*—This alloy consists of a single solid solution. The stress-temperature curve is given in Fig. 10, and is plotted from the results given in Table IV. It is of the same form as those of copper and aluminium, and the temperature of recuperation is about 710°. The strain-temperature curve (Fig. 11) differs from those of the pure metals. The elongation falls off till a

temperature of about 650° is reached, and then increases somewhat rapidly, reaching a maximum at about 700° C. It then falls off again up to 750° C., and lastly rises till a temperature of at least 1,010° is reached. The melting-point of this alloy was 1,190° C., but it was not found practicable to carry out experiments at temperatures much above 1,000°, hence no evidence of a final turn back of the curve in the neighbourhood of the melting-point could be obtained.

Table IV.—Series II.—*Aluminium (Rolled).*

Temperature of test, degrees Centigrade.	Maximum Stress.		Elongation per cent. on 2in.	Contraction of area, per cent.
	Lbs.	Tons per square inch.		
20	946	8·6	11·0	—
20	940	8·6	12·0	—
200	701	6·3	15·0	—
275	545	4·96	17·2	—
330	371	3·4	20·3	—
375	190	1·7	25·0	—
396	105	0·96	56·0	—
450	—	—	—	—
520	45	0·40	68·5	—
565	27	0·24	70·3	—
610	33	0·30	75·0	—
625	21	0·19	39·0	—

Table V. (Series IV).—*Copper-Nickel Alloy.*

Temperature of test, degrees Centigrade.	Maximum Stress.		Elongation per cent. on 2in.	Contraction of area, per cent.
	Lbs.	Tons per square inch.		
17	O.T.	27·1	26·0	—
17	O.T.	29·8	28·2	—
17	—	29·2	28·0	—
300	2596	23·7	23·5	—
456	2016	18·4	20·3	—
505	1736	15·8	20·0	—
580	1323	12·0	15·5	—
675	735	6·7	20·2	—
685	498	4·5	31·2	—
760	321	2·9	23·4	—
760	273	2·5	22·0	—
795	287	2·6	26·5	—
850	241	2·0	27·2	—
950	129	1·1	31·2	—
1010	117	1·0	37·0	—

Table VI. (Series V.)—*Cast Brass.*

Temperature of test, degrees Centigrade.	Maximum Stress.		Elongation per cent. on 2in.	Contraction of area per cent.
	Lbs.	Tons per square inch.		
As cast	O.T.	12·1	39	-
As cast	O.T.	12·2	37	-
290	—	5·7	15	-
325	2229	5·0	11	-
345	2152	4·9	9	-
400	1281	2·9	3	-
432	1101	2·5	2·0	-
465	1279	2·9	3·2	-
496	1057	2·4	4·4	-
530	917	2·0	3·5	-
560	959	2·1	5·0	-
600	833	1·9	9·3	-
620	819	1·8	8·0	—
625	553	1·2	20·0	-
635	685	1·5	18·5	—
650	589	1·3	18·0	-
680	463	1·0	17·2	-
710	443	1·0	15·6	—
745	301	0·67	12·5	-
785	189	0·43	11·0	-

This curve should be compared with that given for 70/30 brass (α solid solution) by O. F. Hudson and the author in Volume IV. of the Journal of the Institute of Metals, and now reprinted in Fig. 12. The form of the two curves will be seen to be nearly similar, and the peaks in the curves, which occur in each case at about the temperature of recuperation, are particularly to be noticed.

The microstructure of this alloy, and the effect on it of annealing, are shown in Figs. 13-17.

Series V. — *Brass* "A." This alloy, like the last, consists of a single solid solution, the α solution of the copper zinc series. The results obtained with it are given in Table VI.,

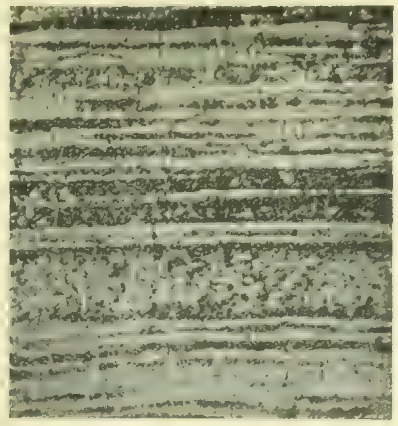


Fig. 13.—Cupro-Nickel (as rolled). Magnification 150 diameters.

Fig. 14.—Cupro-Nickel (annealed 1 hour at 700° C.). Magnification 80 diameters.

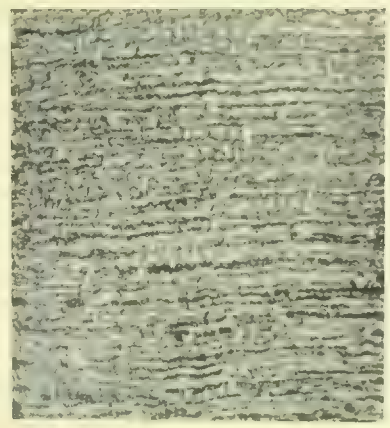


Fig. 15.—Cupro-Nickel (annealed 1 hour at 750° C.). Magnification 80 diameters.

Fig. 16.—Cupro-Nickel (annealed 1 hour at 800° C.). Magnification 80 diameters.

Fig. 17.—Cupro-Nickel (annealed 1 hour at 900° C.). Magnification 80 diameters.

and plotted in Figs. 18 and 19. The stress-temperature results appear to fall on two curves, which meet at about 440°, and are both approximately straight lines. Fig. 18 should be compared with the stress-temperature curve for 70/30 brass wire given in Vol. IV. of the Journal of the Institute of Metals by O. F. Hudson and the author.

The strain temperature curve of this alloy is remarkable. The elongation falls quite rapidly till a temperature of just over 400° C. is reached, and it may be mentioned here that this phenomenon occurs in all alloys which contain the α solution of the copper zinc series in any considerable quantity, as well as in some alloys that only contain a trace of it. In the case of the brass now being considered, and of the wire used in the experiments already referred to by O. F. Hudson and the author, the minimum values for

elongation were obtained in each case at a temperature of about 410°, and are practically identical numerically, namely, 1·5 and 2 per cent.

Above 430° C. recovery sets in with both these alloys. In the case of the wire this recovery is very rapid, and a new maximum of value is obtained at 450°. With the cast bar the recovery is very much slower, and the new maximum is only reached at a temperature of 625° C. In both cases the actual value is approximately the same, namely, 18·5 and 17·5. After the maximum is reached, the elongation falls off, in the case of brass "A," quite steadily up to the melting-

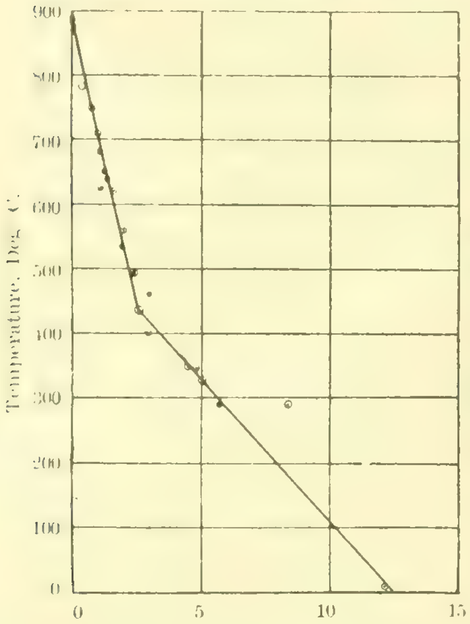


FIG. 18.—Cast Brass A.

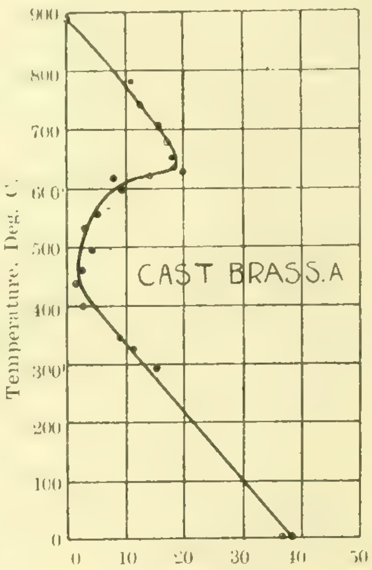


FIG. 19.—CAST BRASS A.

point. In the case of the wire the curve resembles that of the copper-nickel alloy, and the fall only takes place in the neighbourhood of the melting-point.

It will be seen that though there are several points of resemblance in the general form of the curves, there are also points of difference. Perhaps a close resemblance could hardly have been expected between material so different physically as a hard-drawn wire ⅛in. diam. and a 1in. cast bar. Chemically, the latter differs from the former in containing an additional 0·5 per cent. of lead, and a considerable part of the difference between them may probably be put down to this fact.

(To be continued.)

Inventors and the Patents Act.—Major W. A. O'Meara (chief engineer to the General Post Office) presided at a meeting of the recently-constituted Inventors' Institute in London on the 15th inst., when it was announced that since the formation of the Institute a month ago 86 members had been elected. It was hoped that at least 500 members would be obtained within a year. It was agreed that steps should be taken with a view to acquiring suitable premises for the Institute in the vicinity of the Patent Office. Considerable discussion ensued with regard to the Patents Act, and members were invited to bring forward at the next meeting amendments that they considered should be brought before the notice of the Board of Trade.

A Costly Lift Accident.—In the King's Bench Division on the 13th inst., before Mr. Justice Coleridge and a special jury, damages amounting to £1,183 were awarded Dr. Edward Hoare Sweet and his wife in respect of injuries which the lady sustained in Harrods Stores, Brompton Road, on May 17th last. Mrs. Sweet was ascending by the lift to one of the upper floors of defendants' premises, and when it reached the first floor the cable broke, the lift dropping some 30ft. to the bottom of the well. Mrs. Sweet was rendered unconscious, and had to be removed to hospital. Defendants admitted liability, but denied that the injuries were so serious as plaintiffs represented. His Lordship, in summing up, remarked that in this case there was a controversy between medical gentlemen on either side. The jury must try to arrive at some safe road between these conflicting opinions. The jury found a verdict for the plaintiffs, assessing the damages at £1,183, and his lordship entered judgment accordingly, with costs.

THE PRODUCTION OF SOUND STEEL.

BY SIR ROBERT A. HADFIELD.

THE question of producing sound steel is quite as important a factor in meeting the requirements of the times as ever it was. By sound steel is generally meant material free from (*a*) segregation, (*b*) blowholes, and (*c*) piping. Unless these requisites are fulfilled trouble and breakdown of the material may occur in some stage of its history. Fortunately, as a rule, the remedy which obviates or overcomes any one of the difficulties tends to improve all. For example, steel which is sound and free from blowholes is less liable to segregation or intermingled slag, and the ingots made therefrom, if properly fed, will have the defects under (*c*), that is, piping, largely reduced.

Many simple devices as well as complicated arrangements have been suggested and tried to overcome the difficulties in question, as for example, fluid compression, from the top, also from the bottom; feeding and settling by gas-generated heat, compressing or squeezing from the sides, and many other devices. These have given more or less satisfactory results. There are, however, some disadvantages in these systems, such as the expense of application owing to the heavy cost of apparatus, and so on.

For some time I have been working at methods which I believe are simple yet efficient. Although the following description refers to patented methods, yet in view of the great importance of obtaining sound material I venture to think it may be of general interest. A system of this kind with suitable modifications could be applied to the manufacture of sound ingots for rails and other purposes. The terrible results of railroad disasters, such as that on the Lehigh Valley Railroad, show the importance of obtaining sound material in the ingots from which the rails are to be rolled.

At the works of my company, Hadfield's Steel Foundry Company, Ltd., Sheffield, large quantities of special steels are made, in which it is absolutely essential to have material perfectly sound and free from the defects mentioned above. The method now described has enabled the desired object to be fulfilled both cheaply and efficiently. Moreover, it has the important advantage of enabling not only soundness to be obtained but also a much larger percentage of the ingot to be used, and this with perfect safety. As will be seen from the results of the experiments described, in many cases no less than 93 per cent. of the fluid steel in the mould is made utilisable, and this at small expense.

Granted, therefore, sound piping or settling steel in the first instance, which is easily obtainable by ordinary care in manufacture, there seems to be no reason why ingots should not be made sound, free from blowholes, piping, and segregation. This being so, rails or other articles rolled therefrom should be of the highest grade. It is true that large quantities of rails as now made are of excellent quality, but it is just the "tenth" case which it is important to improve. It is the bad heat here and there, the bad ingot now and then which gives the fatal rail which in service fails, involving catastrophe and all the troubles consequent upon such disasters.

The following description of the Hadfield method of casting steel ingots, castings, &c., ensuring soundness, freedom from piping, and absence of segregation, may be of interest. The method of carrying out the process is shown by the accompanying Figs. 1 and 2. As will be seen, this consists in heating the metal in the upper part of an ingot or other mould and maintaining it in a liquid condition by the combustion in contact therewith, or in close proximity thereto, during the cooling and shrinkage of the metal in the lower part of the mould, of solid fuel—for example, charcoal—by means of a blast of compressed air which is caused to impinge on the fuel while the fuel is directly or indirectly supported by the metal below; also the interposition of a layer of fusible material, such as iron slag, which has no injurious action on the metal, between the metal and the fuel.

The cost of carrying out the method is trifling compared with the large saving gained in reducing loss and waste of

material. Moreover, the quality of the product is improved: for example, in making rails produced from such ingots, not only would there be less discard, but the material would be sounder. During the last few years many thousand tons of ingots have been made by this patented process, which has been found of great advantage.

As a specific example, it may be mentioned that ingots have been made weighing about 4,000lbs. each, in which the piping and discard do not amount to more than about 7 per cent. This small loss is not the only advantage, the chief one being that material is obtained which is quite sound and free from hidden pipes or other defects on the whole length of the ingot.

It is estimated that on a large output the saving by this method would be from 8s. to 12s. per ton. Thus, on a large tonnage of hundreds of thousands of tons annually there would be a very considerable saving each year, as well as obtaining sound ingots, free from blowholes, piping, and segregation.

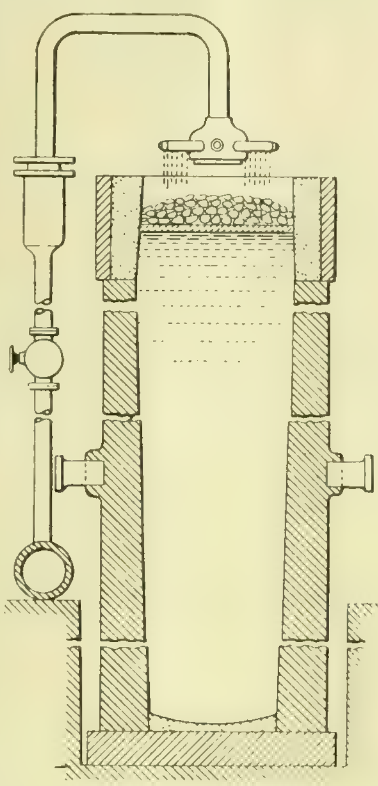


FIG. 1.—HADFIELD PROCESS OF AVOIDING PIPING AND SEGREGATION IN STEEL INGOTS.

In an experiment carried out upon ingots weighing about 2 tons each the segregation only a few inches below the feeding head placed at the top of the ingot was almost entirely absent. At about 3in. below the surface of the sinking head the percentages of sulphur and phosphorus were practically the same as in the original steel, viz., about 0·3 per cent. each. The sand "head" was 14in. square where it joined the ingot, tapering to 9in. square in a length of 16in. The steel was filled up in the sinking head to a depth of 14in., the remaining 2in. of the sand head being filled with a layer of ground slag, having a thickness of about 1½in. The slag was put on the molten steel, then the heating carried out by means of the charcoal and blast. The head was afterwards cut off the ingot, and was found to be free from piping or segregation. Following are the details:—

Total weight of ingot.			Weight of sand head.			Weight of sound ingot.		
Cwts.	Qrs.	Lbs.	Cwts.	Qrs.	Lbs.	Cwts.	Qrs.	Lbs.
38	3	0	2	2	10	36	0	18
(4,340lbs.)			(290lbs.)			(4,050lbs.)		

This is equal to a waste of about 6·7 per cent. The steel "fed" well, practically the whole of the molten steel in the head having descended bodily to feed the cooling shrinkage of the ingot. The head was drilled and analysed to find if there was segregation. The results are shown in the table below. It will be seen that even C is almost normal in its composition, and D, a little lower down, has practically the same analysis as the bulk of the ingot. The original analysis in this heat, as shown by the test ingot, was: Carbon, 0·50; silicon, 0·16; sulphur, 0·033; phosphorus, 0·037; manganese, 0·80.

Position of test piece below surface of feeding head.	Analysis. Carbon.	Sulphur.	Phosphorus.
A—1in. below	1·41	0·175	0·135
B—2in. below	1·20	0·12	0·10
C—3½in. below	0·59	0·041	0·041
D—Where ingot itself commences	0·50	0·033	0·037

This ingot, with the sinking head described, is a still further advance in the improvements effected in this matter, the segregation being very slight. It would appear that 93 per cent. of this ingot may be utilised for commercial purposes.

The following further experiments with this patented method were carried out: Two heats were made of Hadfield's mild and ordinary steel. In the first the carbon was 0·20, silicon 0·40, and manganese 0·60; in the second the carbon was 0·45, silicon 0·50, and manganese 0·80. In the preparation of the ingots sufficient slag was placed upon the upper portion of the molten steel in the ingot mould, then charcoal and blast applied by means of the special blowpipe arrangement. Each ingot was provided with a sand-top, placed at the top of its ordinary length of the cast-iron mould. The exact method is shown by Fig. 1. The following were the results obtained:—

Mild Steel. — Seven ingots were cast from heat X9428-1843, and seven cast from heat X9438-1843. Total weight, 6 tons 17 cwt. 2 qrs.; forged, 25·3·08.

	Tons.	Cwts.	Qrs.	Lbs.	Per cent.
Head scrap	0	8	0	0	6·0
Billet scrap	0	1	2	0	1·0
Forge waste	0	2	2	0	1·8
125 billets	6	5	2	0	91·2
	6	17	2	0	Total waste 8·8 per cent.

Ordinary Steel. — Seven ingots were cast from heat X9387-6 and seven cast from heat X9396-6. Total weight, 6 tons 17 cwt.; forged, 24·3·08.

	Tons.	Cwts.	Qrs.	Lbs.	Per cent.
Head scrap	0	7	3	0	5·6
Billet scrap	0	1	0	0	0·7
Forge waste	0	2	0	0	1·6
126 billets	6	6	1	0	92·1
	6	17	0	0	Total waste 7·9 per cent.

These ingots forged well in each case, and the billets produced therefrom were sound and satisfactory in other respects.

In the experiments made it was found that, with the exception of 8·8 and 7·9 per cent. waste, respectively, practically the whole of the remaining portion of the ingots represented saleable and serviceable billets. The same results may be obtained with either small or large ingots. From the results obtained in the finished product it would appear that

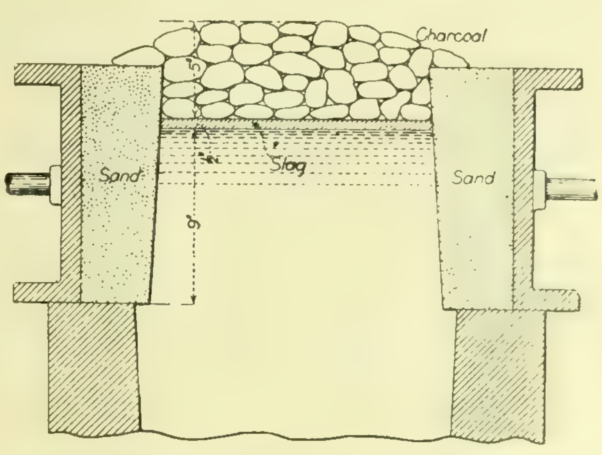


FIG. 2.—ENLARGED VIEW OF UPPER PART OF FIG. 1.
The mould is for a 15in. ingot.

there is great improvement over the methods ordinarily practiced, whether as regards saving in waste or improving the quality of the material.—"The Iron Age."

Institution of Engineers and Shipbuilders in Scotland.—At a meeting of this Institution, held on the 13th inst. at Glasgow, Prof. James Muir, D.Sc., M.A., delivered a lecture on "Colour: Its Production and its Application to the Determination of Stress." After showing the production of colour by absorption and reflection of light with spectrum experiments, Prof. Muir referred to the production of colour by the scattering of light, which accounted for the blue of the sky and the sunset, and discussed the production of colour by the interference of polarised light, mentioning the recent work by Prof. Coker, of Finsbury College, investigating the distribution of stress materials by the polarised light colours produced in specimens of celluloid. The lecturer afterwards showed interesting illustrations of the three-colour theory of vision.

CORRESPONDENCE.

"Smoke-prevention Enthusiasts."

To the Editor of "The Mechanical Engineer."

SIR,—Your issue of February 2nd contained a leading article under the above heading in which certain references were made to "the contemplated action of the officials of the National Smoke Abatement Society." The Smoke Abatement League of Great Britain is the only "National Smoke Abatement Society," and as secretary of this League I crave for a little of your valuable space to set forth exactly what is the "contemplated action" of the officials of the League, of which the writer of your leading article has obviously a very imperfect knowledge. In the first place, then, I should like to point out that the smoke prevention enthusiast does not always view the atmosphere "with a purely æsthetic eye, and with a profound ignorance of chemistry and of manufacturing requirements." On the contrary, the members of the Executive Commitee of the Smoke Abatement League are almost entirely practical and business men, who have expert first-hand knowledge of the problems involved, and who have the interests of manufacturers at heart as much as those of the many millions of our population whose lives are darkened and prematurely shortened by the smoke-cloud which hangs like a pall over so many of our great cities. There is not the least likelihood of these men pressing forward a Bill which would interfere with the legitimate carrying out of any industry in this country. But the weight of expert evidence shows, and it is indeed admitted by Prof. Arnold in the articles to which you refer, that in the case of ordinary boiler furnaces almost all smoke can now be prevented, and prevented with positive financial gain to the manufacturer. In other words, far from being a sign of commercial prosperity and success, smoke is in these cases a visible and glaring proof of a perfectly avoidable waste of fuel. It is only in the case of metallurgical furnaces that there is any real doubt as to the practicability of economical smoke prevention, and even here, as is shown by the letters of Mr. Kershaw and others, in answer to Prof. Arnold's articles in the "Sheffield Daily Telegraph," there is a very considerable body of expert evidence which says that it can be so prevented. We are perfectly well aware that probably some 50 per cent. or 60 per cent. of the smoke in large towns is due to domestic chimneys. But is this any argument at all against attempting to do away with the other 40 per cent. or 50 per cent. caused by factory smoke, and so practically halving the damage done by smoke? As a matter of fact we do everything in our power to stimulate the use of smokeless fuels, and particularly gas and electricity for domestic use, and the policy of many Municipal Councils in supplying gas and electricity at preferential rates for cooking and power purposes, in fixing free and in loaning and hiring out gas and electric cookers, heaters, &c., is already having very beneficial results. In conclusion, Sir, may I just briefly state what are the intentions of the League with regard to legislation on the subject of smoke abatement? Though we can guarantee not to press forward any Bill which will interfere with the legitimate carrying out of any industry in the country, we are attempting to obtain a general tightening up of the law all round against smoke producers, because we know that the ignorance of tradesmen and manufacturers, or their undue influence upon local town councils, prevents many Local Authorities from doing their duty in the matter of smoke prevention. Can we not appeal to the patriotism and public spirit of all classes in the community to help us in our endeavours?—I beg to remain, Sir, yours, &c.,

E. D. SIMON, Hon. Secretary.

Smoke Abatement League of Great Britain,
29, Mount Street, Manchester, Feb. 12, 1912.

[The above letter furnishes no reason for modifying our statements. We could wish our correspondent and those for whom he speaks would deal more with facts and less with sentiment. The talk about "millions of lives darkened and prematurely shortened" is gush, not argument. Smoke is unpleasant; it may be a nuisance; and on grounds of public cleanliness it may be desirable to control its emission. But to assert that its escape from a boiler chimney is "a glaring proof of waste of fuel" is not true. Smoke emission may be consistent with a very high degree of furnace efficiency. In 1895 there was a campaign against smoke in Sheffield. An association was formed, and a prize was offered to the boiler fireman "who evaporated the greatest quantity of water in a given time with the smallest quantity of fuel and the least smoke." These conditions were somewhat contradictory, but it is interesting to note—we quote from the report of the test—that "one of the competitors obtained the largest evaporation of water with the smallest consumption of coal, but at the cost of a very high percentage of smoke." He was the worst on the list as regards smoke emission (and did not get the prize), but he evaporated over 9lbs. of water from and at 212° Fah. per pound of coal, as compared with less than 8lbs. on the part of the man who got the prize, and, moreover, evaporated 7,829lbs. of water per hour, as against only 6,537lbs. by the successful fireman. We are not advocates of uncontrolled smoke emission from boiler furnaces, for we believe it is possible with skill to combine high boiler efficiency with very little smoke emission, but the margin of fire control in such cases is narrow, especially if a boiler is hard-pressed, and a slight disorganisation of the stoking arrangements may then cause an emission of smoke even with the most skilful attention. Further, the presence or absence of smoke in no way alters the quantity of deleterious gases in the shape of carbonic acid and sulphurous acid given off from a chimney, and which are not less objectionable to health because they are invisible.—ED. *M.E.*]

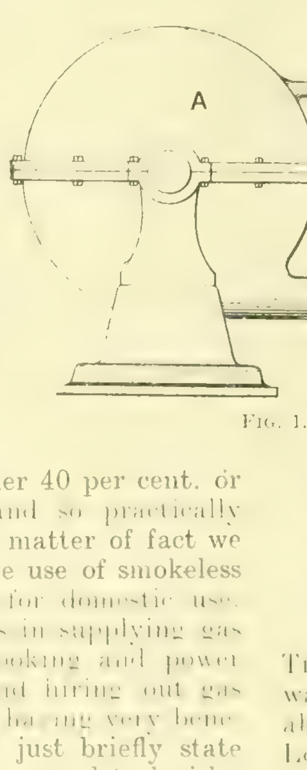


FIG. 1.

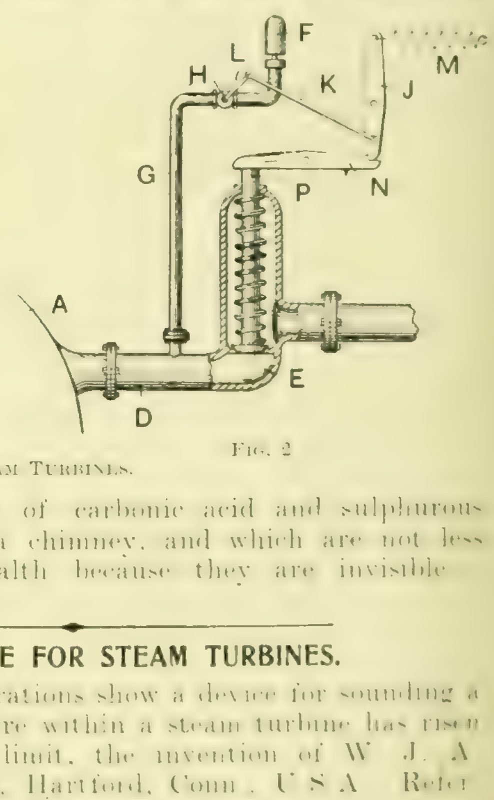


FIG. 2

ALARM DEVICE FOR STEAM TURBINES.

ALARM DEVICE FOR STEAM TURBINES.

THE accompanying illustrations show a device for sounding a warning when the pressure within a steam turbine has risen above a predetermined limit, the invention of W. J. A. London, Windsor Street, Hartford, Conn., U.S.A. Referring to Fig. 1, A represents the external casing of a turbine; B the main exhaust pipe; C a controlling valve in the exhaust pipe; D a relief pipe made up as desired and leading from the interior of the casing A to the free side of the exhaust. E represents a pressure-controlled check valve shown in section in Fig. 2. A spring is provided to hold this valve closed against the outflow of fluid excepting as at such times as the pressure back of the valve C in the region of the relief pipe D may rise to a point beyond that adapted to be resisted by the means for holding the valve E closed, when, at such period, the valve opens, thereby relieving the pressure within the casing A. A whistle F is provided, the same being in communication with the relief pipe D, and preferably at a point between the valve E and the casing A. This whistle operates only when the pressure rises to a point corresponding substantially to the pressure at which the valve E opens, so that simultaneously with the opening of this valve, or, if desired, slightly in advance thereof, the whistle will be blown for the purpose of causing an alarm to warn

the attendant that the predetermined pressure has been reached.

In the modification shown in Fig. 2, the whistle F is directly connected by a pipe G with the exhaust D. A valve H is arranged in the whistle pipe G. J represents a spring-controlled lever connected by a link K and arm L with the valve H. When the lever J is in the position shown in Fig. 2, the whistle pipe G is closed. The lever J is held in this position against the tension of the spring M by the trigger N. In this instance, the valve stem P co-acts with the trigger N in such a manner as to trip the trigger and release the lever J whenever the valve E opens. Upon releasing the lever J, the spring M moves the stem in a direction to open the valve H, whereby the whistle warning will be sounded. The warning, instead of being sounded by a whistle, as shown, may be sounded by means of a bell or by any other suitable device.

INSTITUTE OF MARINE ENGINEERS; PRESIDENTIAL ADDRESS.

The Marquis of Graham delivered his presidential address at the Institute of Marine Engineers, Stratford, E., on Monday, the 12th inst. In the course of his remarks he said the Institute deserved credit for the study it had encouraged in the internal-combustion engine. The steam engine using coal depended on several units of labour, the miners, the railwaymen, the dockside labourers, and the stokers, each adding to the cost. Where oil was used it could be run from the source of supply to the reservoir by a pipeline, and run by gravity from there into the ship's tanks. It could then be blown into the furnace or automatically turned into the power cylinder; in fact, with oil it was possible to provide power without the fuel being handled by men, thus effecting great economies in labour. He was one of the few members of the Institute who had had experience with both gas engines and oil engines. It was difficult to say which were the better, as both had distinctive features. With a coal-gas engine in the gun-boat "Rattler" they had made a non-stop run of 220 miles from Liverpool to Glasgow in very rough weather, and no engine worked more sweetly or smoothly. The fuel costs worked out at about 4d. per nautical mile per b.h.p., using anthracite. If bituminous coal had been used the costs would have been much less. The difficulty of direct reversing in connection with the gas engine had been mastered, but until a good bituminous producer for marine use was obtained the gas engine would not be a success. He had had experience with one of the Beardmore semi-Diesel type fitted in his yacht. It was a two-cycle engine of 130 b.h.p., and he had run it on crude Texas oil, specific gravity ·93. The cylinders were 9in. bore by 13in. stroke, and the revolutions per minute 350 at full speed. The cost of the oil was 52s per ton at Glasgow, and comparing that with a ship of the same power using Welsh coal at 20s. per ton the comparative cost for a 24 hours' run would be—for oil £8. 6s., and for steam £12. 8s. With Scotch coal at 14s. per ton the comparison would be £8. 6s. for oil, against £8. 19s. for coal, but in addition to this there would be a saving in labour, space, and stand-by losses, all of which were in favour of the motor.

Prevention of Coal-Dust Explosions.—At a recent meeting of the local section of the Society of Chemical Industry at Liverpool University, Dr. J. Harger, in the course of a paper on this subject, announced that he had made experiments which justified him in declaring that coal-dust explosions could be prevented. His experiments proved, he said, that a small reduction of oxygen and the addition of a little carbon dioxide was sufficient to render coal-dust ignition impossible. The reduction in oxygen necessarily varied with the different coal and with the method of working. In most mines a reduction of 1 per cent. in the oxygen and the addition of ½ per cent. carbon dioxide was sufficient. With others a reduction of nearly 2 per cent. in the oxygen and an addition of ¾ per cent. carbon dioxide was necessary to render them safe. If the reduction in oxygen was made to 17½ per cent., with ½ per cent. to 1 per cent. carbon dioxide, absolute safety was secured, not only from coal-dust explosions, but from firedamp explosions, also from fires of wood or coal in the roads, and from gob fires. For respiration such an atmosphere was as good as ordinary air.

RESONANCE EXPERIMENTS.

At a meeting of the Glasgow University Physical Society Mr. Charles C. Mylles read a paper on "Resonance." The author first explained the meaning of the term resonance as applied in physics. A structure which can be set vibrating in a particular way will, when once so disturbed and left to itself, continue to vibrate with a practically constant period, known as the free period. If then this same structure, initially at rest, is subject to a series of disturbing rhythmic impulses occurring at intervals which correspond to the free period, a large amount of vibration may be set up. This phenomenon is known as resonance. It is of far-reaching importance, not only in physics, but also in engineering problems. The simplest examples, however, are seen in sound experiments. Thus the hollow boxes on which tuning forks are mounted act as resonators to the note of the fork and increase the volume of the sound. Sensitive flames and water jets can also be constructed which are greatly affected by notes of certain pitch, and these and also such pieces of apparatus as Helmholtz's resonators may be employed to determine the pitch of a musical note. Mr. Mylles exhibited many interesting experiments on this subject.

THE INCORPORATED MUNICIPAL ELECTRICAL ASSOCIATION.

The seventeenth annual convention of this Association will be held at Harrogate from June 18th to 21st. According to the preliminary programme, just issued, the convention will be opened on the first day by the Mayor of Harrogate, and will afterwards be addressed by the President, Mr. George Wilkinson, chief electrical engineer to the Corporation of Harrogate. The remainder of the morning will then be taken up by a discussion on "Means for Securing Reliability and Maintaining Continuity in Electricity Supply," while in the afternoon a discussion on "A Cooking Load, from the Supply Station Point of View," will be held. There will be a reception by the Mayor in the evening. On the second day there will be a visit to Leeds, and papers will be presented by Mr. S. L. Pearce, of Manchester, on "Limitations of Profit from Municipal Trading," and by Mr. R. A. Chattock, of Birmingham, on "Organisation of Electric Supply Undertakings." The annual dinner will be held at Harrogate in the evening. On the third day there will be a visit to Middlesbrough, and a paper on "Automatic Pressure Regulation" will be read by Mr. S. J. Watson, of Bury. The concluding day will be taken up by the annual general meeting and by excursions. Further information in reference to the convention may be obtained from Mr. C. McArthur Butler, of 28, Bedford Square, London, W.C.

"NOMINAL" HORSE-POWER.

At the University of Manchester, on the 15th inst., Mr. Dugald Clerk delivered a lecture on "The Rating and Power of Internal-Combustion Engines." The rating of an engine's power by means of cylinder dimensions was, he said, no new problem, but one which arose immediately upon the perfecting of the steam engine by James Watt. It produced a series of more or less divergent rules, all intended to give the power of the steam engine directly from the cylinder dimensions. The power given by rule was long known as the nominal power of the engine, and steam engines used to be sold as so many horse-power nominal, capable of working up to some fabulous power. No doubt in the early days of the steam engine these rules gave a close approximation to the actual power of the engine, but the progress of experience and invention so greatly changed the conditions that before the practically final disappearance, about 25 years ago, of the term "nominal" the power of the engine was generally three times the nominal, and sometimes six. This conception of nominal horse-power was a great annoyance for many years to the engineering world. The term "nominal" was not used to the same extent in connection with internal-combustion engines, and now in such stationary engines a rated brake-power was given on which the engines could run continuously and a maximum or over-load power was specified capable of being obtained for short periods. No attempt had been made at evolving a rating rule for stationary internal-combustion engines, but practice had now become almost standard in certain particulars. The requirements of the motor car, however, necessitated an attempt to solve the problem.

INDUSTRIAL AND TRADE NOTES.

New Docks and Shipyards for Argentina.—The Argentine Government has promulgated a law authorising Messrs. Vickers to establish near the port of La Plata shipyards and docks costing five million gold pesos.

Foundry Workers' Wages.—The Home Secretary has appointed Sir Ernest F. G. Hatch, Bart. to be a Commissioner to enquire and report whether the provisions of Section 116 of the Factory and Workshop Act, 1901 (particulars of work or wages to be given to piece workers), should be extended to foundries, and, if so, with what modifications.

Sheffield Moulders to Strike.—On Saturday last the whole of the moulders employed in the engineering trades of Sheffield handed in their notices, to take effect next Saturday. The cause of this action is dissatisfaction at the development of modern methods in foundry practice, which have a tendency to give to coremakers work which was formerly allocated to moulders at a higher rate of pay than is given to coremakers.

Big Contract for British Firm.—Messrs. Pethick Brothers, of Plymouth and London, have secured a contract from the Hudson Bay and Pacific Railway Development Company for the construction of docks, granaries, station yard, buildings, &c., at Port Churchill, Hudson Bay. The amount of the contract is one and a half million pounds, and work is to be started within twelve weeks. The Hudson Bay Company holds a concession from the Dominion Government.

Rise in Ship Plate Prices.—The English and Scottish Steelmakers' Association have advanced the prices of ship and tank plates for export by 5s. per ton, making ship plates £7 per ton basis, and boiler plates £7. 15s. Boiler plates for the home trade have also been raised by 5s. per ton, raising the price for Lancashire and Cornish boiler plates to £8. 7s. 6d., and 5s. extra for the marine type. The prices are subject to 2½ per cent. discount. This is the second advance within a few months.

"Mauretania" Ready for Service Again.—The Cunard liner "Mauretania" was undocked on the 13th inst. from the Canada Graving Dock, Liverpool, after undergoing repairs through damage sustained when she broke adrift from her moorings on the Mersey early in December. The repair work was so extensive as to occupy nine weeks. Hundreds of men have worked at the ship in night and day shifts seven days a week, and no less than 500 tons of new plating material has been worked into the hull and decks.

Oil Prices Advancing in Scotland.—The advancing tendency of petroleum products continues, and the Scottish mineral oil companies have just intimated an advance of 7s. 6d. to 12s. 6d. per ton in the prices of their heavy and fuel oils. This represents an advance of £1 per ton within the last few months. The output of heavy oils aggregates about 85,000 tons per annum. The advance in fuel oil is attributable to the rapid expansion of the demand, particularly for naval purposes. Foreign imports have also largely increased.

Scottish Steelworkers Receive Notices.—At all the blastfurnace works in Scotland, which number 17, and employ a large number of men, notices were posted on Thursday last week by the owners intimating that their contracts with their workmen would terminate in 14 days. This step has been taken in the belief that a strike of coal miners appears to be inevitable, and that the supplies of coal for the furnaces will not be available. Should the strike unfortunately occur the furnaces will at once be damped down or blown out.

Extensions to the Sunderland Electricity Undertaking.—At a meeting of the Sunderland Town Council held on the 14th inst., the recommendation of the Electricity and Lighting Committee that additional plant be obtained for the Hylton Road power station at an estimated cost of £22,207, and that alternating current and continuous current mains be provided at an estimated cost of £15,880 was considered. The committee's recommendation was unanimously adopted, and the Finance Committee was instructed to take the necessary steps to borrow the amount.

Trade Circulars.—Sir W. G. Armstrong, Whitworth & Co., Ltd., send us a little pamphlet of instructions for the heat treatment in hardening and tempering their various classes of high-speed steel. Messrs. Donovan & Co., Cornwall Street, Birmingham, a descriptive pamphlet relating to their Barwick Motor Starting and Regulating Gear. R. Waygood & Co., Falmouth Road, London, S.E., some descriptions of recent installations of electric lifts. Siemens Bros. & Co., Ltd., Caxton House, Westminster, a pamphlet describing the construction and advantages of their various types of water meters.

Northern Blastfurnaces.—The return of the blastfurnaces in operation has just been issued for the past quarter. At the end of the period there were 53 blastfurnaces at work in Cleveland, and 25 in Durham, which are numbers that show only a very slight reduction on the numbers for the previous quarter. In West Cumberland only 13 furnaces were in blast at the end of the quarter, out of about 34 built, but there are three others which are re-building or re-lining. There appears to be the largest proportion of furnaces in operation in Scotland, and next in Cleveland and Durham in the large smelting districts. In all about 318 furnaces are in operation in the United Kingdom.

A Railway "Mediator."—The London & North Western Railway Company have we learn, appointed an official whose duties will be to receive and attempt to remedy all grievances between employed and employers before they become subjects for the conciliation boards. In this way the company hope to meet the complaints of the men that minor officials are in the habit of aggravating grievances instead of attempting to remedy them. It is also anticipated that the higher officials in all departments will welcome the innovation, as the new official will be given considerable power to order changes and to adjust differences between men of different departments. The men are said to be pleased with the arrangement.

Cement.—We have received a copy of some lectures on "Cement" recently delivered before the Institute of Chemistry by Mr. Bertram Blount, F.I.C. With these lectures the Council of the Institute have inaugurated a scheme under which Fellows who have special knowledge and experience in various branches of work are engaged to deliver lectures chiefly for the benefit of young chemists and advanced students such as those preparing for the final examination for the Associateship of the Institute. The object is to indicate the scope and character of the work actually carried out in various branches of professional practice as distinct from purely academic training. The lectures are published free to Fellows, Associates, and registered students, but the charge to other persons is 2s. 6d.

State of the Skilled Labour Market.—The Labour Department of the Board of Trade, reporting on the state of the labour market, states that employment in January continued good on the whole. As compared with a year ago, most of the principal industries showed an improvement which was considerable in the iron and steel, engineering, shipbuilding, and tinplate trades. There was a decline in the pig iron trade. In the 394 trade unions, with a net membership of 820,874, making returns, 2·7 per cent. were returned as unemployed at the end of January, compared with 3·1 per cent. at the end of December, and 3·9 at the end of January, 1911. The returns from firms employing 436,187 work people in the week ended January 27th last shows a decrease of 8·5 per cent. in the amount of wages paid, compared with a month ago, and of 3·1 compared with a year ago.

Hy. Bessemer & Co., Ltd.—The directors of this firm report that the net profit for the year has been £23,197. 18s. At 31st December, 1911, there was a balance available of £97,857. 17s. 5d. The directors recommend the following allocations: To write off for depreciation of the plant and machinery, £7,000; to reserve fund, £20,000; to pay a dividend on the preference shares for the second half year at 5 per cent. per annum, £2,500, to pay a dividend on the ordinary shares of 5 per cent., making with the payment in July of 2½ per cent., 7½ per cent. for the year, £10,000—making a total of £39,500, and leaving a balance of £58,357. 17s. 5d. to be carried forward to next year's accounts. The works have been well employed during the year except that operations were interrupted to a more than ordinary extent by holidays and by the railway strike in August. Prices also continued to fall until the later months of the year, whereas raw materials and fuel advanced. For the previous year profits were £19,000 and the dividend 5 per cent.

Suspension of Bonus System in Government Dockyards.—At the Admiralty, on the 16th inst., Mr. Churchill received a deputation from the Parliamentary Committee of the Trades Union Congress on the question of conditions prevailing in the Government dockyards. Referring to the premium bonus system, Mr. Churchill said that the system now only existed at Chatham and Sheerness dockyards, and, although the Admiralty must always reserve to themselves powers of dealing with the defences of the country, they proposed the entire suspension of the bonus system for the present. Continuing, he said they were working eight hours a day in the Government dockyards, and they would continue to observe that principle by precept and example. The Admiralty had done nothing that could be considered injurious to the maintenance of an eight-hour day in dockyards, but he could not give any promise with regard to the eight-hour day in private yards certainly not until Parliament had had an opportunity of fully discussing it.

Foreign Trade and Commerce.—The Commercial Department of the Board of Trade has issued the usual monthly statement of trade of certain foreign countries and British possessions.

including figures received up to January 31st last. A comparison of the total figures for the twelve months ended December 31st is possible for the following countries:—

Imports

	1911.	1910.
United Kingdom	£577,838,000	£574,496,000
Germany	469,285,000	439,057,000
United States	319,361,000	325,605,000
France	326,427,000	286,933,000
Belgium	165,639,000	157,651,000

Exports.

	1911.	1910.
United Kingdom	£454,282,000	£430,385,000
Germany	398,339,000	367,504,000
United States	428,804,000	381,046,000
France	246,883,000	249,352,000
Belgium	135,387,000	128,814,000

British Coal Supplies.—The following question relating to the duration and conservation of our coal supplies will shortly be put to the Home Secretary in the House of Commons: "Whether, in view of the increase in coal consumption during the last 40 years, and of the circumstance that, in any event, the duration of the known and workable fields is limited, and their exhaustion at the present rate of consumption can be approximately determined, the Government are satisfied to rest on the opinion of the Royal Commission that the rate of increase in output would become slower, to be followed by a stationary period, and then a decline, as affording sufficient ground for assuming that no steps are necessary for the conservation of this source of energy, instead of regarding it as an indication of increasing difficulty in maintaining the supply; or, having regard to the vital national importance of industrial energy supply, will the Government consider the suggestion of Sir William Ramsay (President of the British Association) that a small Commission should be appointed, sitting permanently, to enquire and keep the Government advised as to the rate of exhaustion and probable further duration from time to time, and as to what, if any, steps should be taken, in the light of further knowledge to conserve and utilise the remaining supplies to the best advantage of the nation?"

Railwaymen's Wages.—A report has just been issued by the Board of Trade regarding the earnings and hours of labour of railway servants. The figures given relate to the year 1907. and refer to 401,437 employés, of whom 365,901 were adult workmen. It is pointed out that since the period covered by the report many changes in the direction of increases of wages and reductions of hours have taken place. The average rates of wages for a full week were: Adults 24s. 4d., and lads 11s. 3d The actual average earnings were: Adults 26s. 8d., and lads 11s. 11d. The average actual earnings per week of several of the principal grades were as follows: Engine drivers, 45s. 11d.; goods guards and brakesmen, 31s. 2d.; passenger guards, 29s. 3d.; signalmen, 27s. 6d.; firemen, 27s. 5d.; shunters, 25s. 7d.; goods guards and porters, 21s. 10d.; permanent-way labourers, 21s. 8d.; platelayers and packers, 21s. 2d.; coaching and traffic porters, 21s. 9d. The value of allowances has not been included in the figures given. The hours of labour for the United Kingdom as a whole averaged 58 per week for adults and 58·9 for lads. Of adult workmen 50 per cent. worked 60 hours or over and 10 per cent. worked under 54 hours. In the case of electric railways the average actual earnings are returned as 30s. 1d. per week for adults and 13s. for lads. The average hours were: For adults 54 per week of six days and 60·2 per week of seven days.

American Pig Iron Output in 1911.—According to the report of the American Iron and Steel Association, the total production of all kinds of pig iron in the United States in 1911 was 23,649,344 tons, against 27,303,567 tons in 1910, a decrease of 3,654,223 tons, or over 13·3 per cent. The production of Bessemer and low-phosphorus pig iron in 1911 was 9,409,107 tons, against 11,245,642 tons in 1910. The production of low phosphorus pig iron alone in 1911 amounted to 282,460 tons. The production of basic pig iron in 1911, not including charcoal of basic quality, was 8,520,029 tons, against 9,084,608 tons in 1910. The production of charcoal pig iron in 1911 amounted to 278,676 tons, against 396,507 tons in 1910. A small quantity of pig iron made with charcoal and electricity is included in the figures for both years. No pig iron was made in 1910 or 1911 with mixed charcoal and coke. The production of spiegeleisen and ferromanganese in 1911 was 184,717 tons, against 224,431 tons in 1910, a decrease of 39,714 tons. The production of ferro-manganese alone in 1911 was 74,482 tons. The number of furnaces in blast on December 31st, 1911, was 231, against 212 on June 30th, 1911. The number of furnaces idle on December 31st, 1911, including furnaces being rebuilt, was 235, against 261 on June 30th, 1911. During the last six months of 1911 the number of furnaces actually in blast during a part or the whole of the period was 275, against 297 in the first half of the year. In the last half of the previous year 332 were active, against 374 in the first half of the year.

British Shipping in 1911.—The "Statistical Tables" for 1911 issued by Lloyd's Register of British and Foreign Shipping shows that the total addition to the steam shipping of the United Kingdom during the year was 1,334,387 tons gross; and that to sailing tonnage 21,864 tons gross—a total of 1,356,251 tons gross. Of the tonnage added to the register about 92¼ per cent. consisted of new vessels. The gross deduction of steam tonnage from the register amounted to 854,483 tons and of sailing tonnage to 163,551 tons; or, in all, to 1,018.034 tons. The number of steamers on the official register of the United Kingdom increased by 244, and the tonnage by 479,904 tons, while the number of sailing vessels decreased by 254, and the tonnage by 141,687 tons. The total number of vessels on the register, therefore, decreased during the year by 10, and the total tonnage increased by 338,217 tons. Of new vessels 670 of 1,373,399 tons were classed by Lloyd's Register during the year. Corresponding with the general improvement in the shipbuilding industry, the figures show an increase of about 316,000 tons on those for 1910. A large number of vessels of special design were classed during the year. These included 24 steamers of 109,113 tons (three for the American Lakes) built on the longitudinal system of construction and one on the topside tanks system, six vessels fitted for burning liquid fuel, five steamers of the cantilever framing and topside tanks type; one steamer, the "Shinyo Maru," fitted with steam turbines; two steamers, the "Orama" and the "Demosthenes," with a combination of turbines and reciprocating engines; and the "Holzapfel I.," fitted with engines worked from a suction gas plant and with screw shaft connected by an hydraulic transformer, together with other steamers intended for channel and coasting purposes Of the tonnage classed, 1,132,969 tons, or about 82½ per cent., was built in the United Kingdom. The average size of the new steamers classed was in 1891 just 2,100 tons It rose to 2,600 tons in 1898; and to 2,906 tons in 1901. In 1902 it passed 3,200 tons; in 1907 it was 3,383 tons; in 1910 the average was 3,341 tons; and for the past year it was 3,723 tons—the highest average yet attained.

METAL QUOTATIONS.

TUESDAY, FEBRUARY 20TH.

Aluminium ingot		65/- per cwt.
,, wire, according to sizes, &c.	from	102/- ,,
,, sheets ,, ,,	,,	120/- ,,
Antimony	£27/10/- to	£28/-/- per ton
Brass, rolled		7⅞d. per lb.
,, tubes (brazed)		9⅞d. ,,
,, ,, (solid drawn)		8d. ,,
,, ,, wire		7¾d. ,,
Copper, Standard		£63/-/- per ton.
Iron, Cleveland		49/4½ ,,
,, Scotch		55/4½ ,,
Lead, English		£16/2/6 ,,
,, Foreign (soft)		£15/17/6 ,,
Mica (in original cases), small		6d. to 2/- per lb.
,, ,, ,, medium		2/6 to 4/- ,,
,, ,, ,, large		4/6 to 8/6 ,,
Quicksilver		£8/7/6 per bottle.
Silver		27 3/16d. per oz.
Spelter		£26/15/- per ton.
Tin, block		£194/10/- ,,
Tin plates		13/6 ,,
Zinc sheets (Silesian)		£29/10/- ,,
,, (Stettin; Vieille Montagne)		£30/-/- ,,

Exhaust Gases from Motor-cars.—The Local Government Board have issued an order under the Motor Car Acts, providing that from and after the 31st March next every person driving or in charge of a motor-car on the highways shall not use any cut-out fitting or other apparatus or device which will allow exhaust gases from the engine of the motor-car to escape into the atmosphere without first passing through a silencer expansion chamber, or other contrivance suitable and sufficient for reducing, as far as may reasonably be practicable, the noise which would otherwise be caused by the escape of such gases. The order does not apply to motor-cycles.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1910.

Method of and apparatus for producing boron and zirconium. Weintraub. 25033.

1911.

Cutting helical gear wheels. Sykes. 1759.
Gas meters. Kennedy McGregor. 1869.
Machines for forging and sharpening rock drills. Leyner. 1923.
Spray producers or apparatus for atomising liquids. Dronsfield. 1932.
Hub contained variable speed gear and driving clutch for motor cycles. Sturmey Archer Gears, Ltd., and Cohen. 2013.
Irreversible steering gear for motor road vehicles. Tuckfield and Garland. 2090.
Valve for use on internal combustion engines. Stuart Turner, Ltd., and Masters. 2211.
Steam generators. Aitken. 2324.
Cooling arrangement for internal-combustion engines. Daimler Motoren Ges. 2340.
Mechanism for regulating and controlling the action of governors for engines. Morley. 2352.
Joint making packing. Bingham & Wilson. 2353.
Means and apparatus for use in enamelling iron castings. McCourt & Wilson. 2448.
Apparatus for the propulsion of vessels by the direct action of explosions upon the water. Czuprykowski. 2471.
Chain belts. Yoxall & Thorneycroft. 2538.
Sand moulding machines. Phillips. 2544.
Valve gear for internal combustion engines. Wolseley Tool and Motor Car Company, and Rowledge. 2566.
Furnaces for hardening steel cutters. Brayshaw. 2579.
Guards for saws. Collins & Mawson. 2622.
Two cycle internal-combustion engines. Sears. 2672.
Pulley blocks. Welin. 2715.
Turret lathes. Austin. 3051 and 7678.
Gas purifying apparatus. Lessing, and Gibbons Bros., Ltd. 3109.
Valve gear for pumps. Nimmo & McLuckie. 3390.
Rotary valve mechanism for internal combustion motors. Baverey. 4164.
Regulating and equalising the driving power required by machines having variable loads. Feuillette. 4516.
Means for automatically controlling winding engines. Grimmitt. 4755.
Nut tapping machines. Schiementz. 5691.
Lubrication of shaft bearings. Unbreakable Pulley and Mill Gearing Company, and Stroudley. 5792.
Extraction of metals. Perret. 5867.
Treating iron pipes for the prevention of rust. Skinner, and Patent Corporation. 6138.
Variable speed gears. Collier & Collier. 6857.
Thermostatic fuel controlling valve. Davis & Twigg. 7210.
Apparatus employed in the manufacture of fuel. Smith. 7273.
Lathes. Klehe & Muller. 7607.
Registering mechanism of gas meters. Berry, Glover, and Meters, Ltd. 7727.
Valve mechanism of internal combustion engines. Matthew and Argylls, Ltd. 7942.
Flue covers for the setting of steam boilers. Stuart. 8629.
Automatic coupling and locking gear for railway rolling stock. Berkley. 9437.
Rotary engines. Oswald. 9967.
Steam superheaters. English & Mills. 10130.
Lead and salt bath furnaces employed for hardening or melting metal. Fletcher, Russell, & Co. and Fletcher. 10884.
Sockets for twist drills. Lyon. 10919.
Appliances for drying moulds. Roxburgh & Dobeson. 11085.
Rolling beams and girders of I, H, and like sections. Sellge and Deutsch Luxemburgische Berg werk und Hutten Akt. Ges. 12167.
Internal combustion engines. Thomson. 12337
Crucible furnaces. Cothias. 13,678.
Locknuts. Moore & Oakley. 13741.
Engines and pumps. Barbey. 14512
Apparatus and process for burning coal and gas produced therefrom. Kunze. 15030
Automatic couplings for railway vehicles. Trombetta. 15127
Fluid pressure transmission gear. Norman. 16006.
Two stage piston compressor with cooling arrangement. Köster. 16313.
Gas producers. Royston. 16512.
Fluid pressure engines or pumps. Redrup. 17155.
Cocks or valves. Spiridonofe. 17297.
Pipe couplings. Richardson. 17432.
Manufacture of chilled rolls for rolling metal. Trafford. 17532.
Turbine engines. Fisher & Peck. 17895.
Apparatus for delivering liquids in measured quantities. Satterstrom. 18030.
Valve gear for multi-cylinder internal-combustion engines. Guèret. 18238.
Winding gear for hoisting and lowering. Burrell. 19240.
Screw-threading tools. Cowell. 19306.
Regulating and reversing apparatus for regenerative gas furnaces. Kopper. 19372.
Drill sockets. Maier. 21156.
Gas heated boiler. Fenlon. 21617.
Automatic lubricator. Kofoed. 21669.
Belting for machinery. Hay. 23362.
Track or point switch operating mechanism for tram lines. Scherf. 23996.
Automatic lubricator. Rath & Behnke. 24618.
Bearings for shafts and shafting. Benson, Willison, and Head, Wrightson, & Co. 24984.
Apparatus for actuating and locking points or switches on railways. O'Donnell, and British Pneumatic Railway Signal Company. 25343.
Starting device for internal combustion engines. Allison. 26492.
Diesel motors. Marks. 26518.
Elastic fluid compressors. Soc. Anon. pour l'Exploitation des Procédes Westinghouse Leblanc. 26630.
Means of operating a cross slide of a machine of the turret type. Austin. 28313.

ELECTRICAL, 1911.

Automatic time switch. Thompson & Bowden. 2283.
Secondary batteries. De Karavodine. 2493.
Device for electrically igniting miners' safety lamps. Prestwich. 2552.
Wireless signalling. Fessenden. 2617.
Electrical systems and apparatus for railway signalling. O'Donnell and British Pneumatic Railway Signal Company. 2887.
Switch systems for electric lighting. Ward & Walmisley. 2911.
Electric heaters. Kohn. 2968.
Fusible electric cut outs. British Thomson-Houston Co., and Wedmore. 3761.
Electrical fuse boxes. Austin. 3779.
Electrical heating and cooking devices. Prentice. 3883.
Electric conductors. Evans, and St. Helens Cable and Rubber Company. 3996.
Electric switch for controlling a combination of electric circuits. Peto & Radford, Ltd., and Genese. 4521.
Process and apparatus for transmission to a distance, by electricity, of pictures, writing, &c. De Bernochi. 8017.
Electrical switches. Rawlings. 10318.
Electric heating devices. British Thomson Houston Co. 10549.
Electrodes for secondary galvanic cells. Porscke & Achenbach. 10859.
Vapour electric devices. British Thomson Houston Co. 11140.
Electrically controlled valves. Nicholson & Brooking. 12118.
Conduits for cables. Heitmeyer. 12545.
Supporting devices for electric illuminating bodies. Friedreich. 13026.
Apparatus for the control of gas valves and electric switches. Boult. 14427.
Registering circuits for automatic telephone exchanges. Siemens Bros. & Co. 15129.
Means for cooling enclosed electrical machines. Huther. 17110.
Vapour lamps. Kaufman. 17613.
Wiring of electric installations. Handcock. 18131.
Electric oscillation circuits and their connections. Thompson. 18231.
Electrodes for electrical furnaces. Planiawerke Akt. Ges. fur Kohlen fabrikation Ratibor. 18733.
Automatic sectioning means for limiting accidental interruptions of electric current supply in central stations. Brandenburg. 21001.
Electric circuit controlling devices. Hewlett. 23734.
Pole changer for electric motors. O'Donnell and British Pneumatic Railway Signal Company. 25344.
Self regulating arc lamps. Physikalisches Laboratorium Mechanisch Technische Werkstatte Hans Thoma Ges. 27817.

1912.

Starting means for vapour electric devices. Conrad. 37.
Adjustable inductance coils. Fessenden. 346.

The Mechanical Engineer

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Municipal Trading.

THE question of municipal trading has formed the subject of considerable discussion during recent years, and opinions differ widely as to its benefits. The extent to which it is permissible is determined by the powers conferred upon corporations by Act of Parliament, and the measure of advantage or disadvantage of such trading to the community opens up wide questions on which arguments can be advanced from opposite directions. This has been strikingly shown during the past week in a case before Mr. Justice Eve, in the Chancery Division, in which an action was brought by a Sheffield tradesman, supported by the Contractors' Association, against the Sheffield Corporation, claiming a declaration that the Corporation have no power to carry on the trade or business of erecting and installing electric light and bell fittings, or of selling electric motors outside the city of Sheffield. It appears that the Corporation had opened a showroom, to which anybody, whether a Sheffield citizen or not, could go and buy almost any electrical fitting from a cigar-lighter to a motor, and the grievance of the plaintiff was that in so doing the Corporation traded both inside and outside their area and thereby exceeded the powers under their Act of 1903, which enabled them to supply motors in connection with the supplying of electric power. The question here involved was simply a legal one, and it is not necessary therefore to discuss the arguments which were advanced on either side and which occupied the attention of the court for some five or six days. The judgment, however, which was against the Corporation, is important, though it is not final, inasmuch as it is their intention to appeal to the House of Lords during the present law sitting unless in the meantime parliamentary assent is secured to a Bill now being promoted which will specifically confer the powers in question. The facts put forward by the plaintiff were not seriously disputed, but the Corporation urged in defence that, being incorporated by Charter, they had power to do anything

not expressly prohibited, and that as the plaintiff had not established affirmatively any contravention of the Municipal Corporation Act of 1882, his plea could not be upheld. To the lay mind this defence seems peculiarly weak, and was dismissed by the judge as devoid of substance. Another point urged involved the construction of the Sheffield Corporation Act of 1903, which specifically empowered them to supply electric motors in connection with the current within the area of supply, and which also, it was contended, enabled them to supply the detail fittings to which exception was taken. Into the details of the argument it is not necessary to enter: suffice it that the judge ruled them to be inadmissible, and guided by a previous decision of Mr. Justice Neville in a case in which the Leicester Corporation were concerned, he held that the powers of the Sheffield Corporation were strictly limited to the sale of motors, which were the source of power, and did not include anything beyond, and under these circumstances made the declaration claimed by the plaintiff, and, further, ordered the defendants to pay the costs of the action, though for a limited period he declined to grant an injunction in view of the contemplated appeal. The judgment of course only touches upon the legal aspects of the case. The ethics of municipal trading opens up wider and more complex questions. The advantages of municipalisation in certain directions is generally admitted, on grounds of public health and convenience, which impose on every citizen a sacrifice to some extent of private rights for the general weal. In such services as the supply of water, gas, and electricity, and the disposal of sewage or refuse, individual rights are seldom invaded, or if they are, the compensations leave little ground for complaint. It might be true that private enterprise could even in such services, as in most other affairs of life, perform them more cheaply and efficiently than governing bodies, but such services must from their nature partake of the nature of monopolies, which in private hands are nearly always open to abuse, and the knowledge of this and the obvious inconvenience to traffic and transport which would result from the distribution of such services amongst independent bodies, with possibly rival and conflicting interests, has dictated the lines of modern town development and municipal control. The cost of distribution of a commodity depends upon the nature and the character of the service. In such matters as drainage and water supply this is fairly uniform and to some extent proportional to the size of the area, though it is easy to see that in these cases the economical service requires to be of a certain magnitude to justify expenditure in any particular undertaking, and similar reasoning applies also to gas and electric current, though the more fluctuating demand for these commodities and the conditions of supply bring the manufacturing authorities into contact with further and more difficult questions. These fluctuations are not so easily predicted and provided for as in the case of water supply or drainage, while the services are not free from danger unless adequately safeguarded. In the case of gas, irregularities of demand may arise at short notice owing to weather conditions, but the continuity of service is nevertheless essential and hence the necessity for huge storage tanks and large capital expenditure, and the fact that the establishment charges remain fairly constant even within a wide range of production gives rise to strong inducements to push sales, which is emphasized in the case of large cities by a desire to promote a cleaner atmosphere by substituting gas instead of coal for power and domestic purposes. It is easy to understand therefore why municipalities under these influences have been led to enter upon spheres of action which were not originally contemplated, such as the provision of cooking and heating stoves on terms which users could not obtain individually. The convenience of this is generally admitted, and it must be equally admitted that it compels the authority to indulge in a certain measure of trading and supervision of details, inasmuch as it has to undertake complete responsibility for the equipment. In the case of electricity the temptation to enter upon the sale or hire of equipment and details is even stronger than in the case of gas, because electricity, unlike gas or water, cannot be stored in bulk, or at all events for town purposes is not practicable, and variations have therefore to be provided for by costly outlay on power plant, with its correspondingly high fixed charges. Economic considerations make it doubly desirable to reduce as far as possible the peaks in the load, which largely result from lighting service, and this can only be done by securing as wide adoption as possible in other directions to secure a steady use of current. Here again reliability and safety of service demands more than ever supervision over the fittings and equipment used, as well as ability to supply them on terms that will lead to their adoption, and therefore little can logically be urged in the abstract against the policy of supplying fittings and equipment by municipalities. The justice or injustice of it depends on circumstances and the methods by which it is pursued, and it cannot be denied that in many instances these have not been satisfactory to the community or fair to individuals. It is not satisfactory to the community if, apart from considerations of public health or of the initial losses accompanying any enterprise, the municipal departments are run at a loss, inasmuch as this may confer a benefit on one section of the community at the expense of the rest, which is unfair, and further, may inflict special hardships on individuals. This, we take it, was the gravamen of the plaintiff's contention in the Sheffield action and appeared to be supported by the facts set forth in the judgment, for although the revenue of the fittings department had nominally exceeded the expenditure, the judge pointed out that in arriving at this result no charge had ever been made for interest on capital or for rent of Corporation premises, nor had any allowance been made for depreciated and obsolete stock. Much of the opposition to municipal trading springs, we believe, out of the misleading presentation of accounts, for it is obvious that a department which can trade with the ratepayers' money and enter into competition against a private tradesman without incurring the charges which fall upon him must place him at a disadvantage. Conducted upon proper lines and within the same strict limits as those imposed upon the individual, no objection can be urged against the municipalisation of enterprise wherever in the interests of the community it can be proved economical, but we are far from believing that all and every kind of work can be so undertaken. The extent to which the policy has been pursued has been determined by prolonged trial and not a few errors, and it is along these lines alone that future schemes can successfully proceed.

Personal.—Prof. Arnold, D.Met., of the Sheffield University, has been elected a Fellow of the Royal Society. Prof. Arnold has been identified with Sheffield steel since 1879. He has been Professor of Metallurgy at the Sheffield University since 1889, and is regarded as one of the most eminent metallurgists in the world.

SIR OLIVER LODGE ON WIRELESS TELEGRAPHY.

SIR OLIVER LODGE, the Principal of the Birmingham University, delivered a lecture on "Wireless Telegraphy," on the 22nd ult, before the members of the Engineering Society, at the University. He began by briefly summarising the early history of the subject of wireless telegraphy from the time of Clerk Maxwell to the year 1896, and showed that electrical signalling across space without wires could be accomplished by simple means in the laboratory, and over distances of a few hundred yards, and through walls, as was fully demonstrated in 1894. Two years later, in 1896, the energy, enterprise, and perseverance of Mr. Marconi began to take these laboratory experiments into the field of practice. He made use of all that had been done before, and added thereto the erection of vertical aerials of considerable height, with an earth connection. Signor Marconi also interested Government officials and financiers in the project, set up stations on a large scale, and gradually developed the application of the waves of Clerk Maxwell and Hertz into a practical commercial system of ocean telegraphy. The initiation of tuned or syntonic wireless telegraphy was then explained by the lecturer, who described the fundamental method started by himself in 1897, together with improvements by Marconi in 1900, and this part of the address was illustrated by the apparatus in work. The similar work of Prof. Braun and the Telefunken Company in Germany was also mentioned, and Sir Oliver said that by that means it was demonstrated that great precision of tuning could be obtained, and the interference of other stations eliminated, though unfortunately at present the existence of an International Convention hampered the free use of different wave-lengths for purposes of conversation, and restricted the advantages which, by electrical means, could readily be obtained from the several tuned systems of wireless telegraphy now known. The result was a difficult time for operators on ships, through the frequent "jamming" or interference with free speech by the crowd of messages which were liable to be overheard when nearing a port. Those were difficulties not of a scientific, but of an administrative kind, and presumably would be overcome by mutual arrangement and a better understanding of the position.

OIL VERSUS GAS ENGINE.

PROF. BURSTALL, addressing a meeting of the Midland Association of Gas Managers, held at Birmingham University on the 15th ult., dealt with the conditions under which a particular type of gas-engine may be installed. Briefly speaking, he said, there were two methods of working—one to take gas from the town main, and the other to generate gas by means of suction gas producers. As to which was preferable depended upon the relative prices of coal and gas, but it might be generally stated that in a city like Birmingham, with an engine of moderate power it was advantageous, taking everything into account, to obtain the gas from the city main. No doubt as gas became cheaper its usefulness would increase rather than diminish. Larger engines were almost invariably put down in places a fair distance from the centre of the town, or should be, and in that case a producer was probably the best way if the price of coal were reasonable. There was another point worth considering. That was the question where heavy oils could be obtained cheaply. If these were used in Diesel motors, which were now extensively employed for marine propulsion, they got the cheapest possible power that could be generated by any means. There was little doubt that a revolution in the production of power was imminent, and the probability was that it would be produced from oil if the oil supplies of the world were in any way adequate to the demand. This could only be expected when further oil fields were opened out, but there was no doubt the production of power from oil would be a serious factor to be taken into consideration.

The Jungfrau Railway.—The tunnel continuing the Jungfrau Railway from Eismeer Station to the Jungfrau Joch Saddle, which is 11,400ft. above sea level, was pierced a few days ago. The tunnel is now only some 2,000ft. below the summit of the mountain. The railway was begun 16 years ago, and it is expected that the summit of the Jungfrau will be reached about three years hence.

ASSOCIATION OF TECHNICAL INSTITUTIONS.

THE nineteenth annual general meeting of the Association of Technical Institutions was held on the 20th ult. at the Goldsmiths' Hall, London. Sir Henry F. Hibbert (the retiring president) presided at the opening of proceedings, and, in responding to a vote of thanks for his services during the year, he reviewed the work of the technical institutions throughout the country. Contrasting the work in this country with that accomplished in Germany, he expressed disappointment at the fact that England compared unfavourably with that country. Sir George H. Kenrick was unanimously elected president of the association for the ensuing year. In his presidential address on "Shall We Teach Trades?" Sir George Kenrick said it might be objected that this was a foolish question, because it was well known they did teach trades. That was correct in part, but they also taught many things that could not be described as trades, and the amount of trade actually taught at the present time was very small compared with the total instruction given, and his question really covered that very much larger question. Referring to the textile, iron and metal, chemical, engineering, building, and other industries, he asked if anyone could say that for the young people entering the industries there was anything provided in the nature of adequate training. In no industry did there appear to be any conception of the duty of the trade to make proper provision for filling its ranks with well-trained and capable workmen. The only way in which progress could be made was by such training. It was useless to expect the late discoveries in science to be applied to industries unless they had teachers who would make it their business to master these discoveries and explain them to the young people who were learning the trade.

He next referred to the practical work accomplished in Continental countries, especially Germany, and asked if it could be seriously asserted that we in England were so different in faculties and abilities from the Germans, that, while such a thing might be necessary for them, it was totally unnecessary for us. Great as was his faith in the ability of Englishmen to tackle all kinds of trades and business, he was confident they would succeed still better were they backed by the efforts of instructed and trained workpeople. As to how it should be accomplished, he would say "slowly." He felt it would take a great deal of instruction and persuasion before the British manufacturer would be thoroughly convinced of the necessity of what he was advocating. Progress must be made by the combination of the elementary and technical school. The technical schools had really been solving the problem for a number of years by finding the teachers the right kind of work for the students, and the workshops, and they were mostly waiting for tenants in the daytime. But the elementary school had much of the character that a technical day school would have, and the student would on the whole more closely resemble the elementary scholar than the evening scholar. Moreover, the elementary school would have charge of his training up to the period of entry into the technical school and should have prepared him to some extent for the particular occupation in which he might be engaged. It was therefore desirable that the two should combine and use their experience to solve the greatest of the large educational problems of the present day.

On the occasion of his retirement and in appreciation of his services to technical education, Mr. J. H. Reynolds, director of higher education to the City of Manchester and Principal of the Municipal School of Technology, Manchester, was presented with an illuminated address from the members of the association, the presentation being made by Sir Henry Hibbert.

Mr. W. Calderwood (Woolwich Polytechnic) and Councillor A. Trimble (Belfast) were elected governors, and Mr. T. T. Rankin (Wigan) and Mr. F. W. Shurlock (Derby) as officials. Mr. C. B. Bragg (Birmingham) was appointed chairman of the council. Principal F. W. Shurlock, Technical College, Derby, afterwards spoke on science examinations and grouped course certificates, while Principal W. M. Gardner, Technical College, Bradford, dealt with the function of the practical workshop in technical colleges.

THE BALANCING OF LOCOMOTIVES.—II.

BY JAS. DUNLOP.

To those interested in the modern 4-cylinder so-called "balanced locomotives," the outside 2-cylinder single-driver engine, illustrated in Fig. 10, should form a useful reference, especially when it is understood that the system of balancing embodied in the design was patented by J. G. Bodmer in

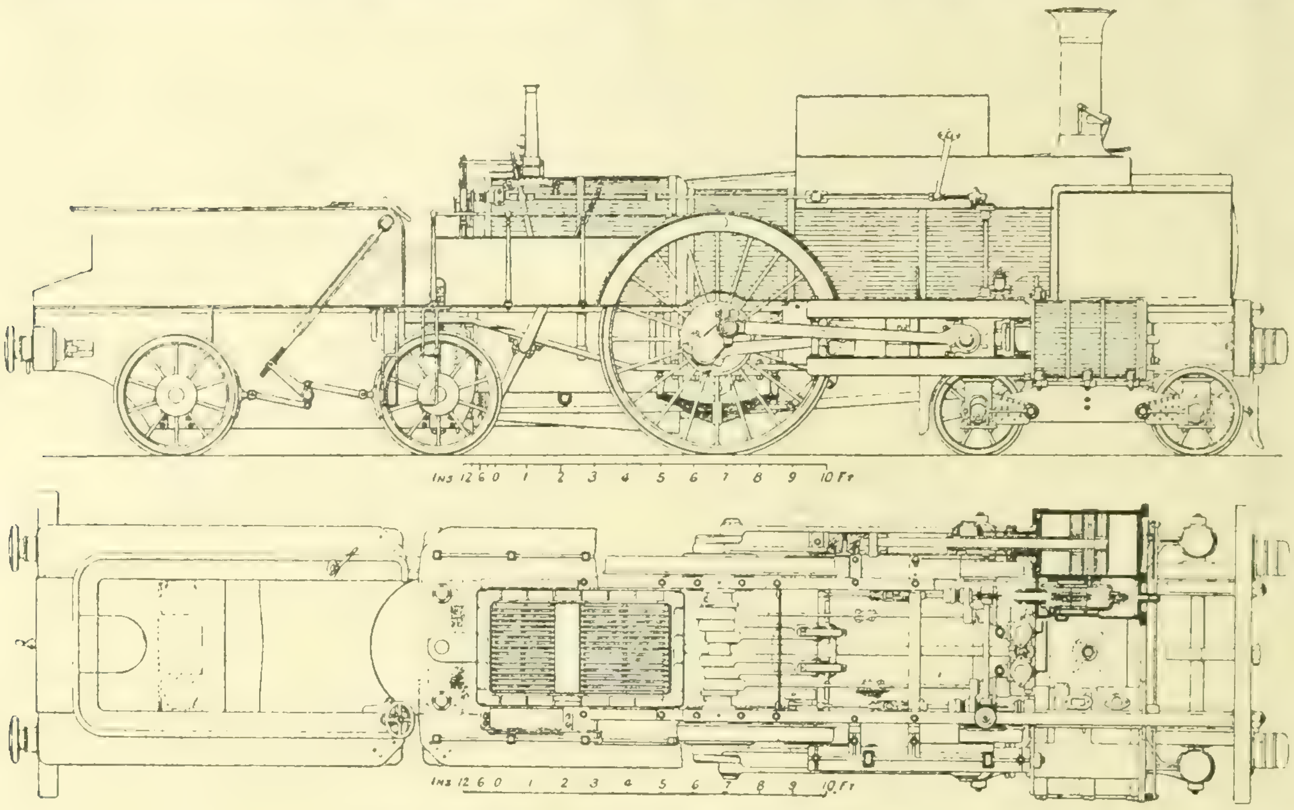


FIG. 10.—OUTSIDE 2-CYLINDER SINGLE DRIVER ENGINE.

the year 1834, and that a number of inside cylinder engines on this system were in use on the Sheffield and Manchester, the London and Brighton, and the London and South-Eastern Railways in 1845. Each cylinder had two pistons connected to cranks set at 180° apart, the piston rod of the front piston being solid and sliding inside the piston rod of the back piston, which was tubular and carried a stuffing-box at its junction with its crosshead. The slide bars were of V-shaped trough form, and the connecting rods were jointed to overhung pins formed on the crossheads, on opposite sides, to suit the length of the crank-pin bearings and the thickness of the overhung cranks. The steam was admitted alternately between and on the outer faces of the pistons, giving practically the effect of a 4-cylinder engine, and the intention of the whole construction was to make one set of moving parts balance the other set moving in the opposite direction without the necessity of using balance weights in the wheels.

From the fact that the pistons, piston rods, and crossheads move in opposite directions and in the same plane, it might appear to a casual observer that the object intended had been achieved, but such is not the case. In the first place, the connecting rods do not move in the same plane, consequently the inertia effects acting at different distances from the centre of the engine have a tendency to turn the engine around a vertical centre in opposite directions alternately. In the second place, the connecting rods are both on the forward side of the driving axle, so that while one rod is making a forward stroke the other rod is making a backward stroke, and a reference to Fig. 1 or to Tables I or II will show that even were the connecting rods moving in one plane there could not possibly be a mutual balance owing to the difference between the inertia effects on forward and backward strokes respectively. The weak feature of the design of these engines was the overhung crosshead pins, with the resultant cornering action on the crossheads and the bending action on the piston rods.

In Fig. 11, which illustrates an outside 4-cylinder single-driver engine, built by Haswell, of Vienna, for the Austrian State Railways in 1861, the weak feature of the previous engines is entirely eliminated, but it has no feature of superiority so far as balancing is concerned. The two cylinders on either side were served by a single valve admitting steam on the forward face of the top piston and the backward face of the bottom piston simultaneously, and the opposite alternately. The duplicate crosshead, slide-bar, and connecting-rod construction ensured there would be no unusual cornering or bending action such as took place in the previous engines, and to that extent the design may be considered superior, but considering the imperfection of the balance attained it does not appear that 4-cylinder single-driver engines were ever likely to justify their continued use.

Fig. 12 illustrates an outside 4-cylinder engine of no great interest from a balancing point of view, but rather from the fact that it is neither a single-driver, an independent driver, nor a coupled engine, although it has two driving axles. The peculiarity arises from the fact that it is a rack rail engine. The two cylinders on either side are served by one valve admitting steam simultaneously to the front or back faces of the pistons, and so causing the pistons to move in unison. The pistons are connected to independent driving axles in the usual manner, the driving axles having pinions gearing with the rack rail. Through the rack rail the engine is to all intents and purposes a coupled engine, but at unequally worn portions of the rack rail each pinion continues to do an equal share of the work, from the fact that the independent pistons need not move absolutely in unison so long as they commence and end their strokes at approximately the same times. Rack rail engines as a rule call for some clever designing, and this engine is certainly one of the cleverest. It was constructed by Messrs. Beyer, Peacock, & Co., Manchester, under the Lange and Livesey patent.

Fig. 13 illustrates an outside 2-cylinder single-driver engine with vertical cylinders, built by Messrs Carmichael, of Dundee, for the Dundee and Newtyle Railway in 1833. As a matter of historical interest the first locomotive built by the famous Manchester firm, Sharp, Roberts, & Co., was of almost similar construction, except that the driving axle was in front of the firebox, and a pair of carrying wheels were placed where the driving wheels are in the engine illus-

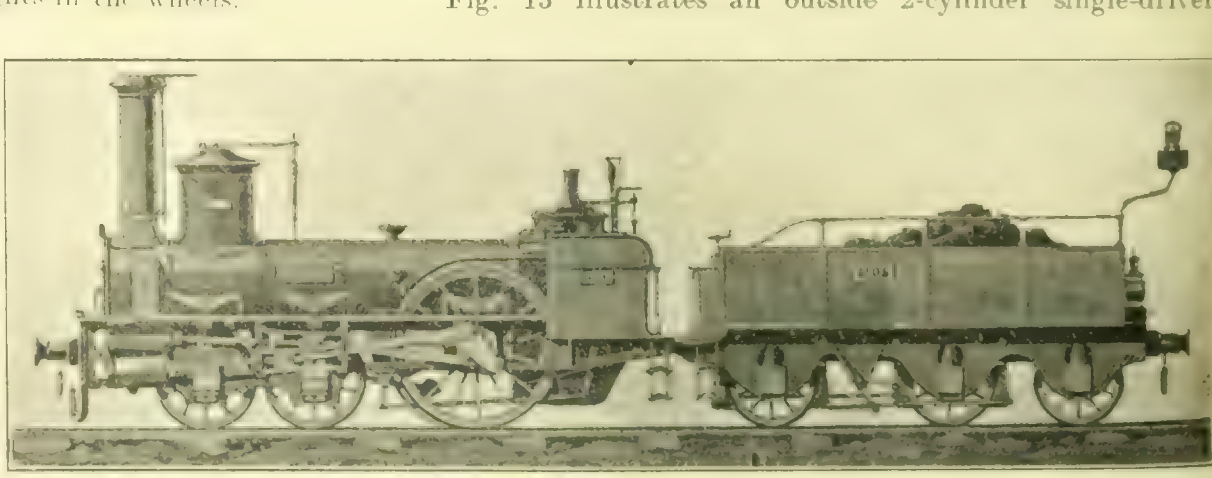


FIG. 13.—OUTSIDE 2-CYLINDER SINGLE DRIVER ENGINE.

trated. The placing of the cylinders vertically made it possible to have a fairly steady longitudinal movement, but the vertical inertia forces accentuated the rocking movements to such an extent that very few engines of this design were built. It may be noticed that, unlike ordinary types of engine, this engine transmitted its "hammer blow" to the rails through its springs. Also, any weight placed in the wheels to counteract the inertia forces would require to have been placed at right angles to the crank, and, consequently, would have at once upset the longitudinal balance. Further, it would have been effective in one direction only—the upward—and that through the springs, while in the downward direction it would have had its maximum effect on the rail direct. Had there been special reasons for the continued use of this type of engine the bell crank would have become a tee bob, and a weight placed on it to balance the vertical reciprocating parts.

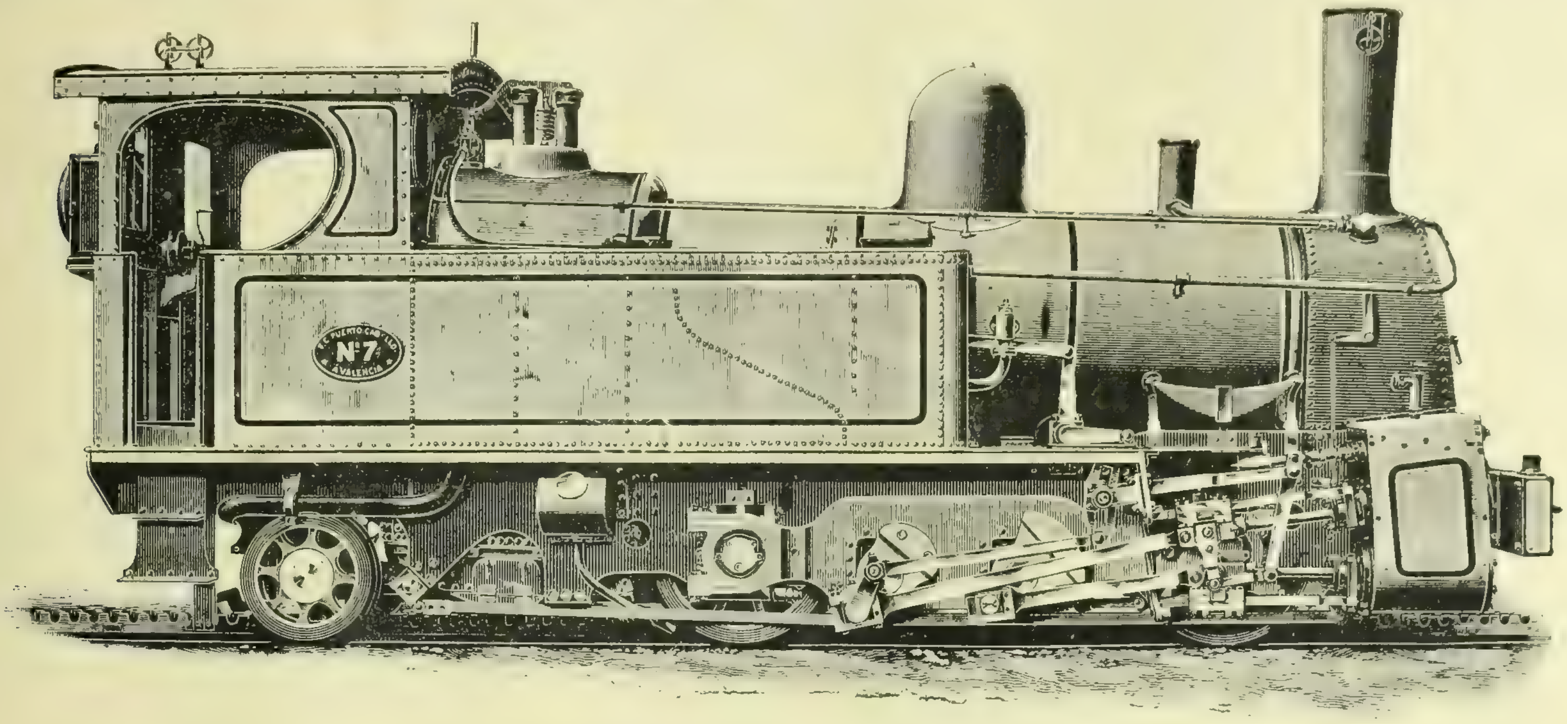


FIG. 12.—OUTSIDE 4-CYLINDER RACK RAIL ENGINE.

Fig. 14 illustrates a type of inside 2-cylinder single-driver engine in which the balancing is almost identical with that of a coupled engine. The cylinders are placed under the smokebox, and drive on to an intermediate crank-shaft placed in front of the firebox. Coupling rods from cranks on the ends of this crank-shaft operate the driving wheels placed behind the firebox. The coupling rod is not seen in the illustration, being hidden by the outside framing. This system of locomotive construction is known as the Crampton system, and was used to accommodate a longer boiler than was usual on locomotives at the period at which these engines were built. The longer wheel base thus made necessary resulted in these engines being comparatively stable in the longitudinal direction. Other constructions of the Crampton engines had the cylinders placed outside, in the position shown in the sketch Fig. 15. It was claimed for these outside cylinder engines that the particular position of the cylinders ensured a more stable engine than if they had been in the usual position outside the smokebox. That, of course, is not the case. In either position the centres of the cylinders would be the same distance from the longitudinal centre line of the engine, and give rise to the same turning moments around a vertical centre. The only difference between the outside-cylinder Crampton engine and an ordinary outside-cylinder single-driver engine, with its driving axle behind the firebox, was in the length of the wheel base, and as a result the Crampton engine, with its longer wheel base, could not be otherwise than the steadier engine.

The extraordinary single-driver engine illustrated in Fig. 16 is interesting chiefly from the facts of the abnormal upward inclination of its cylinders, that no provision whatever seems to have been made for balance, and that it drives through friction gear wheels. With regard to the latter, it is rather difficult to conceive any valid reason for their use at all, when a simple enlargement of the ordinary driving wheels would have met the case of high-speed better in every respect. As may be noticed from the illustration, the friction wheels are held in contact by a heavy spring, and that by a system of multiplying levers small steam cylinders can be used to increase the adhesion weight for starting purposes or for incline working. The cylinders being inclined upward at an angle of about 30° must have caused serious rocking movements, due to direct steam pressure reactions, in addition to all the effects of centrifugal force and inertia from the moving parts of a totally unbalanced engine.

Fig. 17 illustrates an extraordinary single driver engine that ran on the Great Western Railway in 1838. Its interest from a balancing point of view lies chiefly in the fact that the wheel base was extremely short, and unbalanced forces must have caused excessive movement of the flexible steam and exhaust pipe connections. The driving wheels were 10 feet in diameter. In addition to being short of adhesion weight, and consequently unable to haul the trains it was intended to, the pipe connections proved troublesome from the fact that the coupling between the engine and boiler carriages being of the simple link form could not control their relative movements as in modern articulated engines. For these reasons the engine was laid aside after an accident to its large driving wheels.

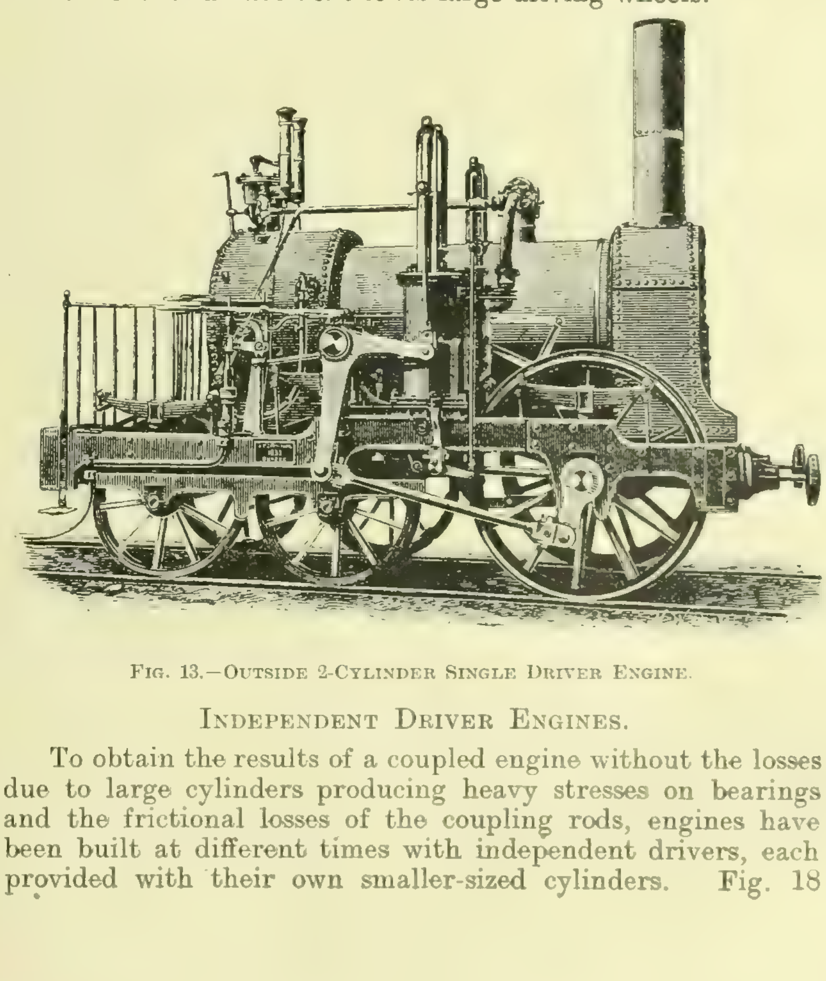


FIG. 13.—OUTSIDE 2-CYLINDER SINGLE DRIVER ENGINE.

INDEPENDENT DRIVER ENGINES.

To obtain the results of a coupled engine without the losses due to large cylinders producing heavy stresses on bearings and the frictional losses of the coupling rods, engines have been built at different times with independent drivers, each provided with their own smaller-sized cylinders. Fig. 18

illustrates an outside-cylinder independent-driver tank engine built for the Northern Railway of France in 1862. For balancing purposes each pair of cylinders and driving wheels would be treated as an ordinary single-driver engine, but the running of these engines gives rise to certain peculiar results. In the illustration it will be noticed both cranks are in their bottom positions. In moving from these positions in either direction the two pistons will move together towards either the front or back end of the engine, thus combining their inertia effects and so producing a certain longitudinal disturbance. If on the other hand one of the cranks had been in its top position while the other was in its bottom position, then the pistons would move in exactly opposite directions to each other whichever direction the engine moved in, and as a result the inertia effects would mutually balance each other, thus, under the circumstances, rendering the balance weights for the reciprocating parts entirely superfluous. For the time being there would exist the contradictory condition of practically perfect balance of the reciprocating parts along with "hammer blow" from the balance weights for these parts. Throughout the whole running time of independent-driver engines of this type, either from "slipping" or "creeping into or out of phase," this peculiar passing from one extreme of balance to the other takes place. The action is entirely spasmodic, and is only controllable by coupling rods.

Fig. 14.—Crampton Inside 2-Cylinder Single Driver Engine.

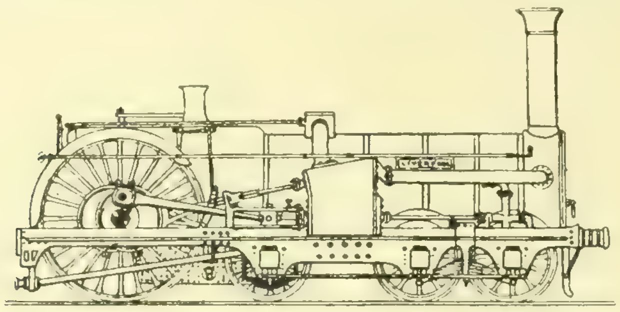


Fig. 15.—Crampton Outside 2-Cylinder Single Driver Engine.

An outside-cylinder independent-driver engine, in which the cylinders are all placed in the usual position outside the smokebox, is illustrated in Fig. 19. In this case the independent driving wheels are much different in size, the object being to obtain a powerful starting effort from the small drivers. In fact, at starting and during incline working are the only times the small drivers are in operation. At all other times they are lifted clear of the rails by steam cylinders. These steam cylinders also serve to force the small drivers on to the rails to give the necessary adhesion when required and at the same time temporarily increase the adhesion of the large drivers. For both drivers the balancing is the same as for an ordinary single-driver engine. The difference in the diameters of the drivers, as well as the intermittent use of the small drivers, makes the peculiar effect noted in the previous engine of comparatively less account.

The independent inside and outside driver engine illustrated in Figs. 20 and 21 is a 3-cylinder compound engine on the Webb system, introduced on the London and North-Western Railway in 1882. Two outside high-pressure cylinders operate the trailing drivers, and exhaust to a central inside low-pressure cylinder which operates the leading drivers. Although in many quarters adversely criticised, both as regards its arrangements and details, it was this engine that in reality pioneered the modern developments in 3 and 4-cylinder locomotives in both hemispheres. Previous to the introduction of this engine, the engine illustrated in Fig. 18 was probably the only independent-driver engine that had ever been built, and it was not repeated in any numbers.

The balancing of the hind drivers was the same as for an ordinary outside single-driver engine, while for the front drivers all that was necessary was a balance weight in each wheel directly opposite the crank equal to half the amount of weight to be balanced.

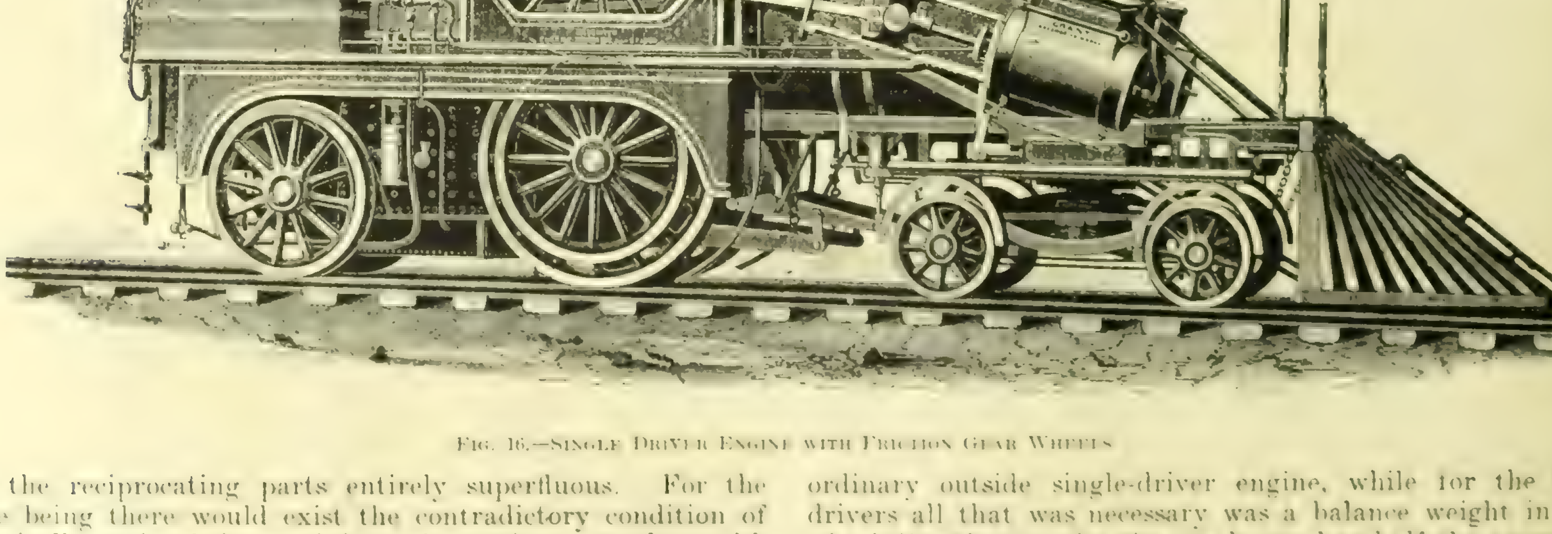


Fig. 16.—Single Driver Engine with Friction Gear Wheels

As in the case of the French engine, this engine suffered

from a spasmodic disturbance in the longitudinal direction, but in this case the disturbance, instead of waxing and waning on both sides of the engine simultaneously, zigzagged from side to side according to the particular outside crank that happened to "phase or not phase" with the inside crank. This action was so pronounced as to excite widespread comment by engineers who travelled in the trains hauled by these engines, but strange to say it was always attributed to the steam action in the single low-pressure cylinder, the inertia effects never apparently having been thought of.

In any case, four years later—in 1886—M. Alfred de Glehn designed the forerunner of the famous Northern Railway of France 4-cylinder compound locomotives as an independent-driver engine, as illustrated in Fig. 22. This engine was subjected to exhaustive tests, with the result that all succeeding engines were provided with coupling rods between the drivers in addition to the other modifications in the steam system experience had dictated. One important modification was the placing of the low-pressure cylinders inside the frames. The significance of this from a balancing point of view will be appreciated from later demonstrations of balancing problems. It may be said that so far as the Continent is concerned, this engine was the means of initiating that careful attention to balancing so plainly

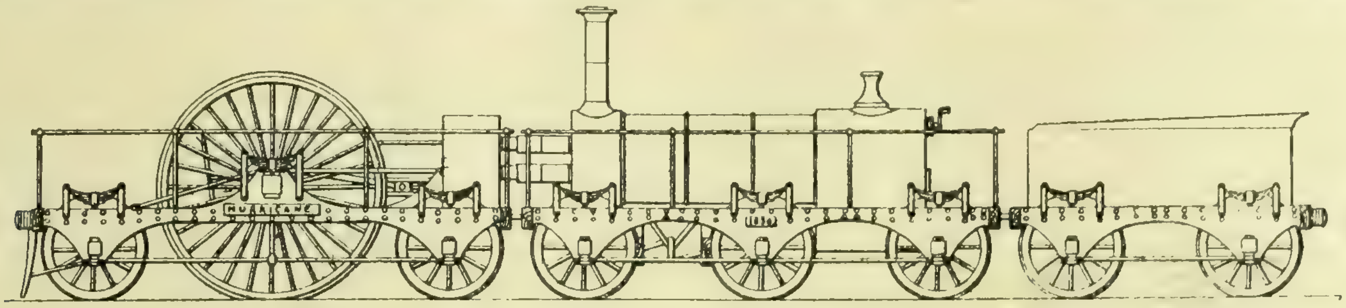


FIG. 17.—SINGLE DRIVER ENGINE

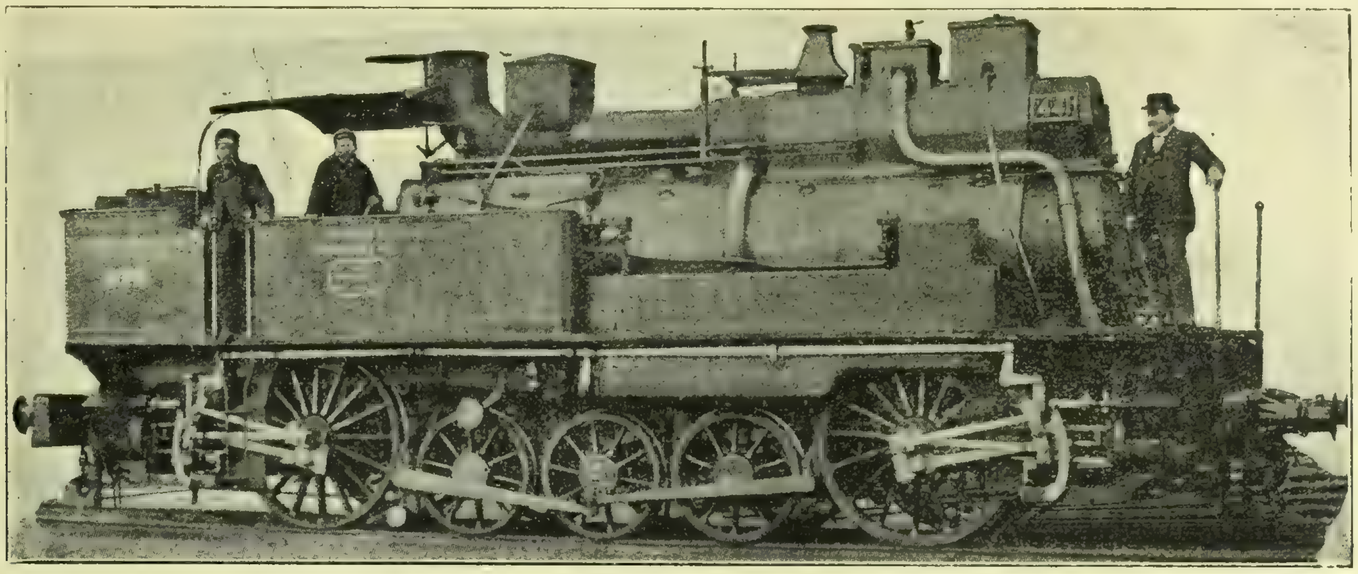


FIG. 18.—OUTSIDE CYLINDER INDEPENDENT DRIVER TANK ENGINE.

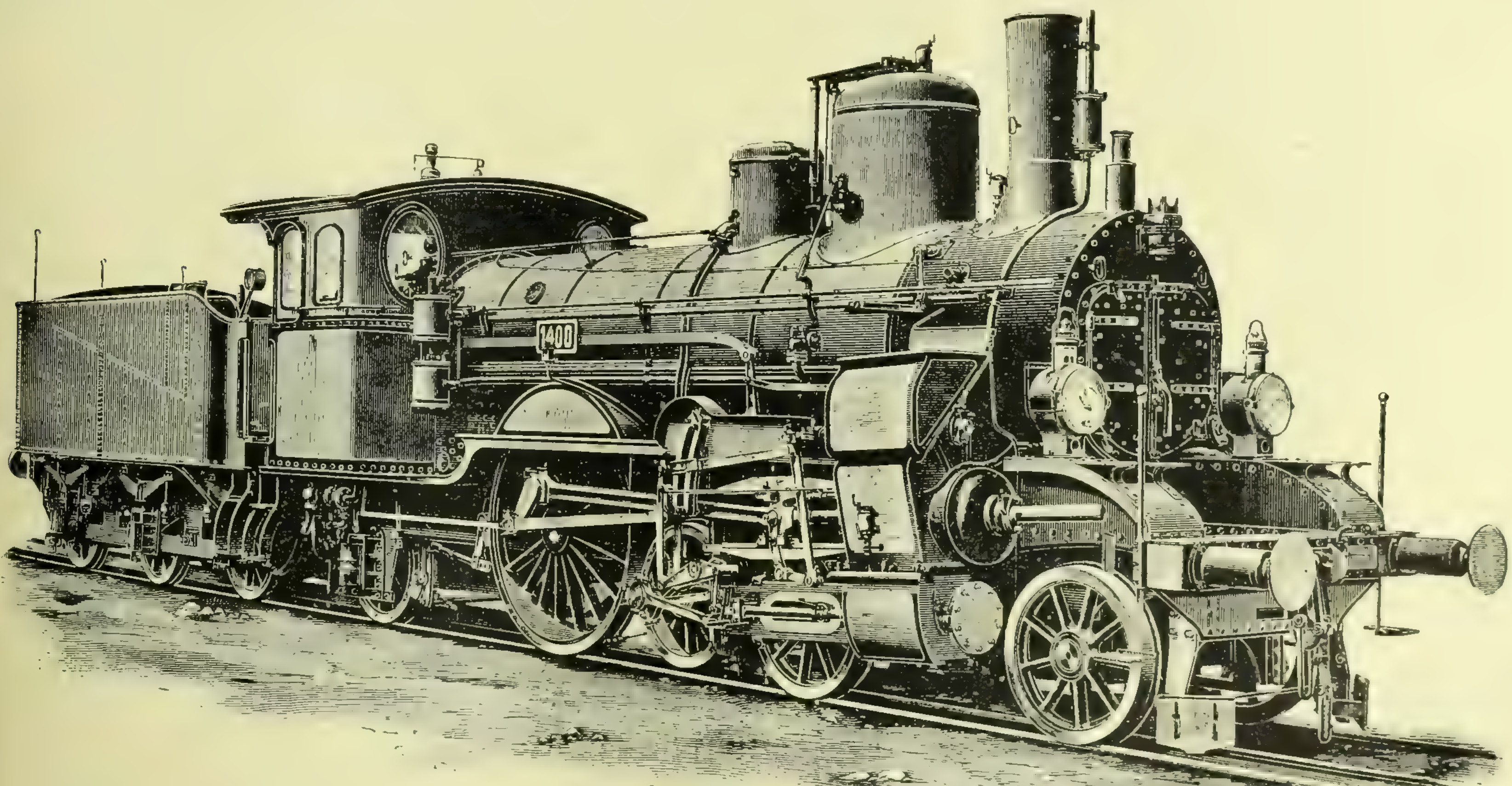


FIG. 19.—OUTSIDE CYLINDER INDEPENDENT DRIVER ENGINE

evident on all modern continental locomotives. British practice relatively is where it always has been.

In 1898 Mr. Dugald Drummond introduced on the London and South-Western Railway the powerful these independent-driver 4-cylinder engines the left-hand crank on one of the axles had been made to lead the "in and out of phase" effects noted would have been considerably minimised.

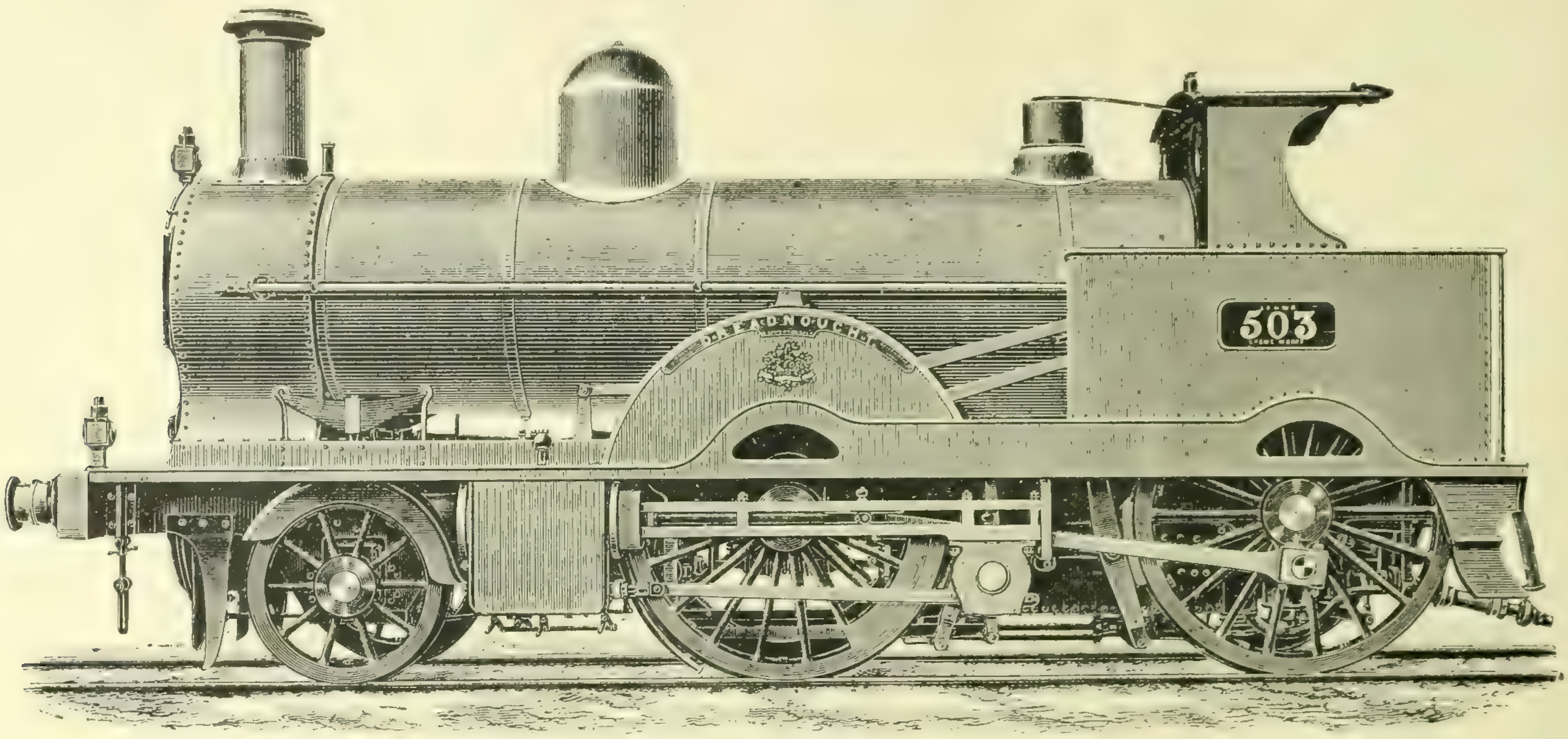


FIG. 20.—INDEPENDENT INSIDE AND OUTSIDE DRIVER ENGINE.

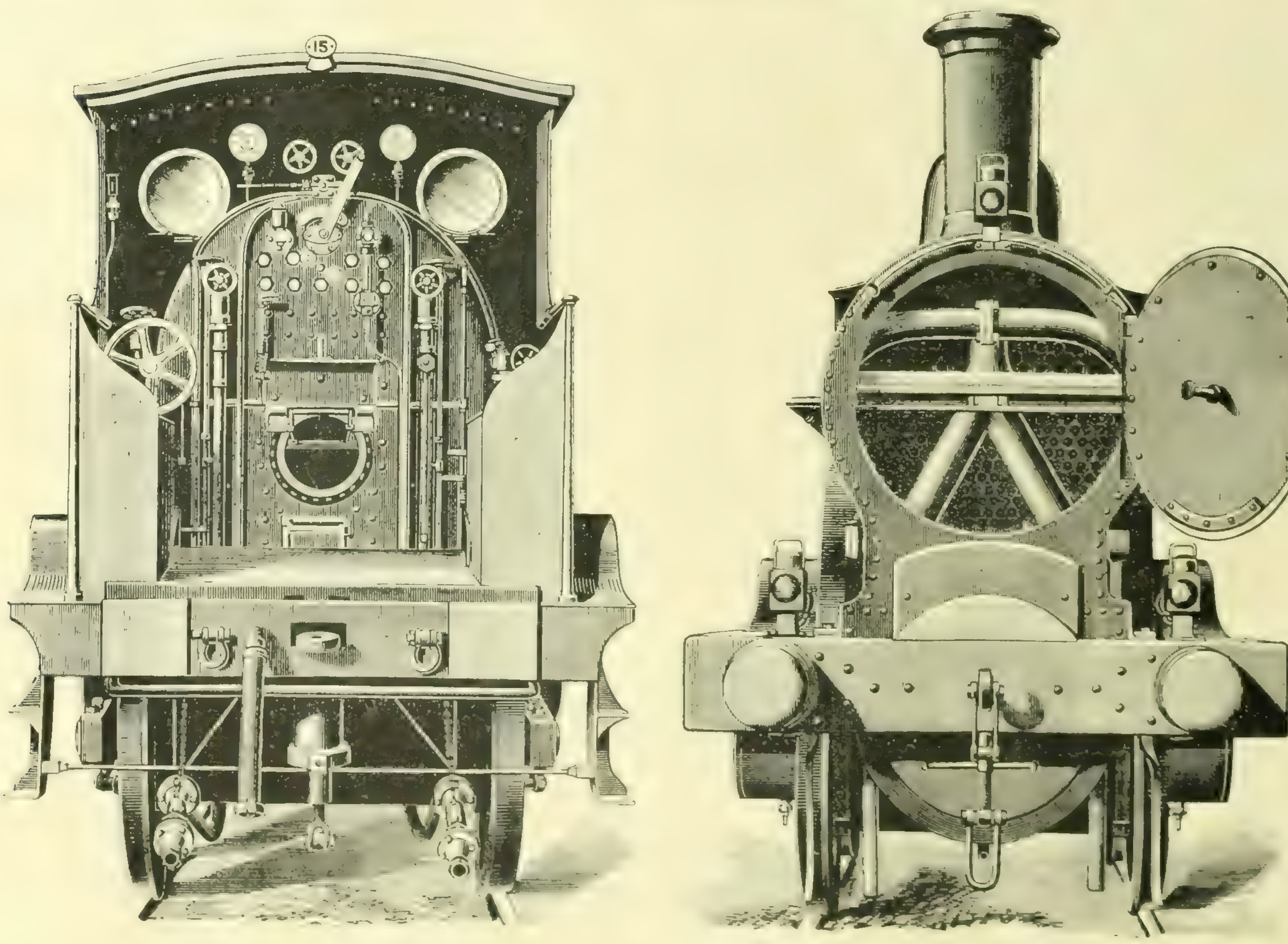


FIG. 21.—INDEPENDENT INSIDE AND OUTSIDE DRIVER ENGINE.

4-cylinder independent inside and outside driver engine illustrated in Fig. 23. The engine is a single-stage expansion engine using high steam pressure, Mr. Drummond being the pioneer in this country of high steam pressures in locomotive practice. To what extent the "in and out of phase" effect was noticeable in this engine the writer has not heard, but the later 4-cylinder engines on this railway have coupling rods.

It may be of interest to note here the usual practice is to make the right-hand cranks lead in forward running. If in

WORM AND SPIRAL GEARING.*

WITH SPECIAL REFERENCE TO MACHINE TOOL DESIGN.

BY W. HAUGHTON.

IN spur gearing the formulæ have become so simple and familiar that they present very few difficulties to any who will give the most rudimentary attention to them. Worm and spiral gearing cannot by their very nature be made to appear quite

* Abstract of paper read before the Basingstoke Association of Mechanical Engineers, February 3rd, 1912.

so easy and plain, so many factors come into the problem. In the case of spur gearing it is quite easy to say that a certain wheel of a given pitch will be such and such a diameter, the diametral pitch method having made that simple mental arithmetic. Although spiral wheels cannot be so easily dealt with, I think that much may be done to render the calculation easier and with less liability to error. The difficulty most people find is that the mind is apt to get the various factors of angle tangent, cosine, normal pitch, real pitch, pitch or lead of spiral, and diameter rather mixed up, and so get out of patience with the whole matter and turn to some other form of gear less bothering to work out. I know that this tendency exists among many draughtsmen, and it is very likely the reason why worm drives are not more extensively used.

There are various types of worm wheels, and for a long time their construction was exceedingly simple. The most common practice was to cut the teeth in a straight line diagonally across the periphery of the wheel at an angle corresponding to that of the worm in which it has to mesh. This

Under the impression that it is necessary to increase the wearing surface upon the teeth of worm wheels, it has become increasingly the practice to make the face of the teeth hollow with a radius corresponding to that of the bottom of the worm thread and to hob the teeth. This form of tooth has no doubt a very attractive appearance, as it looks somewhat like a true section of a nut thread, and without doubt it has a greater wearing surface than either of the foregoing types, but whether this increased surface is not obtained at the expense of efficiency may be open to question. One effect of the hollow shape is for the teeth to become thin upon the highest points. It is well to turn these edges off and leave a considerable flat upon either side of the hollow. Some designers prefer to dispense with the hollow altogether at the top of the teeth and simply to sink the hob into a flat surface to the depth of the teeth at the centre ; it is claimed for this that it is cheaper to turn, easier to hob, and is in every way satisfactory, besides reducing unnecessary friction upon the teeth. In the hobbed type of worm wheel, it is of the utmost importance

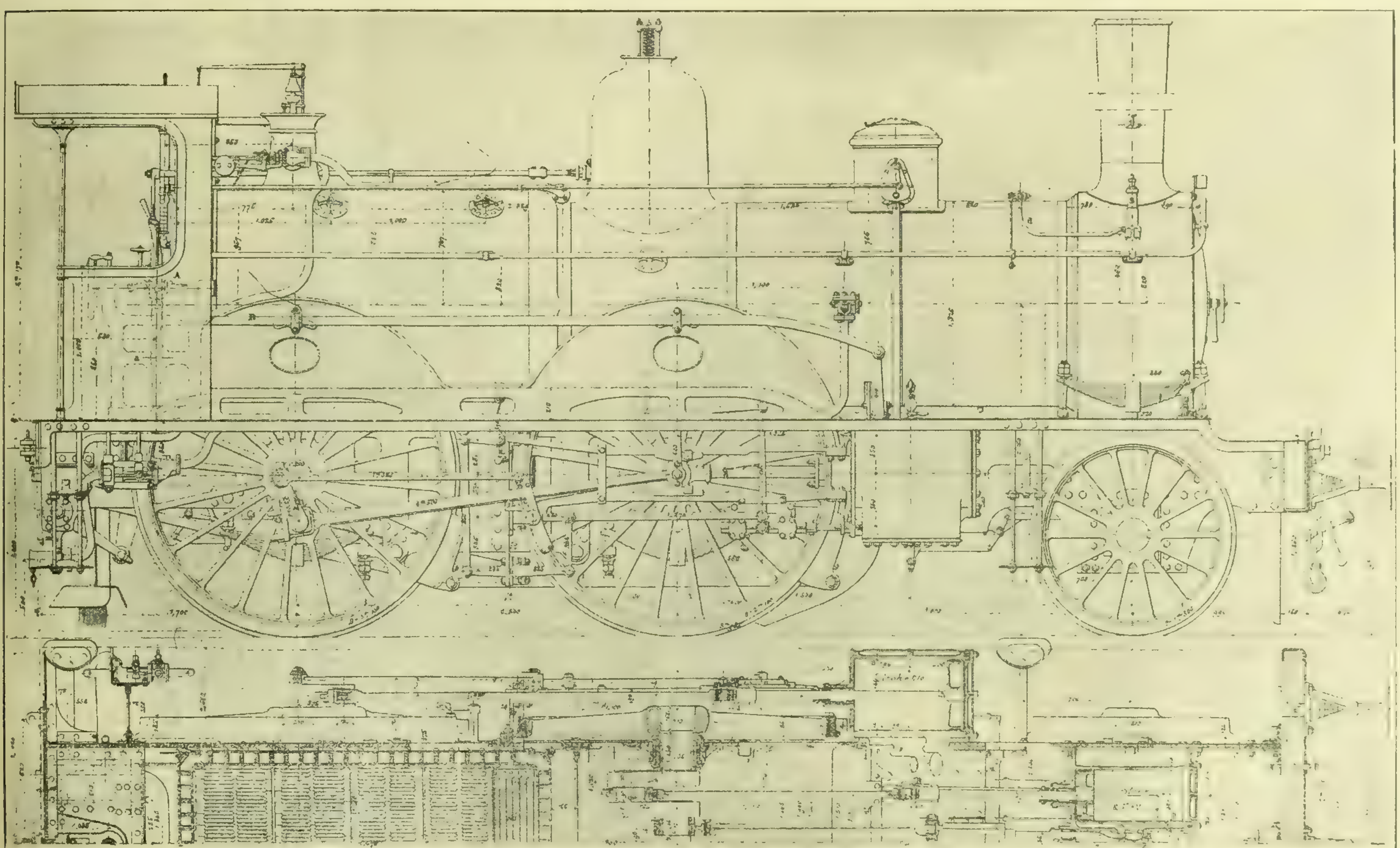


FIG. 22.—4-CYLINDER COMPOUND INDEPENDENT-DRIVER ENGINE (see page 255).

form of wheel was and is perfectly satisfactory for many purposes, especially in cases where the angle is but small and the power transmitted not great. It is the cheapest and easiest way for those who have few machines at their disposal. Theoretically, of course, it is wrong, as it is a straight surface working upon a spiral, but nevertheless it is a perfectly satisfactory method for many purposes and should not be too lightly set aside as out of date. I have no doubt many of you can recall cases in which such wheels have been in operation for 10, 20, or 30 years, and are still performing their functions quite satisfactorily and are by no means worn out.

A very much better worm wheel of a similar design to the above would be obtained by cutting the teeth a true spiral angle corresponding to the worm angle. This type of wheel would be inexpensive to cut upon a properly equipped machine, as no holes are required. Holes are a very expensive item in worm-wheel cutting, and it is well to avoid using them unless the conditions make it absolutely necessary. There is little doubt that this form of worm wheel would be very efficient. The loss from friction would be small and the worm would work very smoothly.

that it should be mounted centrally with the worm ; a very little out of centre at either side will cause a very considerable loss of efficiency and may speedily wear out the teeth. In hobbing these wheels it is well to have the hob somewhat larger in diameter than the worm, in order to ensure that the bearing of the worm thread shall be hardest in centre of the teeth. It is obvious that a worm that is rubbing hardest upon the wheel is setting up a wedging action and is causing an undue amount of side thrust upon the wheel.

Another form of worm drive is that in which a worm or spiral toothed wheel is engaged in the teeth of a rack. A notable example of the successful application of this principle is known as the Sellers worm drive for planing machine tables. In this case the rack of the table is propelled by a spiral pinion, and it is said to work most smoothly, seldom to wear out, and to be vastly more efficient than a screw or nut drive. Some years ago I met with a case in which the saddle of a radial drilling machine was moved along the arm by means of a spiral rack pinion with the teeth at 45 angle. It was very noticeable that for smoothness of motion and absence of backlash this was distinctly better than straight teeth, and this in

spite of the fact that the rack's teeth were cast and not machine cut. These instances seem to point to the inference that the hollowed face in worm wheels, whatever advantages they may have on account of increased wearing surface, are certainly less efficient transmitters of power than where the teeth are simply cut spirally across the face of the wheel. At the present time there is a sort of fashion to hob teeth, hobbing being pointed to as a panacea for all the ills worm wheels are subject to. There is no doubt a great deal to be said in favour of hobbing the teeth, one important advantage being the generation of the proper curves to the teeth, but in view of the recognised waste of power which can take place in screw section, it might be well to see whether after all a spirally-cut tooth minus hobbing would not wear all right if made of suitable materials. It would certainly waste far less power and can be produced more cheaply.

Still another form of worm drive is that known as spiral or skew gear. The question is often asked, "when does a worm wheel cease to be a simple worm wheel and become a spiral wheel?" Strictly speaking, of course, all worm wheels are spiral wheels, and all spiral wheels worm wheels. The same principles govern the construction of both types, but in what are commonly understood as worm wheels the worm is usually considerably smaller in diameter than the wheel, though it may, in fact, be any diameter, as the principal factor in the calculation is the number of threads per inch of the the wheel in each case. Spiral wheels are very efficient as power transmitters, as they lose comparatively little in friction.

The foregoing types are all for cases in which the axis of the worm is at right angles with that of the wheel. There is another type in which the axes are parallel with each other. These are known as helical or herringbone wheels, the object of the spiral form of tooth being to secure silence and smooth running, and in this particular they are very successful. The teeth being spiral, the backlash is very quietly taken up and a kind of gliding motion is got which secures an absence of shocks, another advantage being that a pinion of a smaller number of teeth than is practicable with spur gearing can be used. Of late it has become practicable to cut the teeth of helical wheels, even the double wheels now being made with machine-cut teeth.

The purposes for which worm and spiral wheels are adaptable are very numerous, and this is particularly so in the case of machine tools. They are the most convenient form of right angle drive where a large purchase is required that can be found, being simple and direct and having the capacity for a great range of either speed or power ratio. A use to which spiral wheels might be put to with advantage very much more than they are is for speed increase, especially for cases where the principal need is for speed rather than power. It takes quite a number of pulleys and belts to get much increase of speed,

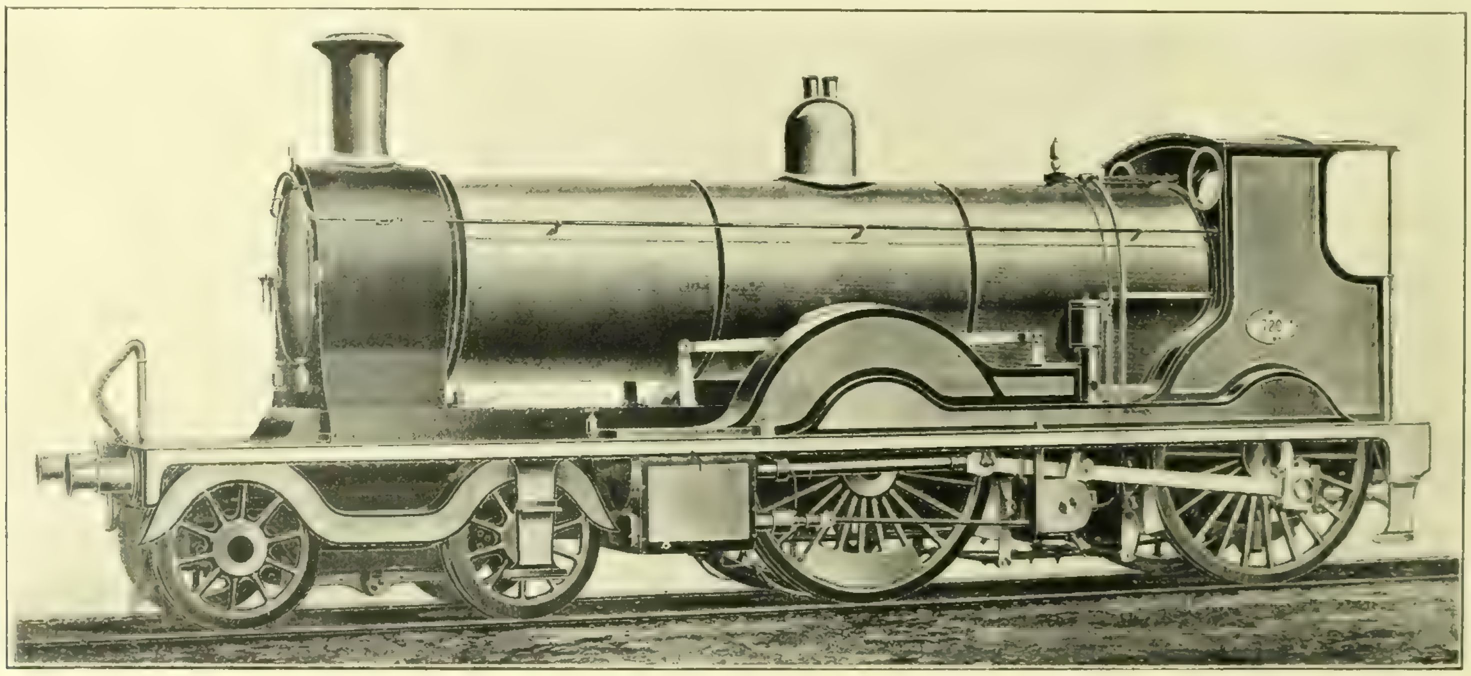


FIG. 23.—4-CYLINDER INDEPENDENT INSIDE AND OUTSIDE DRIVER ENGINE. (See page 256.)

worm. The diameter will, of course, affect the angle of the teeth across the wheel face. It may be single, double, triple, or even quadruple threaded and still retain its characteristics as a worm, though as the number of starts increase it may be said to become transformed into a spiral wheel and will necessitate similar methods of calculation to those essential in spiral wheels. In spiral gears the basis of the calculation is the spiral angle of the teeth. A pair of spiral wheels may be equal in diameter, and yet one may have double, treble, or more times as many teeth as the other, but as the ratio of the number of teeth increases, the first motion spiral merges into a simple worm and the gear may be considered as nothing more than a worm and wheel, the only difference being that the worm is unusually large in diameter. Spiral wheels of equal diameter are very commonly used, a familiar case being the two to one drive for gas-engine valve motions. It is also common to have a pair of spiral wheels of equal diameter and an equal number of teeth; these, of course, have an angle of spiral of 45° in both wheels, and the lead of the spiral is equal to the circumference of the wheels upon the pitch line. Cases occur in which the two to one ratio is preserved, but the first motion wheel is larger in diameter than the second, perhaps to meet the exigencies of an extra-large shaft. This simply involves an alteration of the angle of the spiral pitch. In the case of the two to one wheels of equal diameter the necessary angles are 63° 26′ for the first motion wheel and 26° 34′ for the second motion wheel, these angles being taken from the axis of but in one pair of spiral wheels is contained the possibility of a very considerable ratio of speed increase within a very small compass. In machines such as a boring machine, where the drive is at right angles, spiral gearing seems to be the natural drive, also in cases such as a planer type milling machine; but for some reason not very apparent their use is avoided and a superfluous pair of bench or mitre wheels are put in, which in turn drive a spur pinion and wheel—a rather roundabout way of transmitting power, which the use of a simple spiral pinion and wheel would avoid.

A comparatively recent use for worm gearing is in speed-reducing attachments for electric motor drives. The manufacturers of these are evidently not afraid of the bogey of inefficiency so often held up as a warning against worm gearing. This matter of efficiency has been perhaps the most potent of the objections to the more general use of worm gearing. No doubt with worm gearing the loss of power in friction is a very considerable factor, but experience and experiment has proved this fault to be easy to remedy. Modern well-designed worm gearing is now at least as efficient as the best spur gearing. Some years ago an investigation was made into the question of efficiency. A number of different cases of worm drives were investigated, and one most important fact was brought out. This was that great loss of efficiency was in every case a characteristic of the worm wheel which had a small spiral angle, say, below 8° or 10°. This was a surprise to most people interested in the subject, so the contrary had hitherto been thought to

be the case, probably because it was natural to suppose that the condition which gave the greatest mechanical advantage would also give the best efficiency. However, the mechanical text-books now tell us that the efficiency of worm gearing increases with the increase of angle of spiral up to 45°. In the "American Machinist" of June 18th, 1910, an article appeared written by Mr. S. H. Libby concerning some tests made upon electric hoists. In this case the drive was by means of a pair of spur wheels behind a worm and wheel. To make a comparison the gear was first tried in combination, and then the spur gearing and worm gearing each separately, and it was found that the loss of efficiency was actually greater in the spur gear than in the worm gearing. Another important fact which he mentioned was that when they substituted a double thread worm for a single thread that it increased the angle of spiral from 8° to 16°; the net efficiency of the worm and wheel was increased from 82 to 92 per cent. He also said in concluding his article that they had found that the worm drive of their hoist became more efficient after a few months' wear. The worm drive became more efficient, but the spur gear did not.

Now with regard to the special characteristics of worm-drives—the advantages and disadvantages. In the mechanical world one great desideratum is to perform work with a minimum of noise or vibration. Among the silent transmitters of power may be prominently placed the belt-drive with an absence of gear wheels, and then if the belt-pull is insufficient the next thing is a combination of belt-drive with worm or spiral gear, or an electric motor connected to worm or spiral gearing. I think I am safe in saying that worm-gearing is at once the most powerful and the quietest mechanical agent known to machinists. It is most convenient in application, and has the great advantage of yielding a large variety of ratios of purchase or mechanical advantage within a small space. In one pair of wheels, ratios of 1 to 1 or 1 to 100 may be obtained without excessive diameters. To obtain similar ratios from spur-gearing, double, triple, or quadruple gears would be required. Consider for a moment what even a 20 to 1 ratio means with spur-gearing. To get it with one pair of wheels the size becomes prohibitive, and the multiplication of wheels means increase of friction and consequent loss of efficiency, and moreover an increase of the noise in the running; but worm-gearing is said to be inferior to spur-gearing in the fact that the contact of the teeth is a sliding motion, whereas the teeth of spur wheels are supposed to roll upon each other. That is the theory, but there is a doubt about this rolling motion, and it is open to question whether after all the motion is not a sliding one. Brown and Sharpe in their "Treatise on Gearing" say: "There is no such thing as pure rolling contact in the teeth of wheels, as they always rub, and in time will wear themselves out of shape."

Among the disadvantages of worm wheels is said to be the considerable loss of efficiency due to the excessive friction upon the teeth, and to the end thrust upon the shaft or bearing. Worm wheels are said to wear out very quickly, and consequently to add to the expense of upkeep. With regard to the question of loss of efficiency, I think experience has disposed of that objection, as in practice efficiencies of from 90 to 95 per cent. are obtained with properly designed wheels and when suitable arrangements are made for taking the end thrust. In making comparisons the fact is generally overlooked that loss of efficiency is not peculiar to worm wheels, but may apply in an equal degree to spur wheels; indeed, so much is this the case that of late an attempt is being made to improve the efficiency of spur wheels by shortening the teeth, thus reducing the rubbing surface upon the teeth. Wheels are now being made in which the depth of the teeth is taken from the pitch below that which is being cut; for example, a 4-pitch wheel would have teeth of only 5-pitch depth. This is said greatly to assist in making the wheels run silently.

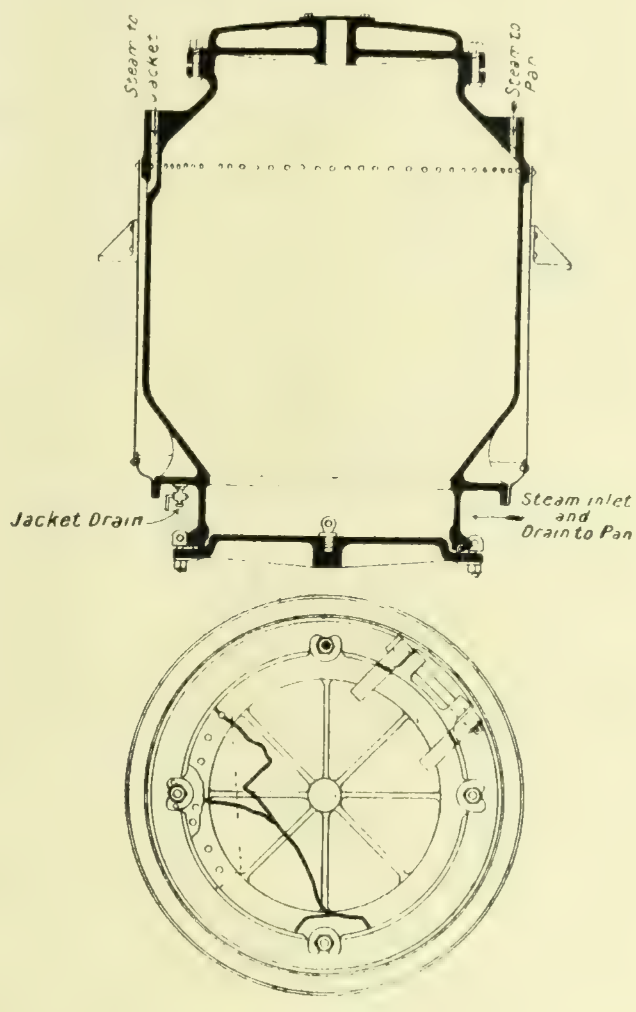
(To be continued.)

Visit of Royal Agricultural Show to Manchester in 1916.—At the meeting of the Manchester City Council held last week, the Lord Mayor announced there was every probability the Royal Agricultural Show may be held in Manchester in 1916. Correspondence which had taken place between the municipal authorities and the Society respecting pecuniary guarantees was read and a resolution of approval was passed.

CAST-IRON STEAMING AND BOILING VESSELS.

ALTHOUGH cast iron is not used now as extensively as it formerly was in the construction of vessels containing fluids and subject to internal pressure, many are, owing to their peculiar shape, still made, in whole or in part, of this material. Owing to the comparatively low pressures at which such apparatus are usually worked, inadequate attention is often paid to their design, and hence failures of them provide subject matter for many of the Board of Trade reports issued under the Boiler Explosions Act. Some of these are instructive, and for the benefit of makers and users we reproduce the leading particulars of several that have been recently published.

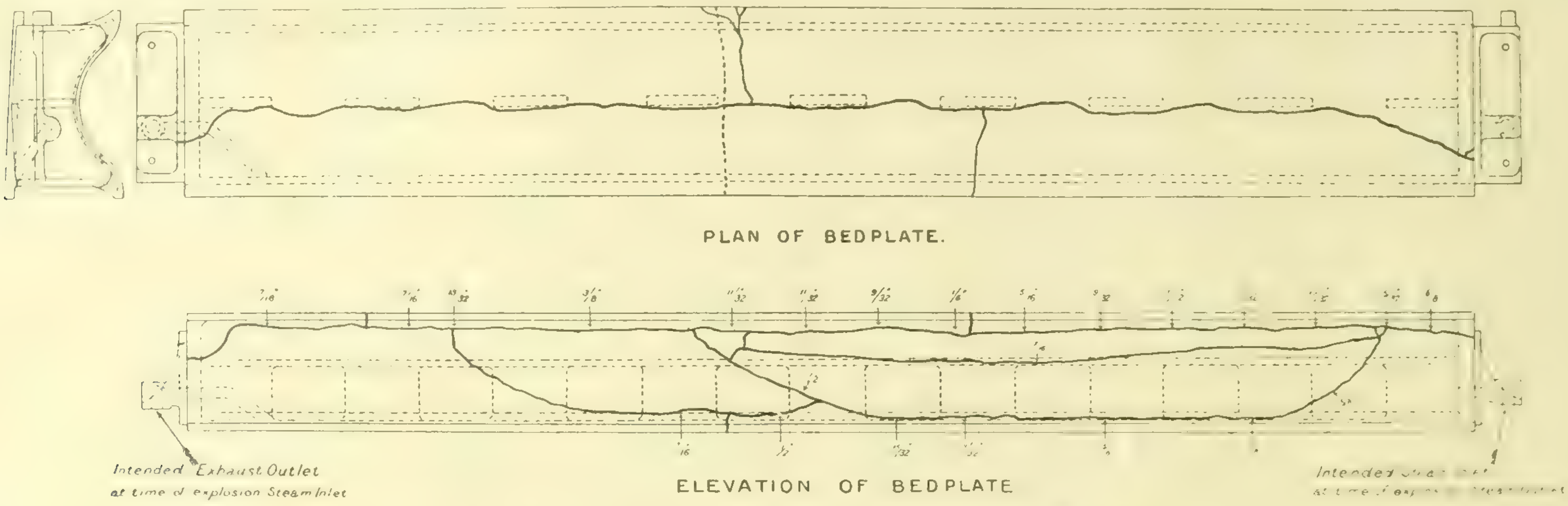
The first case (Report No. 2,077) deals with the blowing off of the lid of a digester at a chemical works at Moss Park, Dumfries, on August 16th last. The apparatus consisted of a cylindrical cast-iron vessel about 4ft. 9in. diam., and 3ft. 9in. in length, surrounded with a steam jacket. It was fitted with a cast-iron door at the bottom, 2ft. $10\frac{1}{2}$in. diam., by $1\frac{1}{4}$in. thick in the body. There was a boss 4in. diam. in the centre, from which radiated eight stiffening ribs, $\frac{7}{8}$in. thick, and the



REPORT NO. 2,077.—VERTICAL SECTION AND PLAN OF BOTTOM OF DIGESTER SHOWING FRACTURED DOOR.

door was held in position by four hinged bolts, $1\frac{3}{8}$in. diam. Steam to the digester was supplied from a locomotive type of boiler, working at 70lbs. on the inch; and the digester was supposed to work at about 40lbs., but the vessel had no safety valve, pressure gauge, or reducing valve, and if the pressure rose in the steam supply boiler over 40lbs., the engineman merely regulated "the steam inlet to what he thought would give not more than 40lbs. in the digester." This obviously was pure guess work, and as the door was unable to bear the pressure in the supply boiler, its failure only awaited the chance arrival of a time when the engineman was wrong in his estimate. It came at length, with the result that the digester was torn from its fastenings, and hurled to a distance of over 40ft., damaging part of the roof of the works in its flight, and severely injuring a workman who was near. In commenting on the case, the report states that the digester was not insured, and also that "great blame attaches to the owners for allowing it to be worked in such a highly dangerous condition."

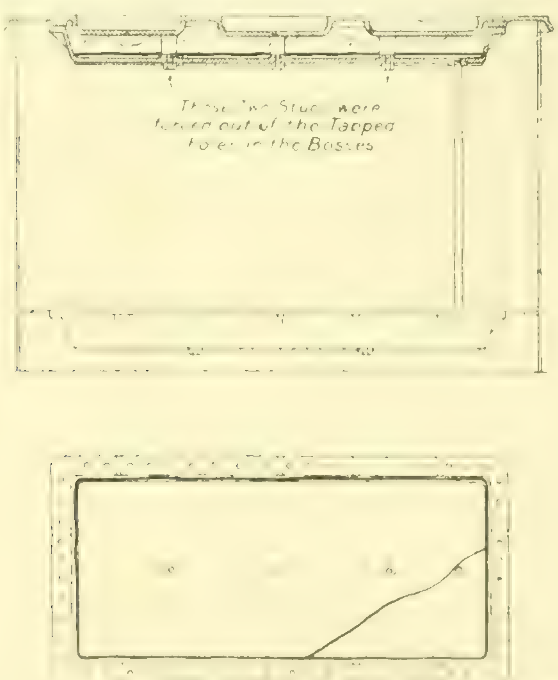
Report No. 2,083 refers to the bursting of a steam-heated calender at a laundry at Cambuslang on September 1st last. The calender consisted of a cast-iron frame about 9ft. long, 16in. wide, and from 6in. to 10in. deep, stiffened at intervals with vertical webs, and the thickness varied from $\frac{1}{2}$in. to $\frac{7}{8}$in., as shown in the accompanying sketch showing lines of fracture. The working pressure was 80lbs., and the makers are stated to have tested the vessel by hydraulic pressure to double this amount. Owing to a mistake, the steam and exhaust heating was supplied from boilers working at 50lbs. on the inch, but was reduced to 8lbs. at the steam table by means of a reducing valve. There was a pressure gauge to indicate the reduced pressure, and also a safety valve on the supply pipe between the reducing valve and the table, but this was found afterwards to be loaded to 20lbs., while the pressure gauge was out of order, and only indicated 10lbs. when the pressure was actually 20lbs. After the failure it was found that the reducing valve had stuck fast, and allowed a higher



REPORT No. 2,083.—VIEWS OF STEAM-HEATED CALENDER SHOWING FRACTURES.

pipes were wrongly connected, in consequence of which the chest could not be properly drained, and the report expresses the opinion that "water-hammer" was the primary cause of the explosion, though the uneven thickness of the casting due to the shifting of the core in the mould contributed to its weakness. It is pointed out that there was no relief valve on any part of the apparatus, and the operators working the machine had to judge the pressure and temperature by results, and, as in the last case, regulate the inlet valve by guess work, instead of being guided as they so easily might have been by a thermometer and pressure gauge.

Steam under pressure is often used to heat flat surfaces in connection with cooking apparatus in hotels and public institu-

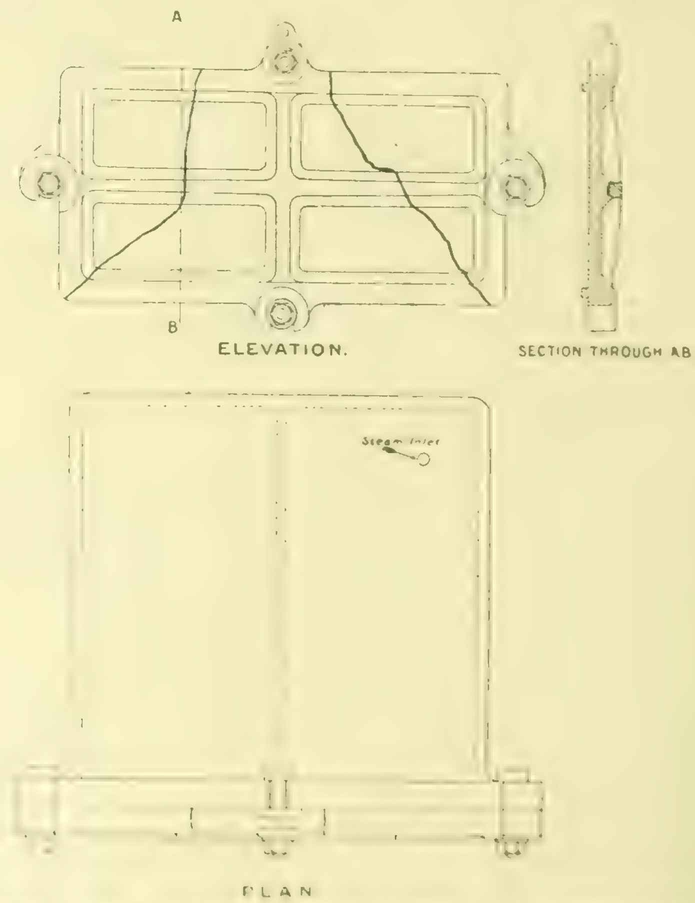


REPORT No. 2,089.—VIEWS OF STEAM-HEATED CARVING TABLE, SHOWING POSITION OF FRACTURES.

tions, and judging from the number of failures that occur, it is to be feared that many of those using such apparatus do not realise there is risk in working them unless they are properly equipped with safety valves, pressure gauges, drain taps, &c., especially when steam is supplied from boilers working at higher pressures than the apparatus can stand. A typical failure of this kind, at a workhouse at Driffield, Yorkshire, on October 3rd last, is recorded in Report No. 2,089, from the bursting of a steam-heated carving table, a flat, rectangular tray measuring about 4ft. 3in. in length by 2ft. in width, by about $\frac{1}{2}$in. in thickness, with three depressions in its upper surface and a steam space beneath. Steam for

pressure than the vessel could stand to get access to the steam space, with the result that the flat bottom was blown out.

Report No. 2,084 deals with the fracture of the flat cast-iron door of a "press plate heating oven," at a textile mill at Morley, on July 10th last. The door was about 3ft. square by $1\frac{1}{4}$in. thick, strengthened by two cross ribs, and held in position by four wrought-iron bolts, $1\frac{1}{4}$in. diam. The failure was the result of carelessness and neglect. The vessel had been in use about 20 years, and until 1905 had been supplied with steam at 80lbs. pressure. At that date new boilers were



REPORT No. 2,084.—VIEWS OF PRESS PLATE HEATING OVEN, SHOWING LINES OF FRACTURE.

put in at the mill, working at 120lbs. pressure, and this 50 per cent. higher pressure was applied—as is often the case when new boilers are installed at mills—without a thought as to the suitability of the subsidiary steaming vessel, and probably accounted for some old fractures which were found in the door, though the immediate cause of the failure was the worn condition of the threads on one of the four bolts holding it in position. "Very ordinary attention," the report states,

"would have revealed the condition of the bolt." Unfortunately, this is seldom paid when the supervision is left to attendants, familiarity breeding indifference to safety until an accident occurs.

WESTINGHOUSE-LEBLANC AIR COMPRESSOR.

We illustrate in Fig. 1 a design of air compressor of the rotary type, particularly applicable to small powers, the invention of Société Westinghouse - Leblanc, 45, Rue de l'Arcade, Paris. The construction of the compressor is such that its rotors can attain peripheral speed of several hundred metres per second whatever may be their angular speed, which is necessary if the compressor is to be used not only for compressing air taken in at the atmospheric pressure but also for producing and maintaining a high vacuum in an enclosed space. The novel feature of the design consists in the construction of the rotors and in particular the constitution of their blades. Fig. 2 is a transverse section and Fig. 3 a longitudinal section through one of the rotors. Fig. 4 is a diagrammatic representation of one of the blades drawn to an enlarged scale and seen in end view, showing that its profile is such that the blade has uniform resistance. Fig. 5 is an end elevation of one of the blades which is rectangular, in side elevation. It may have any suitable profile provided that the width of the blade diminishes with the distance from the base and that its thickness decreases. Fig. 6 is a part side elevation of the blade shown in Fig. 5.

The blade suddenly expands at its base so as to constitute a heel of dove-tail shape. The nave of the rotor is carried by a shaft with which it is cast or forged, as shown in Figs. 2 and 3. Alternatively it may be shrunk hot on to the shaft. Trapezoidal notches A (Fig. 2) are made in the periphery of the nave for the purpose of receiving the heels of the blades B. To maintain the blades in place laterally, annular flanged rings C (Fig. 3) are provided at the ends of the nave on each side of the notch receiving the heel. Into these cells are introduced segments D which expand, owing to their elasticity, and are held in place during working against the flanges of the rings C by centrifugal force. The blades are of vegetable fibres, such as hemp, cotton, flax, or preferably ramie, united together by a suitable agglutinant, such as caoutchouc.

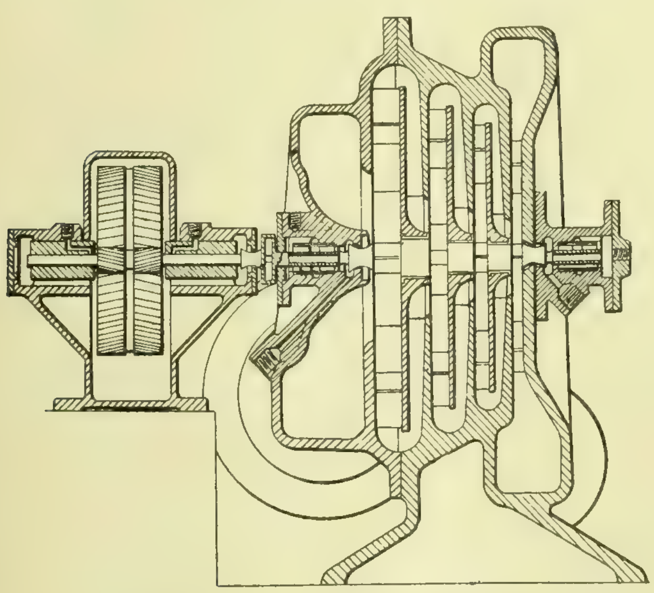
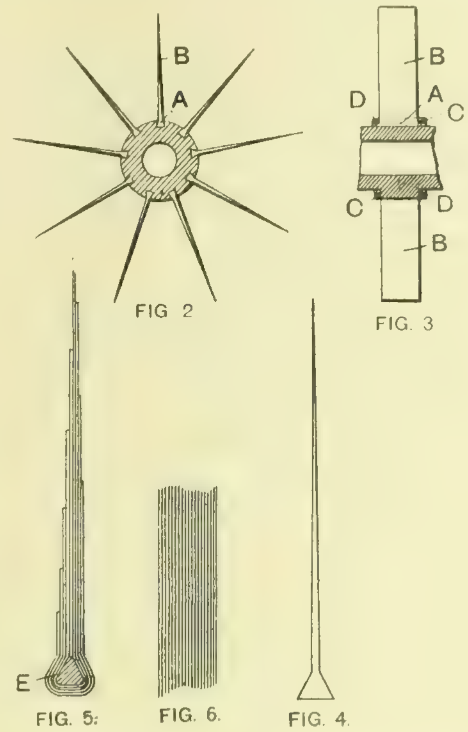


Fig. 1.—Westinghouse-Leblanc Air Compressor.

The blades are made in the following manner: A cylinder is covered with a helix of very close turns, consisting of a very homogeneously manufactured thread of the selected vegetable fibres, the winding being under tension. The whole is then painted over with a solution of caoutchouc containing sulphur and the cylinder is introduced into a stove for drying the solution and causing the threads to adhere to each other. This covering is then cut along a generatrix of the cylinder and unrolled. In this manner there is obtained a very thin rectangular band composed of rectilinear threads stretched parallel to each other and contiguous with each other (Fig. 6). A number of these bands of different length are now folded over an ebonite wedge, such as that shown at E in Fig. 5, the arrangement being such that the superposition of the bands forms a body having substantially a profile of uniform resistance. The assemblage of bands is now introduced into a two-part mould, the internal surface of which is stepped so as to follow the form of the blade, and this forcibly pressed therein. The mould is then introduced into the vulcanising stove. When vulcanisation is complete it only remains to remove the blade from the mould. There are thus obtained ebonite blades strengthened by vegetable fibres in the direction of their length but not in the direction of their width. Every precaution should be taken that in the course of the manufacture the mass



Westinghouse-Leblanc Air Compressor.

of agglutinant used shall be as small as possible compared with that of the vegetable fibres.

For these blades the following advantages are claimed. (1) Their density is close to that of water. The tenacity of the vegetable fibres is sufficiently great to enable them to resist centrifugal force better than the fibres of steel which are seven to eight times as dense. (2) These blades do not suffer appreciably more elongation under the influence of centrifugal force than metallic blades of the same profile do. Moreover, they do not become deformed. (3) The blades have to turn between two metallic plates against which they may rub without injuring them. The blades wear at their edges, being ground to powder, which is immediately thrown outwardly until the friction ceases. If the blades were of metal each rotor would act as a cutter on the plates, and would soon put them out of use. Thus the blades may be a little too wide in the first instance, and may be turned between the plates at a reduced speed for the purpose of wearing them. The most simple arrangement is to have only extremely small play, this being allowable only in compressors of low power. (4) The blades keep themselves straight, all their fibres remaining perpendicular to the true axis of rotation under the influence of centrifugal force, the elasticity of the agglutinant permitting them to move slightly relatively to each other. The action of the blades cannot develop any appreciable couple on the nave or on the shaft which carries it, as would happen if the blades were metallic. The flexibility of the blades dispenses with the use of a flexible shaft.

Fatal Locomotive Boiler Explosion.—A locomotive boiler exploded while pulling New York Central and Hudson River R.R. train No. 49 on January 26th near the western limit of Oneida, N.Y. The engineer was killed and the fireman seriously injured. Only one car left the rails. Reports state that the temperature at the time of the accident was between 15° and 20° below zero, and the explosion is ascribed to the freezing of the feed-water line between the locomotive and the tender.

A STUDY OF THE PROPERTIES OF ALLOYS AT HIGH TEMPERATURES.*

BY G. D. BENGOUGH, M.A.

(*Concluded from page 242.*)

Two-phase Systems.—The mechanical properties of a number of 2-phase systems may now be considered. It must be said at once that the complete interpretation of the curves obtained experimentally for these systems is by no means easy, and the remarks made by the author in dealing with each of these systems are intended to be suggestive rather than authoritative. Much further study is required in this branch of the subject.

Series VI.—*Muntz Metal "A."*—This alloy is the first of the 2-phase systems. Its microstructure is illustrated in Fig. 20. It consists of the α and β solid solutions, and it should be noticed that the α constituent (shown light in the photograph) forms the matrix in which the β solution is embedded. From this it would be expected that the characteristics of the α solution would predominate in the alloy, especially at low temperatures. At high temperatures, at which the β constituent increases in quantity at the expense of the α, it would be expected that the characteristics of the α solution would be much modified.‡ The experimental results are given in Table VIII., and Figs. 21 and 22. The stress curve shows two branches: one is slightly concave upwards. The first branch extends from 0° to 430°, the second from 430° to the melting point 890°. The strain curve is rather more complex, and will now be considered in detail.

Fig. 20.—Copper (as rolled). Magnification 80 diameters.

Between 0° and the 300° the elongation falls off rapidly, and reaches a minimum value at about 350°. It then increases again rather rapidly up to a temperature of 395°. The general shape of the curve in this region resembles that of the α solid solution (Figs. 19 and 38). It differs in that the minimum value is 7·6 per cent. instead of 1·5 per cent., and that recovery sets in at a lower temperature. Both these deviations would be expected as results of the presence of the β phase, which will be shown later to be a phase of low strength but considerable ductility at moderate temperatures whenever its strength can be improved.

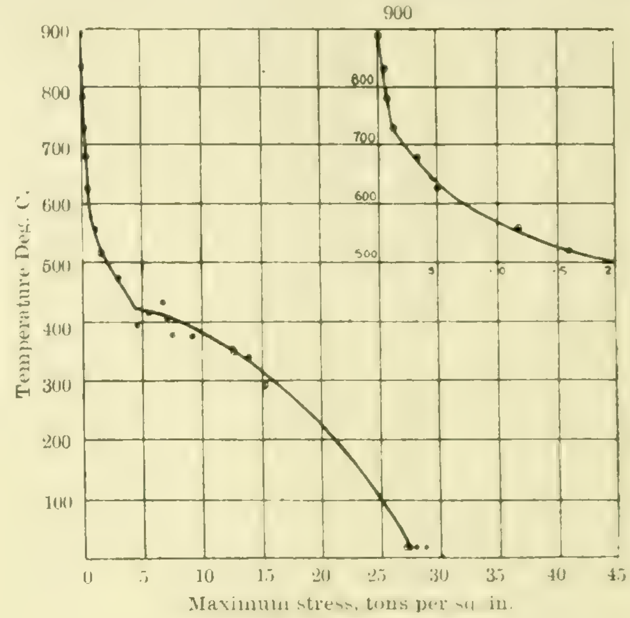


Fig. 21.—Muntz Metal A.

The presence of β, then, when associated with α, masks the entire loss of ductility by the α solid solution, and enables recovery to begin at a lower temperature, namely, 350° instead of 410°. The slope of the curve between 340° and 390° was very difficult to determine, and has been examined experimentally with great care. At first the recovery seems to be due mainly to the increasing importance of β. Above about 400°, however, it will be assisted by the recovery of ductility of the α also.

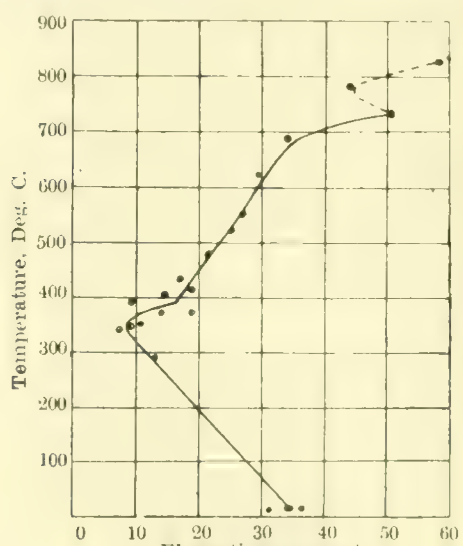


Fig. 22.—Muntz Metal A.

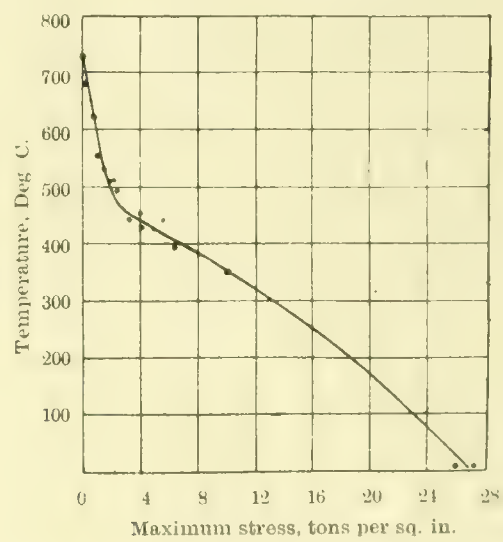


Fig. 23.—Muntz Metal B.

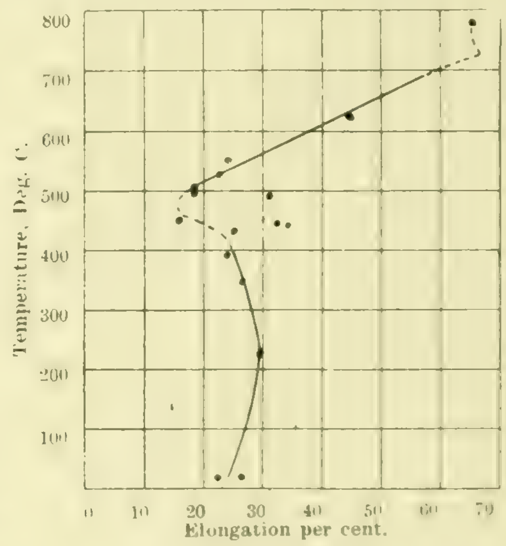


Fig. 24.—Muntz Metal B.

Table VII.—*Brass Wire.*†

Mark	Tested at Deg. C.	Maximum Stress, Tons per Sq. In.	Elongation, per Cent. on 2in.	Contraction of Area per Cent.
W29	310	18·1	2·5	11
W31	310	19·0	2·0	10
W30	313	16·3	2·0	2
W32	415	10·8	1·5	10
W33	415	10·3	1·5	9
W38	440	5·1	6·0	15
W39	453	5·1	17·5	30
W34	465	4·8	16·5	29
W35	472	4·4	16·25	29
W36	472	4·6	16·25	29
W40	500	3·4	13·7	28
W41	500	3·5	13·0	22
W42	590	1·3	16·0	22
W43	590	1·2	14·0	18

These two factors help one another throughout the temperature ranges 400° to 730°, and the increase in ductility is therefore quite rapid. This branch of the curve ends at a temperature of 730° C., and 51 per cent. elongation. The stress curve undergoes a slight change of direction at 720°, and with this is associated the sudden increase of elongation at about the same temperature. Several similar cases of rapid increase in elongation at a critical point in the stress curve may be seen in the curves already described; the phenomenon is a usual one, though perhaps not quite universal.

At 730° the constitution of this alloy undergoes an entire change. Quenched specimens show that above this temperature it consists of pure β. In Shepherd's diagram, Fig. 40, the temperature of this change for an alloy of similar composition is given as 745°, but there is reason to suppose that the precise slope of the curve between the β and $\alpha + \beta$ areas in this neighbourhood has not been determined with an accuracy

* Paper read before the Institute of Metals, January, 1912.

† "The Heat-treatment of Brass," Bengough and Hudson, "Journal of the Institute of Metals," No. 2, 1910, Vol. IV.

‡ It must be clearly borne in mind that the mechanical properties of both the α and β solutions alter with their composition. In all Muntz metals the α solution is always saturated, and so will have definite mechanical properties which only vary with the temperature

greater than 10° or 15° C. Above 730° the curves represent the properties of the partially saturated β solution.

A question arises as to the effect on the mechanical properties of the inversion at 475° discovered by Carpenter and Edwards. The author now believes that, though this change is a very real one, it does not appreciably influence the shape of the curves here published. The reason for this is that the change is too slow to make any serious headway in the short time for which the bars were heated in the furnace.

Series VII.—*Muntz Metal "B."*—This alloy, like the last, consists of two solutions. It contains just 1 per cent. more zinc. A microphotograph of the alloy is shown in Fig. 13. It will be seen that the structure differs from that of Muntz metal "A" in the important fact that the β now forms the matrix, in which the α is distributed, instead of the reverse arrangement. It is to be expected, therefore, that the characteristics of the α curves would be largely or entirely masked, since the stress and strain must now fall principally on the matrix solution.

The curves obtained experimentally from this alloy fulfil these predictions. They are shown in Figs. 23 and 24, and are plotted from the values given in Table IX. Instead of a rapid falling off in the elongation so characteristic of the α solution, the curve is nearly vertical up to a temperature of 500°. At this temperature the α solution has lost practically all its ductility, but the β has acquired a moderate amount. It was found in the experiments that this alloy gave very variable results in the range of temperature between 400° and 500°, and it has been found impossible to plot a characteristic curve in this neighbourhood. The cause of this is probably to be found in the fact that the α and β solutions are present in this range of temperature in very nearly equal amounts, and are also of approximately equal strength, though at the lower temperatures the β is slightly stronger. Consequently the strain may fall on either of them, according to the detail of their relative arrangement in the actual bar examined. If the strain fall mainly on the α the ductility will be very small; if it fall on the β it may be fairly high. Hence in this region no two bars behave exactly alike. At temperatures above 500° the β solution increases in amount at the expense of the α, and consequently impresses upon the bar its properties of great ductility and low strength, with the result that the curve passes off rapidly to the right.

It is interesting to compare the curves for the two samples of Muntz metal. It will be seen that they are of quite different types at all temperatures below 700°—in fact, they are as different as if they represented the properties of two entirely different alloys. The sensitiveness of these alloys to very small differences of composition in this range must be a fact of great industrial interest and importance. The difference in inclination between the two curves at temperatures above 500° must be due to the fact that a slightly increased proportion of the β phase confers on the alloy greater ductility at high temperature.

TABLE VIII.—Series VI.—*Muntz Metal "A."*

Temperature of Test, Deg. Centigrade.	Maximum Stress. Lbs.	Maximum Stress. Tons per Square Inch.	Elongation per Cent. on 2in.	Contraction of Area per Cent
17	O.T.	27·1	32·2	
17	O.T.	28·9	34·0	
17	...	27·7	36·5	
17	...	28·1	34·6	
292	1666	15·1	13·0	
340	1523	13·9	7·6	
349	1401	12·7	9·4	
356	1397	12·7	10·9	
375	1005	9·1	14·1	
376	805	7·3	19·0	
396	511	4·6	9·3	
405	777	7·0	14·1	
416	609	5·5	18·7	
432	735	6·7	17·1	
475	329	3·0	21·8	
520	175	1·6	25·0	
560	133	1·2	27·0	
625	59	0·5	29·6	
685	38	0·34	34·5	
730	16	0·14	51·0	
780	11	0·09	44·0	
830	7	0·57	58·4	

Series VIII.—*Cast Brass "C."*—It was thought that it would be interesting to cast a few bars of such composition that they would consist entirely of pure β. Unfortunately the resources of the author's laboratory did not at the time allow of the metal being melted in sufficient quantities to make the bars required. The matter has since been remedied, but too late for the bars to be cast and tested in time for the present paper. Consequently the bars had to be cast outside the University, and were found to be rather higher in copper than corresponds to pure β—that is, they contained 56·7 per cent. of copper instead of 54. Nevertheless, the tests of these bars are interesting. They consist very largely of β crystals, with quite small α

FIG. 25.—CAST BRASS. A.
Broken at 785°C. near fracture.
Magnification 80 diameters.

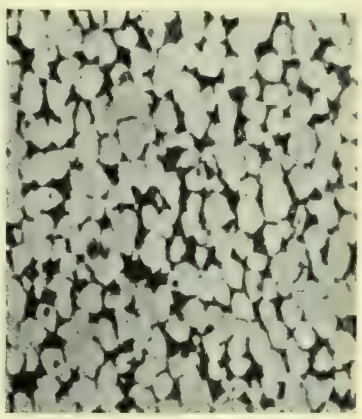


FIG. 26.—MUNTZ METAL, A (as rolled).
Magnification 80 diameters.

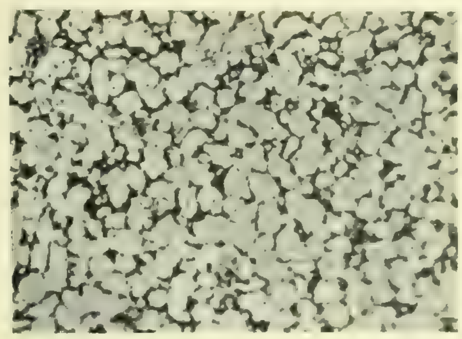


FIG. 27.—MUNTZ METAL, B (as rolled).
Magnification 80 diameters.

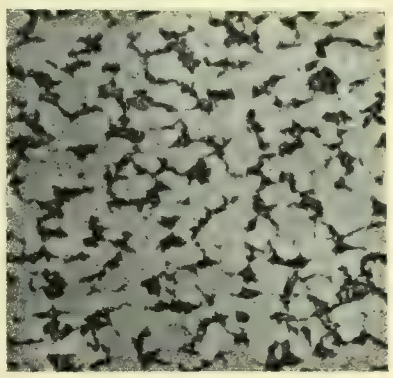


FIG. 28.—MUNTZ METAL, B.
Broken at 625°.
Magnification 80 diameters.

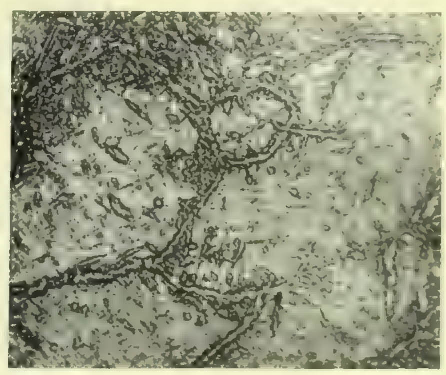


FIG. 29. BRASS, C (as cast).
Magnification 80 diameters.

crystals scattered about amongst the matrix (Fig. 29). It is evident that the mechanical properties of the bar will represent very closely the properties of the nearly pure β solution. The experimental results are given in Table X., and are plotted in Figs. 30 and 31. It will be seen that at the ordinary temperature the β solution has considerable strength. On the other hand, it has practically no ductility. The elongation, however, increases steadily with the rise in temperature up to 610°, when it reaches a value of over 30 per cent. It seems almost certain that the slight check in the rise of the curve at 400° is due to the presence of the trace of α which happened to be arranged in the particular bar tested at this temperature, so that it could exert its influence. At 600° C. the curve turns back, showing a loss of ductility. At this temperature, however, the alloy consists of pure β, and this turn back in the curve must mean that the strength of the

β phase, of the composition of this alloy, has now become so low that its great ductility is not available; in fact, it rather resembles lead in its mechanical properties.

Fig. 34 shows the microstructure of the bar broken at 700°, in the neighbourhood of the fracture. After fracture the bar was withdrawn from the furnace and cooled naturally in air. The large crystals are β, and round the edges of them a thin

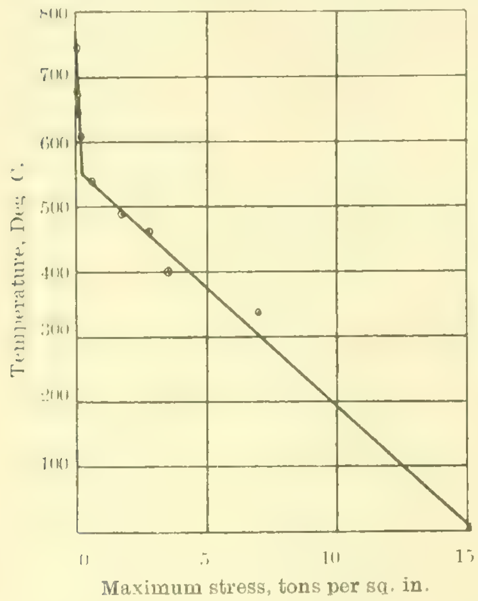


FIG. 30.—CAST BRASS C.

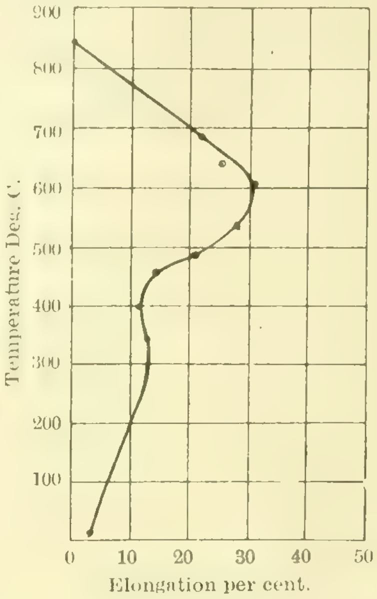


FIG. 31.—CAST BRASS C.

film of α has crystallised out. At the temperature of fracture no α was present, as was shown by quenching small specimens. With regard to this microphotograph it may be mentioned in passing that the β solution, rather high in zinc and approximately pure, is without exception the most difficult alloy known to the author to obtain free from scratches for photography; hence the appearance of the microphotograph in question.

TABLE IX.—Series VII.—*Muntz Metal "B."*

Temperature of Tests, Deg. Centigrade.	Elongation, per Cent. on 2in.	Maximum Stress.	
		Lbs.	Tons per Square Inch.
17	26·7	O.T.	27·2
17	22·7	O.T.	25·8
225	29·6	2569	23·2
350	26·5	1120	10·0
395	24·2	742	6·5
428	25·0	502	4·6
430	34·3	651	5·9
440	32·0	364	3·2
450	16·1	441	4·0
490	31·2	231	2·2
496	18·5	189	1·7
510	18·7	225	2·0
510	...	217	1·9
530	22·5	189	1·7
550	24·0	119	1·08
625	44·5	<105	<0·96
675	51·5	24	0·16
780	65·6	11	0·08

TABLE X.—Series VIII.—*Brass "C."*

Temperature of Tests, Deg. Centigrade.	Maximum Stress.		Elongation, per Cent on 2in.	Contraction of Area per Cent.
	Lbs.	Tons per Square Inch.		
18	O.T.	15·1	3·1	
330	2998	6·8	12·5	
400	1512	3·4	11·0	
460	1202	2·6	14·0	
480	847	1·9	21·0	
530	245	0·56	28·1	
610	98	0·20	31·0	
640	35	0·07	25·0	
685	33	0·06	22·0	
740	30	0·06	—	

Fig. 32 is a photograph of another bar of the same alloy, as cast; the only mechanical work that had been put on the bar was due to screwing the ends. The network seen in the photograph only became apparent after etching. The author believes it to be a very fine cubical cleavage which had been developed in the brittle material by the mechanical stress caused by the screwing. The cleavage has been opened out and made visible by the etching agent gradually finding its way along cleavage planes.

At high temperatures the ductility of bars of this alloy cannot be satisfactorily measured, owing to the fact that numerous wide cracks open up in the bar at considerable distances from the point of fracture. This phenomenon was also observed at all temperatures above 400°, and at 700° rendered elongation measurements meaningless. These bars also showed a tendency to break outside the gauge marks and at the shoulder, and many tests were spoilt in this way. Only the results of satisfactory tests have been recorded in the tables and curves.

Series X.—*Complex Brass.*—The elongation curve of this alloy is very remarkable and is shown in Fig. 37, which is drawn from the results in Table XI. This alloy has two small thermal critical points in the solid, at 720° C. and 560°. There does not appear to be any abrupt change in mechanical properties corresponding with the latter. The analysis of this alloy shows it to be a very complex material, and the object of introducing the subsidiary constituents appears to be to improve and strengthen the mechanical properties of the β phase.

General Discussion of Experimental Results.—It will be noticed that the stress and strain curves of the pure metals show changes of direction which are most abrupt at a temperature of 650° C. in the case of copper, and at 395° C. in the case of aluminium. These points may be referred to as "mechanical critical points," to distinguish them from the well-known thermal critical points of metals and alloys. Now the pure metals, copper and aluminium, exhibit no thermal critical points at temperatures corresponding to the mechanical critical points, and we must come to the conclusion that there is no necessary

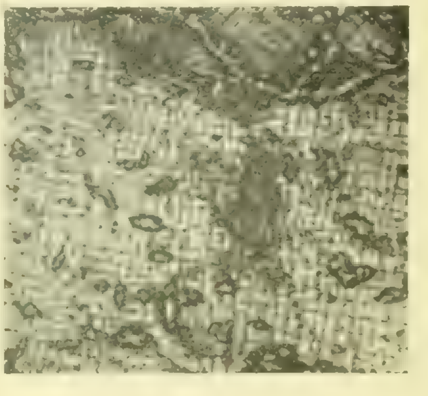


FIG 32.—BRASS C. (as Cast). Magnification 150 diam. (deeply etched.)

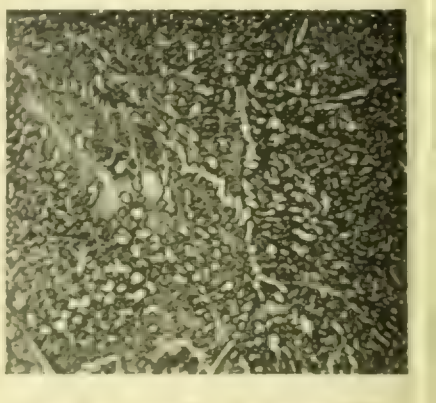


FIG. 33.—BRASS C. Broken at 530 Magnification 80 diameters

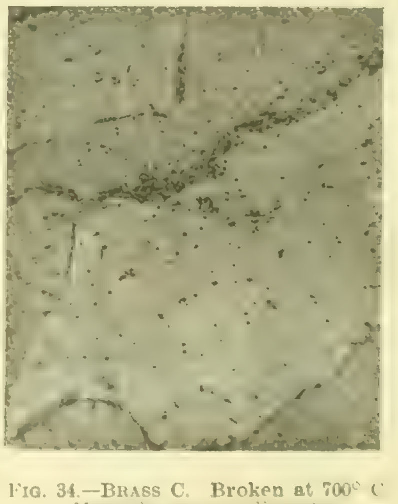


FIG. 34.—BRASS C. Broken at 700° C Magnification 80 diameters

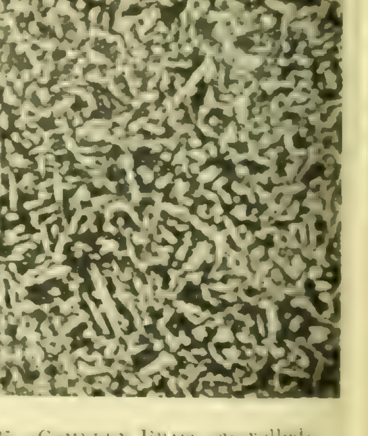


FIG. 35.—COMPLEX BRASS (as rolled) Magnification 80 diameters

relation between the two sets of phenomena. Further, the only changes that take place in the microstructure of these pure metals as the temperature rises are the increasing crystal size, and the removal of the amorphous material formed in and around the crystals as the result of cold work, contraction strains, &c., on the metal. The conclusion, therefore, appears to be inevitable that there are certain powerful factors, hitherto unrecognised, which profoundly affect the mechanical properties of pure metals and alloys, and which have no relation that has yet been traced to their phase relationships.

An examination of the whole series of tensile curves now published will show an interesting difference between those representing materials rolled or worked at a comparatively low temperature, such as aluminium, copper, 70/30 brass, copper-nickel, and those representing cast materials, or materials only worked at high temperatures, such as "extruded metal." In Fig. 38 the curve XYZ is a typical stress-curve of the former class of material; the curve XYV of the latter type. The

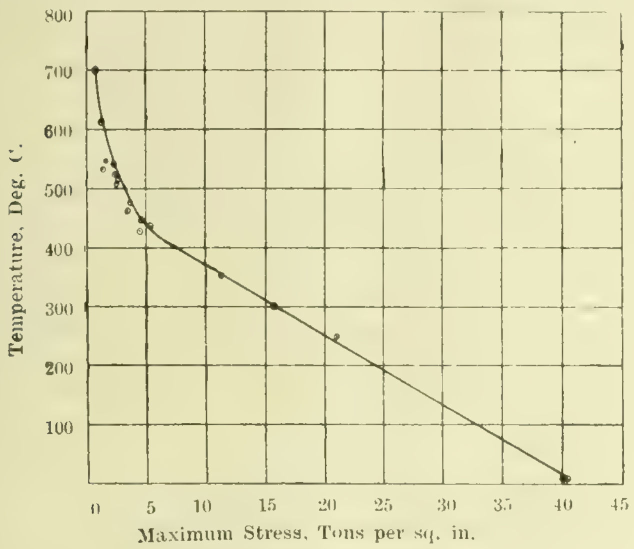


FIG. 36.—COMPLEX BRASS.

curves indicate that at any temperature below Y rolled metal is stronger than similar cast material, but that at temperatures above Y both materials have identical properties. This temperature Y at which the curve XY meets the curves YV and YZ has been determined both for cast and rolled metal in the case of aluminium, and has been found to be 395° C. for both classes of material. A discussion of the position of Y horizontally will be taken up later. The horizontal distance, BC, shows the difference in strength, at a temperature of 250°, between the cast and rolled materials. As the temperature is raised this difference in strength becomes smaller and smaller, till it vanishes at Y.

TABLE XI.—Series X.—*Complex Brass.*

Temperature of Test, Deg. Centigrade.	Maximum Stress. Lbs.	Maximum Stress. Tons per Square Inch.	Elongation. per Cent. on 2in.	Contraction of Area per Cent.
17	O.T.	40·3	21·0	
17	—	40·0	22·0	
250	—	21·2	40·2	
300	1727	16·0	46·8	
350	1267	11·7	60·0	
420	505	4·6	59·3	
432	613	5·5	59·3	
440	496	4·5	51·5	
460	368	3·3	62·5	
475	382	3·4	51·5	
510	307	2·7	48·5	
515	294	2·7	68·2	
524	280	2·4	97·0	
525	140	1·2	105·0	
530	273	2·4	100·0	
535	160	1·5	106·2	
535	183	1·5	107·5	
615	140	1·2	140·0	
700	<105	<0·96	162·5	
750	10	—	156·3	
790	7	—	128·0	

It now remains to discuss the physical meaning of this remarkable series of phenomena, and to supply a rational explanation of it. Before doing so, the physical properties of metals and alloys above the temperature Y and below the melting point must be described. In this range their behaviour resembles that of a viscous fluid; their strength is very small, they exhibit great ductility and plasticity, and the influence of time on the tensile strength becomes important. Moreover, in nearly all cases, they give out a "cry" like that of tin when stressed by loads much less than that required for fracture. This "cry" is particularly noticeable in the case of the brass alloys and copper. The "cry" of tin is usually explained as due to the rubbing of the crystal surfaces against one another, and in its most literal sense the author believes that to be the explanation in the present case.

This remark naturally leads to the consideration of the question why other metals do not "cry" when stressed at ordinary temperatures. The answer may reasonably be given that tin is above the temperature Y, its "temperature of recuperation," at the ordinary temperature, whereas most other metals and alloys are not, and that it is only at temperatures above Y that the crystals can come in actual contact with one another.

It has always appeared a remarkable fact to the author that the fracture of metals and alloys tends to pass through the body of the metallic crystals rather than between the crystalline junctions, especially in the case of pure metals and solid solutions. (Cases of fracture passing through weak inter-crystalline eutectics do not affect the present argument.) It would seem that at the ordinary temperature the cohesion between the faces of separate crystals is greater than that between different parts of the same crystal—a really remarkable phenomenon which has not perhaps received the attention it deserves.

Another fact of some significance in this connection is the peculiar action of etching agents upon pure metals and homogeneous solid solutions. The first action of a dilute reagent is to eat into the crystalline boundaries and so bring out the polygonal structure characteristic of these substances.

The deduction may reasonably be drawn that the individual crystals in a pure metal are normally bound to one another by some substance stronger than the crystals themselves, but more easily attacked by etching agents. This substance must surely be no other than Beilby's amorphous material,* arranged in a thin, more or less continuous layer round the crystals. Its presence has hitherto only been clearly recognised in highly worked or strained metal; from the experiments now described it would seem to the author to exist in all metals and alloys below a certain temperature, characteristic of each material—the temperature of recuperation.

Its presence may be accounted for in the following ways: Firstly, it may result from the counter-attractions of the crystals on either side of it, none of which is sufficiently strong to overcome the crystalline attraction of all the neighbouring crystals, and so to incorporate the last minute trace of still liquid material into its crystalline system. Secondly, it may result, or at any rate be increased in quantity, by the effect of contraction strains in the metal. That these may be very considerable is evidenced by the fact that they sometimes give out audible sound waves during the process of relief.

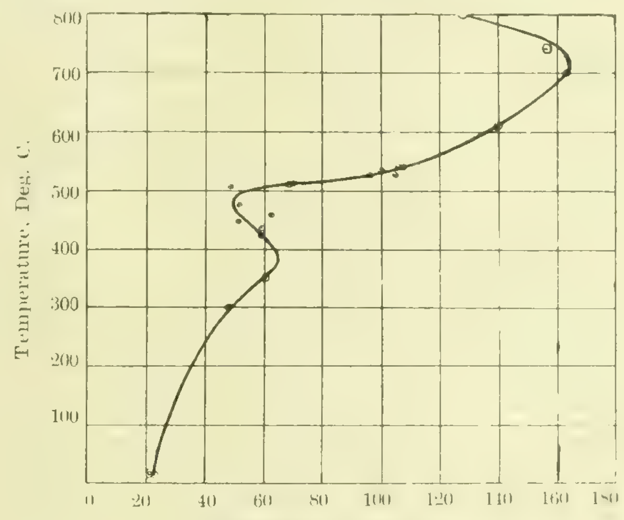


FIG. 37.—COMPLEX BRASS.

Thirdly, it may result from an increase in viscosity of the still molten metal, which in turn may result from the concentration in the last liquid portions of an impurity. Great viscosity is known to hinder crystallisation, and so to help in the formation of amorphous material.†

Now, at temperatures above Y, it may be supposed that the amorphous material which cements the crystalline faces together is no longer able to exist even momentarily. Hence fracture will take place between the crystalline junctions, and the fractured surface of specimens broken at high temperatures serves to support this view. Further, when slip takes place in

* In general, this amorphous material exhibits greater strength but less ductility than the crystalline substance from which it is formed.

† The influence of traces of impurity in destroying the ductility of masses may possibly be explained in this way, since amorphous metallic materials have little ductility.

the crystals themselves, the resulting mobile material instantly recrystallises, owing to the great activity of crystalline growth at these temperatures. Consequently "work" will no longer strengthen and harden the metal, and a precise definition of "hot-work" can be readily formulated. This definition is as follows :—

Hot-work is work performed on a metal or alloy at such a temperature that the amorphous or mobile material formed at the expense of the crystals recrystallises instantaneously, leaving the material in a perfectly soft condition. The lowest temperature at which this is possible is called the temperature of recuperation.

Cold work will be work carried out partly or wholly below the temperature of recuperation, and will result in the formation of the amorphous material in considerable quantity.

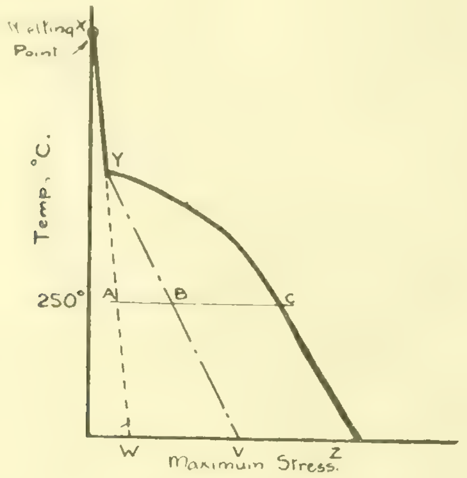


FIG. 38.

The meaning of the term "the limiting temperature of complete recuperation" is now apparent. It means that, *under the conditions of the experiment*, the amorphous substance has no appreciable period of existence. It is also intended to cover the fact that the rapid falling off in tensile strength is abruptly checked.

It will be well to consider for a moment the phenomena which take place in a bar under test at temperatures above the temperature of recuperation. A load is applied; plastic deformation takes place; mobile molecules are formed along the planes of slip; these molecules have an infinitely short period of existence and at once recrystallise, and this may happen before any further load is applied. If, however, the rate of loading is very rapid, it is just possible that complete recrystallisation may not have had time to take place and a residue of amorphous material is left. Therefore, unless the rate of recrystallisation is rapid as compared with the rate of loading, the actual temperature of recuperation determined experimentally will be dependent to some extent on the latter factor. Hence the use of the words "under the conditions of the experiment" in the last paragraph.

Turning now to Fig. 38, the difference in strength indicated by the line BC between a rolled and a cast material will be due to the amount of work put on it by forging, rolling, &c. If the curve XY be extrapolated down to the ordinary temperature, as shown in YW, we shall obtain the area YAWV. The curve YW obviously shows the properties which a metal would have at any temperature if it could be prepared and tested at that temperature in a perfectly crystalline state, without any amorphous material being formed in it. This is, of course, impossible, since the mere act of testing at any temperature below Y results in the formation of the hard amorphous substance. The curve XYW may therefore be regarded as representing the properties of an ideally soft metal, or of a metal whose temperature of recuperaturation is below the ordinary temperature. The line AB, then, represents the strengthening effect of the mechanical work necessarily put upon the metal by the act of testing, and also any small effect which results from contraction strains resulting from cooling.

If the foregoing views be accepted, it will be seen that the unstable, vitreous amorphous material of Beilby plays a far more fundamental part in determining the mechanical properties of metals or alloys than has hitherto been suspected. The industrial alloys of copper, and even copper itself, depend for their commercially useful properties entirely upon this material. Without it all metals would be weak, plastic, viscous bodies, rather resembling pitch, or perhaps tin.

An apparent discrepancy between Beilby's results and those of the author may now be referred to. In his May lecture before this Institute, Beilby republished a number of his results which showed that the amorphous material in his copper wires recrystallised completely at 220° C. This might be supposed to correspond with the author's temperature of recuperation for copper, namely, 650° C. A careful consideration of the two sets of tests will show clearly, however, that there is no direct relationship between them—salient points of difference being that Beilby's wires were comparatively slightly stressed so as to give a 1 per cent. elongation, whereas the author's were stressed to fracture, and that in the author's experiments the amorphous material was being continually reformed in quantity by the test itself.

Returning to the consideration of the experimental results now presented, and leaving on one side any further consideration of the theoretical suggestions outlined above, the author would direct attention to one or two matters that have not yet been considered in sufficient detail.

In the first place, it would appear from the curves that the elongation of an alloy is far more easily upset by variation in temperature, size of specimen, and possibly other factors, than is the maximum stress. The "mechanical critical points" in the elongation curves are decidedly more well-marked than in the stress curves, especially in the case of pure metals. The exact interpretation of some of the curves determined experimentally is difficult, especially in the case of two-phase systems. This arises from the fact that the properties of the α solution are very remarkable, and the elongation curve bends in a manner that is obviously dependent on a number of factors which are not yet clearly known, but some of which may be associated with slight differences of chemical composition and of size of bar. In the author's experiments the thick cast bars were tested at approximately the same rate as the smaller bars and wire. The resemblances and differences between cast bar A and the 70/30 brass wire have already been alluded to. If the respective times under test had been proportioned to the relative thicknesses, a closer resemblance might have been attained, and the shapes of the curves seem to suggest this.

The general type of elongation curve for pure metals is clear from Figs. 7 and 9. From these it may be seen that elongation

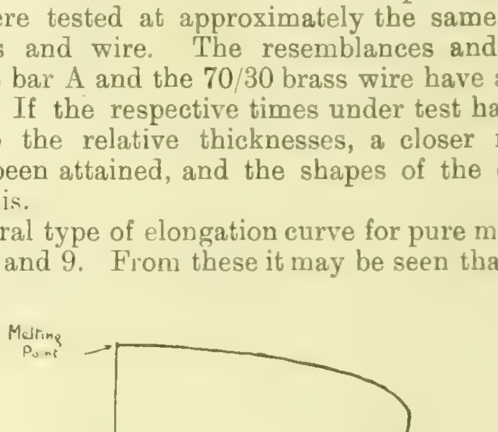


FIG. 39.

may either increase or fall off as the temperature is raised, and it may be inferred that it may remain practically constant up to the temperature of recuperation. At about this temperature it will undergo a large increase, and remain at a high value till the neighbourhood of the melting-point is reached.

The general type of curve for a solid solution is not quite so clear, but the author believes it to be of the form shown in Fig. 39. The dotted curve shows a possible variation where the elongation increases regularly from 0°.

The curves of several two-phase systems have been discussed in some detail already. It is, however, doubtful if we

are yet in a position to give a complete explanation of all the types of curves obtained for these more complex cases. These types have not yet been sufficiently clearly fixed experimentally, and much more work will have to be done before they can be regarded as settled. The author only regards his results as affording a preliminary exploration of the field.

In conclusion, the author would like to draw attention again to the remarkable fact that the most abrupt changes in mechanical properties which have been found in the alloys examined do not occur at temperatures corresponding to phase changes, either in the case of pure metals or in the case of complex two-phase systems. It would appear that the presence of unstable and non-crystalline substances is the

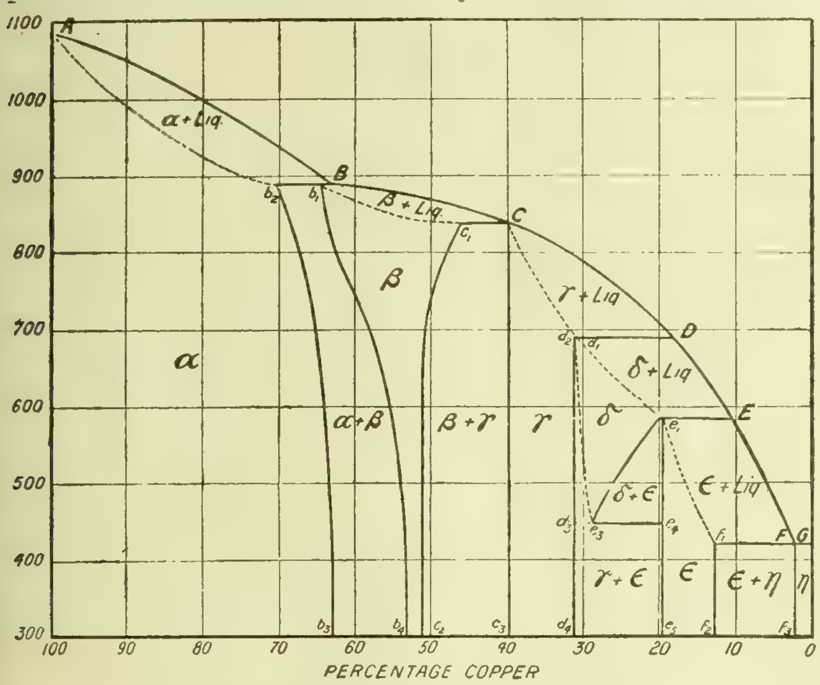


FIG. 40.—SHEPHERD'S DIAGRAM.

most important factor in determining the mechanical properties of metals and alloys at ordinary and moderate temperatures. If this reasoning be not accepted, then some cause other than phase changes must be sought in explanation of the remarkable experimental facts that have been now described. In the last May lecture delivered before this Institute, Beilby drew attention to the importance of amorphous, vitreous, and unstable substances in commerce, and instanced glass as a case in point. Is it not possible that such substances are of equal importance in the case of all metals handled, used, or worked at any temperature removed by more than a comparatively short range from their melting points? If this be so, then the attention of metallurgists must in the future be concentrated much less exclusively on the study of stable systems than it has been in the past.

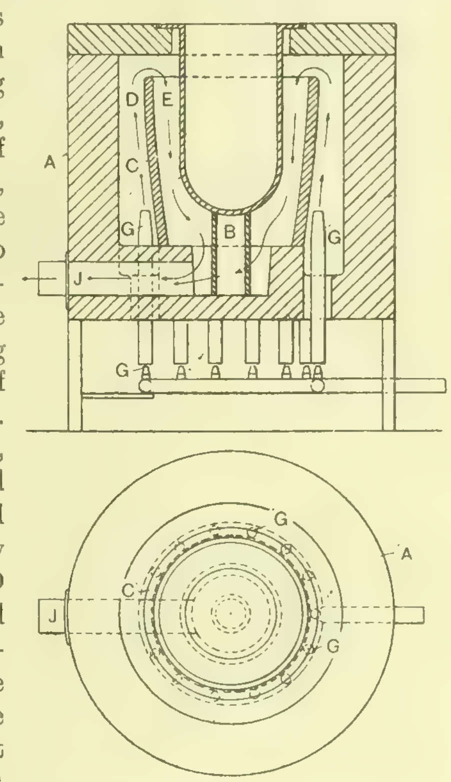
The author desires here to express his cordial thanks to the following gentlemen for their help in various ways: Mr. E. F. Law, A.R.C.S., Mr. H. Jelf-Reveley, and Mr. H. Purser.

APPLICATION OF THE GYROSTAT TO VEHICLES.

AT a recent meeting of the Royal Philosophical Society of Glasgow Dr. J. G. Gray, F.R.S.E., delivered an interesting lecture on "The Application of the Gyrostat to the Stability of Vehicles." After experimentally demonstrating the principal properties of the gyroscope, the lecturer considered the gyrostatic action of the paddle wheels of a steamer, of the flywheel of a motor-car, and of the rotors of a turbine steamer. The paddles of a steamer rendered her steadier than a screw steamer in a cross-sea, for when a wave struck her in such a way as to tend to heel her over to starboard her bows in consequence of the gyrostatic action turned to starboard, and the amount of the roll was diminished, though at the expense of the directness of the course. When a motor-car was turning a corner the gyrostatic action of the flywheel was such as to alter the proportions of the weight of the car carried by the front and rear wheels respectively. For one direction of turning weight was withdrawn from the back wheels and thrown on the front wheels; for the opposite direction of turning the weight on the front wheels was diminished, and if the turning was sufficiently rapid the steering of the car might be seriously interfered with. The gyroscopic action of the propeller and rotating parts of the engine of an aeroplane was also shown experimentally. A small gyroscope was mounted on a model aeroplane with the axis of the flywheel in the fore and aft line of the aeroplane, and it thus represented the rotating parts of the machinery. If, then, the aeroplane were turned horizontally it showed a tendency to dive or to ascend according to the direction of turning, while a change made in the inclination of the aeroplane's course caused it to swerve to the side. Such actions were, the lecturer considered, apt to have dangerous consequences when aeroplanes were manœuvred in restricted space in competitions. Dr. Gray then described and experimentally illustrated the practical application of the gyrostat in the dirigible torpedo, in the Schlick method of steadying vessels at sea, and in the Brennan monorail car. Some novel gyroscopic apparatus due to the lecturer was thereafter exhibited in action. A motor-driven gyrostat provided with suitable arms and legs was made to walk on the floor, to project itself arm-over-arm along two horizontally stretched wires, and to climb up vertical wires. Another gyrostat was shown riding a model bicycle. In the case of an ordinary bicycle stability was obtained by turning the front wheel to the side towards which the machine was tilted, when the forward momentum of the machine and the rider resulted in the re-erection of the bicycle. A gyroscope suitably mounted on the seat of a bicycle and connected by arms to the handle-bars was made to imitate this action, and successfully kept the bicycle in equilibrium.

FURNACE FOR HARDENING OR MELTING METAL.

A DESIGN of lead and salt bath furnace for hardening or melting metal of the class in which a crucible is placed in a firebrick casing and heated by gas is shown in vertical section and plan in the accompanying illustrations. The furnace, which is the invention of Messrs. Fletcher, Russell, and Co., Ltd., Palatine Works, Warrington, is so arranged that a regular temperature is obtained, and the burning or overheating locally of the contents of the crucible is prevented. Referring to the illustrations, a fireclay jacket C is placed between the crucible and the interior of the fireclay casing A with a space D between the casing and jacket, and a space E between the jacket and the crucible, and burners G are arranged so that the heat will pass up the space D over the top of the jacket C and descend into the space E, thereby circulating round the crucible which rests on the support B, and pass to the flue J at the bottom of the furnace.



FURNACE FOR HARDENING OR MELTING METAL.

The Trackless Trolley System of Traction.—A comparison of trackless trolley traction with the three systems of electric tramways was made recently by Mr. H. Jackson at a meeting at the Birmingham University in connection with the local branch of the Institution of Civil Engineers. Having explained in detail the overhead conduit and contact systems, Mr. Jackson, in the course of his lecture, declared that the trackless trolley was the system of the future. It would be most suitable for the development of Birmingham suburbs. He had sketched a route along which this system might with advantage be worked. This route was 27 miles long, and the cost for 30 cars with a 15 minutes' service would be £76,000, as against £331,000 for tramways. This would mean a great saving. If they could give this means of conveyance to people in Birmingham it would greatly facilitate the development of the suburbs.

PROF. OSBORNE REYNOLDS.

EVERY original thinker in the world of physics and engineering will share the deep regret we feel in recording the death at Watchet, Somerset, on Wednesday, the 21st ult., of Dr. Osborne Reynolds, the late Professor of Engineering at Manchester University. For some years the professor's health had been failing, and his retirement from active work some years ago was noted with a pained and reverent sympathy akin to personal sorrow by many old students who now rank high in the engineering world, and to whom his personality and inspiration will always be a treasured memory. It was to Prof. Reynolds that the organisation and development of the department of engineering at Owens College and the world-wide reputation it earned was due, while the lustre of his scientific and philosophical investigations was conspicuous in a generation that included some of the most brilliant of thinkers and witnessed the profoundest scientific discoveries.

Prof. Reynolds was born at Belfast in 1842, and his father was the Rev. Osborne Reynolds, of Debach and Boulge, Suffolk, where he spent his boyhood and where he attended the Dedham Grammar School. He afterwards spent a short time in an engineering works at Stony Stratford, prior to entering Queen's College, Cambridge, where he graduated in 1867 as Fifth Wrangler, and was elected a Fellow of his college. Subsequently he became a pupil with Messrs. Lawson and Mansergh, engineers, of London, and on March 26th, 1868, was appointed to the Chair of Engineering in Owens College, now merged into the Manchester University and with which he maintained an unbroken connection until the sad breakdown in his health caused him to resign some six years ago. In 1878 he was elected Honorary Fellow of Queen's College, Cambridge, and Member of the Institute of Civil Engineers. In the previous year he had become a Fellow of the Royal Society. In 1884 he was awarded the honorary degree of LL.D. by the University of Glasgow, and at the same time was appointed a member of the Council of the Royal Society.

Prof. Reynolds was the contributor of numerous papers to the Royal and other scientific societies. These, with his contributions to various periodicals, were afterwards collected and, by the aid of the Cambridge University Press, published in separate form. These volumes afford striking evidence of his versatility and originality. They comprise no fewer than 67 original contributions on the most diverse of subjects, from the most purely scientific to the most strictly practical. Many of these did not receive the attention they deserved at the time, and it has remained to later workers to point out the important practical bearing and foresight they displayed on numerous engineering problems which at the time were but imperfectly understood, and which as they have become known to a later generation have been regarded almost as new discoveries. To the mathematical and experimental treatment of hydraulics he devoted particular study, and to his investigations must be largely ascribed our existing knowledge of the intricate forces which determine the forms of channels and estuaries; while the development of the high-pressure centrifugal pump as we know it to-day was indicated by him over a quarter of a century ago. He it was also who first indicated the relationship between rate of heat transmission through boiler plates and velocity of flow of furnace gases, interest in which during the last few years has been revived by the further experiments and researches of Prof. Nicolson, of the Manchester School of Technology. It is impossible within the limits of our space to epitomise even briefly the subjects which came within the masterly survey of his intellect, which was equally at home whether discussing the phenomena of comets and solar corona, or such practical engineering problems as friction and lubrication, or the transmission of power by shafts and belts. Whether the subject under review was the formation of raindrops and snowflakes; the effect of oil in destroying waves; the slipperiness of ice; the problems of the screw propeller or of the steam engine, he never failed to illumine the principles that underlay them, and to reduce to reasoned law what had previously been vague guess work. The most monumental scientific work of his life was his memoir on "The Sub-Mechanics of the Universe," communicated to the Royal Society on February 3rd, 1902, and presented to the public in a popular form in a Reed Lecture. The conceptions underlying this stupendous speculation had been slowly evolved as the result of long years of previous work on "The Dimensional Properties of Gaseous Matter" and "The Dilatancy of Media Composed of Rigid Particles in Contact." The profound investigations involved placed it beyond the mental reach of all but a solitary few of the most advanced mathematicians, but the root conception of his theory is that all forms of matter as we know it are but interspaces in an all-pervading uniform medium of spherical grains of changeless shape and size, and so close that the grains cannot change their neighbours, although continually in relative motion with each other, and that such a purely mechanical system was capable of accounting for all the physical evidence as we know it in the universe. To the layman, the conception that what we term "matter" is only a void, a negation, is a staggering inversion of all ordinary ideas, but not more astonishing than Reynolds' rigid mathematical deductions from his premises, which include all the known phenomena of heat, light, electricity, Hertzian waves, and even embrace an explanation of the action of gravity itself, while it may be added that the more recent researches into molecular physics tend to confirm the truth of his theory. We should feel our brief reference to Osborne Reynolds' life and work incomplete without a tribute to his charming personality as a teacher. As a lecturer, measured by cramming standards, he would be considered deficient. His very wealth of ideas made it difficult for him to marshal them in ordered verbal array, but his explanations in the tutorial class were treats to all who sought them, and to none more generously vouchsafed than they who displayed a hungry inquisitiveness to know the "how" and "why" of things. He had a happy knack of putting questions that led on to tracks reaching down to root principles, and therein lay the charm of his merit. He could not pour out standard measures of cut-and-dried knowledge so freely as many less able men, but he could and did do what is far rarer and of infinitely more value to the student who wishes to get below the surface of physical phenomena, viz., him to think. To us who knew him in his prime his imprint in our memory is the beau ideal of physical and intellectual manhood, and fuller acquaintance with his genius only graves the image deeper and enshrines it with reverence.

The Manchester School of Technology Principalship.—Mr. J. C. M. Garnett has been appointed to be Principal of the Manchester School of Technology in succession to Mr. J. H. Reynolds, who recently resigned. Mr. Garnett, who is not much over 30, was educated at St. Paul's Schools and at Trinity College, Cambridge, of which latter he was elected a Fellow. He gained a high place among Wranglers of his year, and also gained a first class in the second part of the Mathematical Tripos. On leaving Cambridge he entered the Board of Education, where he is now one of the examiners.

Smoke Abatement.—Considerable modification has, we understand, been made in the Smoke Abatement Bill as originally drafted. The amended Bill will be submitted for the consideration of a conference to be held in connection with the forthcoming Smoke Prevention Exhibition at the Agricultural Hall. The conference will be presided over by Lord Justice Moulton, and to the proceedings contributions will be made by Mr. Joseph Hurst, the well-known expert on the law of smoke nuisance, Mr. Julian Corbett, who will treat of smoke abatement as dealt with in foreign countries, and by Dr. De Voex, hon. treasurer of the Coal Smoke Abatement Society, who will make a plea for a Royal Commission.

Electrification of the Gothard Railway.—The work of electrification of the Gothard Railway is, we learn, to begin shortly, and the first piece of line to be electrified will be that between Erstfeld and Airolo. The cost of electrification of the Gothard line is put at £2,700,000. The three new power stations to be built will cost £854,800; the necessary electric installations in the machinery houses, &c., another £305,200. It is anticipated that the introduction of electric traction on the Gothard line would result in a reduction of working expenses by about 25 per cent.; indeed, judging by the experiments made with the recently electrified line between Spiez and Frutigen, it is thought that possibly the saving might still be greater.

SOME CONSIDERATIONS ON THE CHOICE OF AUXILIARY PLANT FOR POWER STATIONS.*

BY A. H. FINCH, M.A.

In this paper it is proposed to notice some of the points that should bear on the design of that part of a power installation which is referred to in general terms as the auxiliary system. It may be asked why such a system should be necessary at all; why, that is, a self-contained power installation cannot be devised, comparable in simplicity to a small gas engine. The answer to this question is that auxiliary appliances become necessary for two principal reasons: (1) That they enable advantage to be taken of some thermodynamic principle; (2) that they take the place of an otherwise prohibitive amount of hand labour.

The work of the designer consists partly in balancing the advantages to be gained by the adoption of this or that device whose ultimate object is to reduce the quantity of fuel consumed per unit of energy, against the disadvantages, the cost, the complication, the increased risk of breakdown, or increased upkeep necessarily associated with additional apparatus. The most obvious illustration is the question of condensing *versus* non-condensing; others that suggest themselves are the adoption of economisers, or such a device as the augmenter condenser. These are questions where a definite reduction of the quantity of steam or fuel required per unit of energy must be weighed against the cost of obtaining it.

The two fields where there is probably the greatest scope for successful design in the matter of auxiliary plant are marine engineering and electrical power installations. The factors which govern marine practice are, however, materially different from those applicable on land. The standard of reliability exacted is higher, because the results of breakdown are more serious than on land. Or again, in a ship of war, many considerations must be subservient to speed, to weight, or uniformity with other vessels.

These and similar differences, coupled with the magnitude of the subject, make it impossible to give adequate consideration to both branches in a single paper, and it is now proposed to discuss that aspect of the question which bears on electrical work; and though many of the observations will be found applicable to any type of power station, it will be convenient and will give fixity to the ideas to limit the enquiry to the system of three-phase generation by means of steam, under which conditions practically all important modern installations work.

To facilitate discussion it is desirable to have some sort of definition of what is covered by the term auxiliary. In its widest sense it might be taken to include everything except the principal agents involved in the cycle, which would mean practically everything except main engines, feed pumps, and boilers. More commonly the feed pumps are included as auxiliaries, which term will be taken to include also: (*a*) Thermodynamic appliances not essentially involving moving parts or power (*e.g.*, economisers). (*b*) Apparatus requiring motive power independent of the main engines.

Such a definition excludes transformers and certain small elements such as oil pumps, which are often driven by the main engines. The importance of this section of any large power plant is to be gauged by the proportion which it bears to the whole, whether in capital or running costs; figures are given subsequently which exhibit the ratio of auxiliary to main power in the case of some typical stations; but it presents a sufficiently accurate picture at this stage to say that in a modern power station of 30,000 kw. capacity the auxiliaries would account for 2,000 h.p. and probably £12,000. By way of parallel illustration, though it is outside the scope of the present paper, it may be added that in a battleship of 30,000 h.p. the auxiliaries amount to 4,500 h.p. and consume one-sixth of the whole steam generated. In a tramp steamer these figures are naturally reduced, but taking the estimates given in a recent paper read before this Society by Mr. Morison, the auxiliaries account for between 8 and 10 per cent. of the total steam. It is therefore worth while bestowing considerable attention on a subject which offers such a scope for saving, and careful design will in many cases result in material diminution of the initial outlay and subsequent upkeep.

To illustrate the divergence that can exist in the auxiliary equipment of a power station according to size and circumstances, it is only necessary to enumerate the apparatus employed. Thus it is possible to conceive of a station wherein the simplicity of the early marine engine is copied; where the boiler feed pump, air pump, and circulating pump are driven by levers from one of the main engine crossheads; a chimney produces all the requisite draught; ashes and coal are handled in all their stages by hand labour; and the exciter, if required at all, is directly coupled to the generator shaft. Such a system, with the addition of a donkey feed pump or injector, is perfectly possible, and is approached, if not exemplified, in many small stations. In fact, in non-condensing stations, a feed pump is the only really needful auxiliary.

In the opposite direction it is not unusual to find the following independently driven pieces of apparatus: Exciters, feed pumps, air pumps, circulating pumps, exhaust (or other large) valves, cranes, ash hoists, coal hoists or conveyers, bilge pumps, boiler cleaning pumps, mechanical stokers, fans for induced draught, fans for generator ventilation, fans or pumps for cooling transformers, motor-operated switches, air exhausters for syphon circulating mains, air compressors for cleaning electrical apparatus, circulating water straining appliances, economiser scrapers, oil pumps, and barring or engine-turning gear. Where what is known as a complete unit system is adopted, some of the above items are multiplied by the number of generators, resulting in an enormous aggregate installation.

Two main aspects of the auxiliary question will be considered in this paper: (*a*) The arguments bearing on the adoption or rejection of certain services. (*b*) The most suitable method of driving them.

Choice of Auxiliary Services.—In dealing with this section the classification suggested at the outset may be adopted, that is to say: (*a*) Auxiliaries which render possible some thermodynamic advantage. (*b*) Those which replace labour.

(*a*) Of the former, the most prominent are naturally those concerned with condensing plant. It is taken for granted that condensing is an advantage worth securing. This will not be questioned except in cases of small installations remote from any sufficient sources of water. Neither is it proposed to discuss whether one form of condensing is preferable to another, that being rather a question of the location of plant in relation to the source of water and the quality of the water, which in many cases would altogether preclude jet condensation. But assuming that for any condensing plant air and circulating pumps are required, it is of interest to consider the opportunity for simplification offered by the development during the last two or three years of rotary forms of air pumps. Whatever their merits or demerits as regards capacity for subduing air leakage on a system when contrasted with reciprocating pumps, they possess two attractive attributes from the point of view of simplification in that (1) they occupy a very small space, and (2) they can be directly driven by any high-speed motive agent, whether electric motor or steam turbine. If it can be shown that they require no more maintenance than reciprocating pumps, which is reasonable to suppose from their exceedingly simple construction, a strong case for their adoption exists on these considerations alone. But where a complete use can be made of the exhaust steam there is a further advantage in adopting a steam turbine drive as is shown in the following argument.

Although such small turbines cannot be constructed to make any expansive use of steam below atmospheric pressure, by using the exhaust steam for feed heating, advantage is at once secured even over a drive by electric motor. Let it be assumed that a small turbine is employed to drive on the same shaft the air pump, circulating pump, and water extraction or lift pump attached to a main generating set. And for the sake of illustration let a plant of 3,000 kw. be considered. Then the power may be arrived at thus:—

Steam consumption, 42,000lbs. per hour.

Circulating water, 65 times feed = 273,000 galls. per hour.

Head across circulating pump (for cooling tower conditions) 45ft.

Power for circulating pump, at 60 per cent. efficiency, 100 h.p.

Power for lift pump, dealing with condensed steam and raising it 30ft., with 50 per cent. efficiency, is $1\frac{1}{2}$ h.p.

Power for air pump, 30 h.p.

Hence the power required for the combination is about 135 h.p.

* Paper read before the North-East Coast Institution of Engineers and Shipbuilders.

At 35lbs. per b.h.p. hour, the steam consumption of this auxiliary unit, exhausting at atmospheric pressure, is therefore 1,725lbs. per hour Such a quantity of steam would heat the feed-water from 90° Fah. to 200° Fah. Thus the equivalent of $\frac{4725}{6.5}$ or 727lbs. of coal per hour drives the circulating auxiliaries, and heats the feed 110 Fah.

The alternative, if electric drive be substituted for the small turbine, is 135 h.p. or 112 kw. at 3lbs. = 336lbs. coal for power, plus $\frac{4500}{6.5}$ = 692lbs. coal for feed heating. Total, 1,028lbs. coal as against 727lbs.

Reciprocating air pumps are made with a high degree of efficiency, and may even take less power than the rotary type. But the power, small as it is in comparison with that of the main engine or turbine, is almost wholly dissipated in friction in reciprocating pumps, whereas it can be conserved in the form of heat in some forms of rotary pump; and where, as is the usual practice, separate motors or engines are used to drive the air and circulating pumps the actual size of motor installed for a reciprocating air pump is settled by the consideration that a reserve of power must be provided in the motor, unless dangerously heavy fuses are used, to deal with the case of flooded pumps, such as occurs after a stoppage (from any cause) while the prime mover is running. This means additional cost, and (in the case of induction motors) a bad power factor.

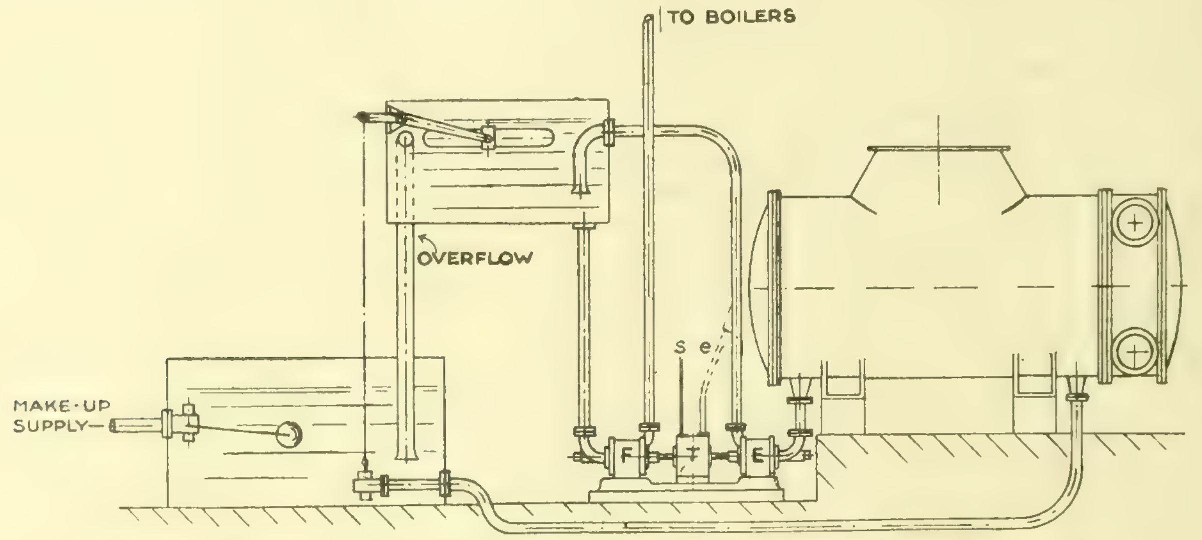


FIG. 1. CLOSED CYCLE SYSTEM OF BOILER FEEDING. ARRANGEMENT PROPOSED BY MR SARGENT. E, extraction pump; F, feed pump; T, auxiliary turbine; s, steam to auxiliary turbine; e, exhaust from auxiliary turbine.

No such reserve of power is necessary with a rotary pump. Consequently the method of independent motors with reciprocating air pumps involves not only two motors instead of one, but that one of those motors should be larger than necessary. This arrangement, too, is likely to consume more energy than a single motor for the combination, and *a fortiori* more than the steam turbine drive, if feed heating is placed to the credit of the latter.

It will be noticed that in the example given above cooling tower conditions were assumed in calculating the power of the circulating pump. Their absence would have reduced the power for the pump from 100 h.p. to perhaps 60 h.p., depending on the location of the source of water. Natural draught towers are responsible therefore for an appreciable increase in the motive power installation, and fan-draught towers for a considerable increase.

So many factors bear on condensing propositions that it is difficult to generalise. It might be supposed that for a plant with cooling towers it would pay to pump the least quantity of water and to spend on abundant cooling surface the money saved on pump and tower. Thus, though capital charges would be the same, running costs would be saved. But the assumptions made lead to a high temperature of outgoing water, and if any hardness is present (often the case in colliery districts where pit water is used) a deposit is formed in the tubes which quickly reduces their efficiency. In such a case a lower temperature of circulating water would have been accompanied by higher tube efficiency.

The question of economisers is almost entirely one of thermal efficiency. It is interesting therefore to note that they have been excluded from much important American practice. They are, on the other hand, used extensively in English and continental work, though to very different degrees. Heating surface may be arranged for either in a boiler or outside it; with these qualifications, that if in a boiler it must be made of steel, but if outside it can be made of cast iron; and, further, that gases cannot, in a boiler, be cooled below the temperature of saturated steam at working pressure or in some cases superheated steam. In most designs of boiler these limitations result in a standard form, and a temperature of outgoing gases between 450° and 600° Fah. Such a standard form is accepted—and properly so—as being the outcome of the boilermaker's experience; and the additional heating surface is arranged for apart from the limitation due to the presence of saturated or superheated steam. But while a certain uniformity is to be found in boiler surface provided for a given output, the number of economiser pipes may vary from nothing up to 12 per 1,000lbs. evaporated. This variation in practice may be accounted for by the space available; but it is often influenced by consideration of the draught necessary.

Draught may be created either by a fan or by a chimney. Where there are peculiar conditions, such as the existence of long and tortuous flues, or the absolute necessity for draughts upwards of 1½in., the question is settled automatically in favour of the mechanical method, practical considerations making it impossible to create a high draught by chimney alone. With a chimney the gases cannot be cooled below a certain temperature; otherwise insufficient draught will result. On the other hand, with a fan, gases may be cooled to any degree desired. Practical limitations are soon set in this direction by the space occupied by the economiser; and the result is that, though at first it might be expected that natural draught would necessarily be associated with smaller economisers than mechanical draught, in practice examples can be found of natural draught stations employing as large an economiser surface as even modern fan draught installations. The mechanical arrangement has, however, one advantage in facility of regulation independently of the weather, and in rendering a short chimney practicable.

The value of control over the draught cannot be assessed except in general terms by those who have had extended experience with both methods. Apart from this, the cost of power absorbed by the fans much outweighs the difference in capital charges due to a high natural draught stack, as the following illustration, applicable to installations of about 10,000 kw., shows:—

For natural draught—	
Cost of chimney 250 feet high, with foundations ...	£3,000
For mechanical draught—	
Cost of chimney 100 feet high, with foundations ...	£1,200
Cost of fans and motors and extra flues...	1,400
	£2,600
Balance of capital expenditure in favour of mechanical system	£400
Representing the annual charge, at 15 per cent., of ...	£60
Against this is to be set running cost of motors, calculated on 200 h.p. for 5,000 hours at ·25d. per unit .	£780

The circumstances of load may, however, demand great elasticity in the steam raising plant, in which case mechanical draught takes the place of additional boilers, and so may justify itself. Moreover, under normal conditions combustion is effected more economically with a high draught, if boiler and economiser surfaces are ample, less air of dilution being required per lb. of coal.

The foregoing discussion is applicable only in cases where very moderate draughts are sufficient; and little variation is called for. The more usual case with an installation supplying

power for general uses is that a certain latitude of draught is necessary for the purposes of the load, but the obstruction due to large economisers coupled with the reduction at the chimney caused by lowering the temperature of the gases would result in insufficient difference of air pressure at the grate. In such cases the choice must lie between natural draught with small economiser, or mechanical draught with large economiser; and the following treatment is put forward as being applicable.

The conditions assumed are as follows :—

Gases issued from boilers at	550° Fah.
Air per lb. of coal, on average...	23lbs.
Temperature of atmosphere	60° Fah.
Specific heat of products of combustion	·25.

In the case of fan draught, it is further assumed :—

Gases leave economiser and enter fan at	320° Fah.
Maximum water gauge required at fan	3in.
Usual water gauge required at fan	2in.
Efficiency of fan...	50 per cent. on average.

In the case of chimney draught :—

Gases leave economiser at	450° Fah.
Height of chimney	220ft.

Then heat rejected from boiler per ton of coal fired is $(2{,}240 \times 24 \times \cdot 25) \times 490$, or 6,585,600 B.T.U. In the case of chimney draught the economiser absorbs $(2{,}240 \times 24 \times 25) \times 100$, or 1,344,000 B.T.U., and of this amount about 70 per cent., *i.e.*, 940,800 B.T.U., is conveyed to the feed water, the balance being dissipated in flues, radiation and influx of cold air through economiser chain holes. In the case of fan draught, the power of the fan to create 3in. water column, with an assumed efficiency of 50 per cent., may be found to be 16·6 h.p. per ton of coal burned per hour.*

The usual horse-power required is therefore $16 \cdot 6 \times \frac{2}{3}$, or 11 h.p. per ton of coal per hour. The number of B.T.U. required to produce this energy, by way of boiler, turbine, alternator, transformer, and motor, with a combined assumed efficiency of 10 per cent., is $\frac{2{,}545 \times 11}{\cdot 1}$ or 280,000 B.T.U. The quantity of heat usefully absorbed by economiser is $(2{,}240 \times 24 \times \cdot 25) \times 230 \times \cdot 7$, or 2,170,000 B.T.U.

Consequently, of the total heat rejected from the boilers per ton of coal burned per hour, viz., 6,585,600 B.T.U., the natural draught method, with small economiser, realises 940,800 B.T.U., while the fan method, with large economiser, realises 2,170,000; less power to fan 280,000, 1,890,000 B.T.U., or about double. Thermodynamically, therefore, under the assumed conditions, there is a gain of over $3\frac{1}{2}$ per cent., really due to the use of the large economiser which is made possible by mechanical draught.

Next, as to the relative cost of the arrangements. This will vary in every case, and no two opinions on the matter will be the same. On the basis of an evaporation of 60,000lbs steam per hour, or a combustion rate of 3·84 tons coal per hour, the capital cost of a fan installation with economiser of 9·6 pipes per 1,000lbs. evaporated per hour, and short chimney will be found to be roughly the same as for a natural draught installation with 220ft. chimney and economiser of four pipes per 1,000lbs., viz., £1,800. Capital charges can therefore be left out of a comparison, which might take the following form :

	Per 60,000lbs. Steam per Hour	
	Mechanical Draught.	Natural Draught.
	£	£
Saving of heat expressed as coal at 8s. per ton, 12,000 B.T.U. per lb., and 80 per cent. efficiency of evaporation	774	336
Maintenance	180	108
Power reckoned for 5,000 hours at ·25d. ...	255	16
	435	124
	339	212

showing an advantage, in the case of mechanical draught, of £127 per annum. To this saving, which will obviously be greater still with greater load factors and in districts where coal is dear, must be added, for whatever it is worth, the convenience of being able to control draught independently of atmospheric conditions, and to force it to a degree unattainable with any chimney.

It may be argued that this proposition depends entirely upon the manner in which the capital expenditure is made up. In the example cited above a variation of 25 per cent. in calculating the capital cost made so as to swell the mechanical cost and reduce the other, would just about make the final results equal. But even in that case there would remain the practical advantages indicated.

Of more importance is the objection that an increase of the cost of power from ·25d. to ·38d. would extinguish the saving altogether. And this leads us to enquire what is the cost of power for auxiliary purposes. For most calculations it may be taken as the cost at generator terminals, plus some addition for transformation if necessary ; less wages, as these are practically unaffected by the small proportion of output used on the station. The cost thus revolves itself into coal, repairs and capital charges on generating and transforming plant. Many stations can now produce energy at 3lbs. coal per unit—some, of course, for much less—but at that figure and 8s. per ton the coal cost is ·13d. Capital charges, at 15 per cent. on £15 per kw. with load factor 40 per cent., amount to ·154d., repairs to ·02d., making a total charge for auxiliary power of ·304d. The figures adopted here are liberal with respect to good modern practice, and the price of ·25d. assumed in former calculations, if low, is not by any means unattainable.

On the whole, it would seem that the deciding factor in settling the matter of draught is the nature of the load. In isolated cases such a question as ability of the ground to carry a high chimney might be important—or again, the quality of ease in removal might recommend a short chimney and fan.

It is only by elasticity of definition that feed pumps can be regarded as apparatus to render a thermodynamic principle advantageous. Yet they do not fall naturally into any other subdivision, being rather one of the main organs for carrying out the cycle. The power station designer has here a wide choice between steam and electrical drive, and between reciprocating and rotating pumps. The latter possess many of the advantages of rotary air pumps already discussed, and practicable forms have been evolved, though it is to be regretted that the manufacture of them has not been developed on the North-East Coast. Such pumps, in respect of minimum wear, absence of valves, elimination of shocks to feed pipes and check valves inseparable from reciprocating pumps, are almost ideal for power station work.

If a rotary feed pump can be combined with the circulating auxiliaries already described, and the whole be driven by a turbine on one shaft, a peculiarly compact and economical piece of apparatus results. There are naturally drawbacks in giving effect to this idea : one that will at once occur to designers and station engineers is that it may be difficult to find one speed suited to four different rotating objects ; to a circulating pump which may possibly have to deal with 70 times as much water as the feed pump ; or to an impeller drawing against 29in. vacuum and one delivering against 250lbs. pressure.

Though not necessarily dependent upon rotary feed pumps, the closed cycle system, whereby the feed water is at no stage exposed to the atmosphere, is rendered so much more attractive by their use that it may be noticed here. The idea underlying its application is that by reducing or altogether eliminating the aeration of the feed much trouble with economisers, feed pipes, and boiler shells may be prevented. Since the feed is at no stage exposed to view as a current, it cannot be measured by the ordinary methods, and where anything more accurate than a Venturi tube test is required an alternative arrangement of pipes must be installed for diverting the feed to the test tanks or recorders. For the same reason it cannot be heated at atmospheric pressure, and surface heaters are therefore necessary. Then some elasticity is required between the discharge of the extraction pump and the suction of the feed pump, to meet the case of boilers not requiring, minute by minute, exactly the same quantity as the steam condensed. And, again, make-up feed for wastage has to be provided for.

There are two or three methods of meeting these points. The simplest, but also the crudest, is to provide a relief valve on the feed discharge, and regulate the admission of make-up feed

* Height of a column of heated products of combustion equivalent to 3 inches water column=306 feet. Maximum horse-power required, with efficiency of 50 per cent.

$$\frac{306 \times 24 \times 2{,}240}{60 \times 33{,}000 \times \cdot 5} \text{ or } 16 \cdot 6 \text{ h.p. per ton per hour.}$$

to the condenser by hand. A more elegant suggestion, due to Mr. Sargent, and shown in Fig. 1, is to provide a tank into which the extraction pump delivers, and from which the feed pump draws. The tank is furnished with an overflow to a main reserve tank below, and a float mechanism controlling a make-up feed valve from reserve tank to condenser. When there is a surplus of water discharged from the condenser it overflows to the reserve tank, and when there is a shortage the float valve opens the connection from reserve tank to condenser. In this manner the system is rendered absolutely automatic, while the external make up for wastage can be introduced by a float controlled valve in the reserve tank fixed at a suitable level. By introducing the external make up at this stage it becomes completely de-aerated before reaching the feed pump. Some stand-by pumping plant might be required for the case of banked fires. This system is noticed here as being one which makes for simplicity without the introduction of anything more difficult to arrange for than a stand-by pump and some alteration to the pipe system. It is true that it multiplies the total number of pumps in a station, but not the number of motors or engines necessary for driving them.

(To be continued.)

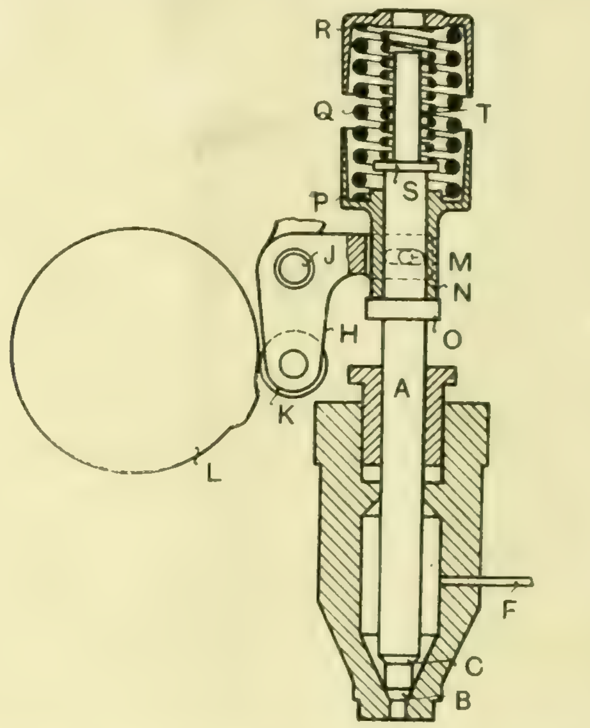
FUEL VALVE OPERATING MECHANISM FOR DIESEL MOTORS.

In Diesel motors which are started with compressed air, the fuel valve must be kept closed during the starting operation in order that the compressed air used for starting shall not enter the fuel supply pipe. For this purpose the mechanism for operating the fuel valve must be placed out of action during the starting operation. This is effected in existing motors by shifting the fulcrum or pivot of the fuel valve-operating lever by means of eccentrics so as to interrupt the transmission of motion from the cam or tappet disc to the fuel valve.

In the arrangement illustrated, the invention of Maschinenfabrik Augsburg-Nürnberg A.-G., of No. 100, Katzwangerstrasse, Nürnberg, Germany, any shifting of the fuel-valve operating mechanism is obviated. The fuel valve needle or spindle is provided with a piston, upon which the injected compressed air for combustion can act with a tendency to open the valve while the valve-operating mechanism is so arranged that the latter does not lift the valve directly but only relieves the valve from the pressure of a spring which has a tendency to close the valve. The area of the piston and the power of the spring are made such that the spring will overcome the pressure of the injected compressed air for combustion upon the piston and thus keep the valve closed against the pressure of the starting air in the cylinder so long as the spring is allowed to act. During the injection of the air for combustion the valve is relieved of the pressure of the spring by the valve-operating mechanism, and the injected air is then able by its pressure upon the piston to push open the fuel valve and thus allow the fuel to pass out. The supply of air for injection is shut off during the starting operation, so that this air can no longer act upon the piston, and therefore the fuel valve will remain closed also when it is relieved of the pressure of its closing spring by the valve-operating mechanism. For this reason it is not necessary to place the valve-operating mechanism out of action during the starting operation.

Referring to the illustration, which shows a longitudinal section of the fuel supply valve, A is the valve spindle, having a conical end B for closing the valve outlet. Behind the cone B a shoulder C is formed on the spindle. The annular surface formed by this shoulder is exposed to the pressure of the air for combustion entering through the pipe F. So long as this air is admitted into the valve it has a tendency to open the latter. A stuffing-box prevents this air from escaping to the outside. H is a bell-crank lever for operating the fuel valve; it is fulcrumed on a pivot J and carries at one end an anti-friction roller K bearing against a cam disc L. The other end of the lever H is forked so as to embrace by means of its two slotted prongs, two studs M, one on each side of a sleeve N. This sleeve is slidable along the valve spindle A, and is formed at one end with a spring cup P; at its other end it bears against the collar O on the valve spindle. Q is a spiral spring bearing at one end against the cup P and at its other end against the cup R. The valve spindle is further provided with a collar S against which bears a weaker spring T.

The operation is as follows: So long as the motor is running normally, air for combustion is injected through the pipe F into the valve casing, where it presses against the annular surface of the shoulder C with a tendency to open the valve. The pressure of the injected air is however overcome by the powerful spring Q, which acts to close the valve through the medium of the sleeve N and the collar O. When, however, the sleeve N is lifted by the cam disc L off the shoulder O, and the valve is thereby relieved of the pressure of the spring Q, then



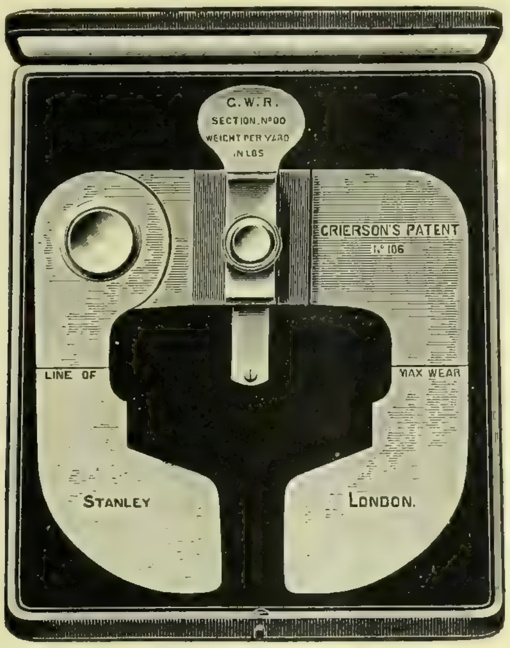
FUEL VALVE OPERATING MECHANISM FOR DIESEL MOTORS.

the pressure which is exerted upon the annular surface C by the injected air is sufficient to overcome the weak spring T, and open the fuel valve. During the starting of the motor, however, the injected air admitted through the pipe F is shut off. Now, when the sleeve N is lifted off the collar O by the valve-operating mechanism, only that pressure acts upon the valve spindle which is exerted upon the end surface of the cone B by the starting air in the motor cylinder. Since this end surface is very small and the pressure of the starting air is generally considerably lower than that of the air injected for combustion, the pressure of the starting air is not able to overcome the pressure of the spring T. The valve therefore remains closed during the starting operation.

The Acidity and Alkalinity of Natural Waters.—At a meeting of the Scottish Section of the Society of Chemical Industry recently held at Glasgow, a paper on this subject by Prof. James Walker, LL.D., F.R.S., and Dr. S. A. Kay, of Edinburgh University, was read by the former. Natural waters, Professor Walker said, might be neutral, alkaline, or acid. The acidity or alkalinity was commonly determined by means of indicators, and it frequently happened that one and the same water was reported as acid by one analyst and alkaline by another. This depended on the indicator used. Acidity depended on the concentration of hydrogen ions and alkalinity on the concentration of hydroxyl ions contained in the water. Absolutely pure water was neutral, and contained these ions in exactly equivalent proportions. A water containing excess of hydrogen ions was acid, and an alkaline water contained excess of hydroxyl ions. In the course of the paper a method was described for determining the concentrations of the hydrogen and hydroxyl ions in the water, and hence the acidity or alkalinity. The method was a colorimetric one and was based on the use of standard solutions of known acidity and alkalinity, which gave definite colours with the indicator azolitmire. A convenient method of expressing the neutrality, acidity, or alkalinity of a natural water in terms of pure water as standard was described.

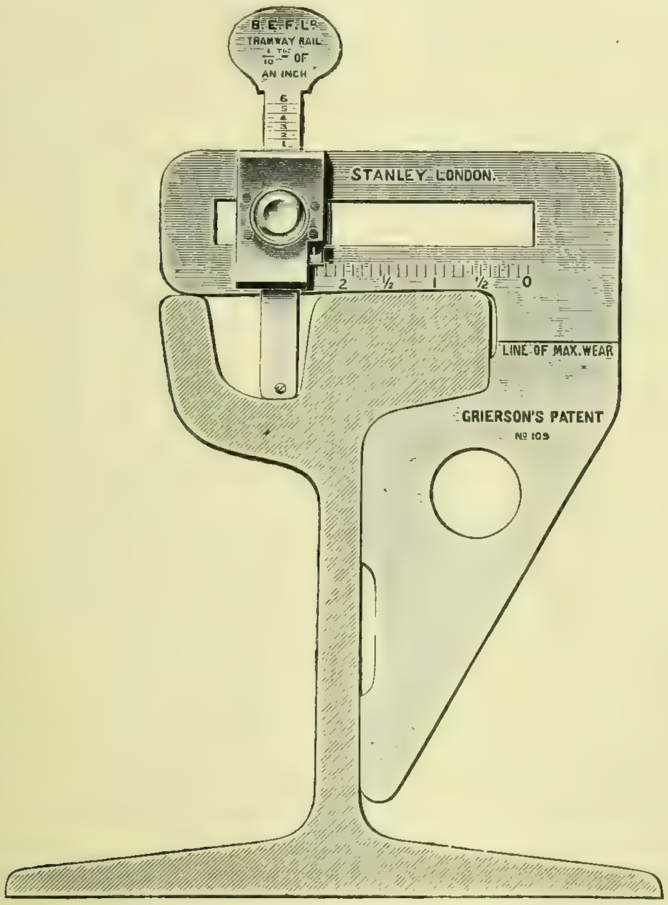
A NEW RAIL GAUGE.

MR. T. B. GRIERSON, M.Inst.C.E., has recently patented a gauge for obtaining the weight of rails in the permanent way. The gauge consists of two arms firmly pivoted, and made to embrace exactly the head of the rail.



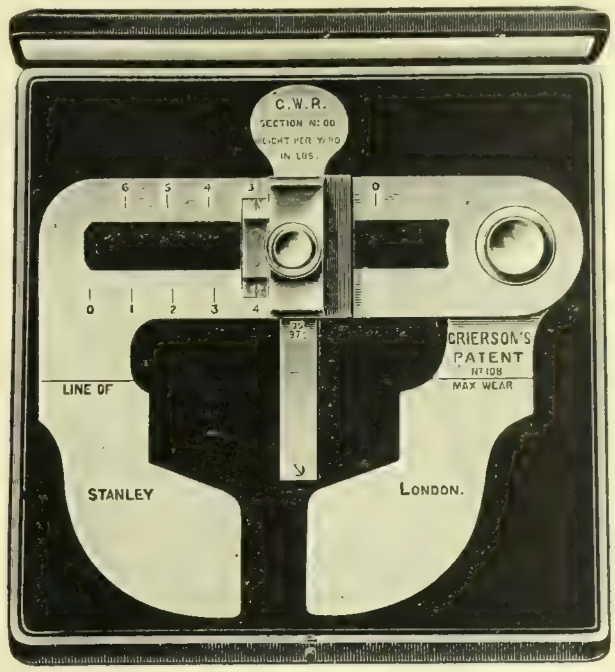
GRIERSON'S GAUGE (Class A), FOR ORDINARY RAILS.

It carries a slide and sliding rod, the sliding rod being divided on one side to indicate pounds weight per yard, and on the other side to parts of an inch to show the rate of wear. The gauge is used in the following manner: The place to be gauged is brushed clean with a steel brush, the gauge is applied to the rail head, and held firm while the slide rod is pushed



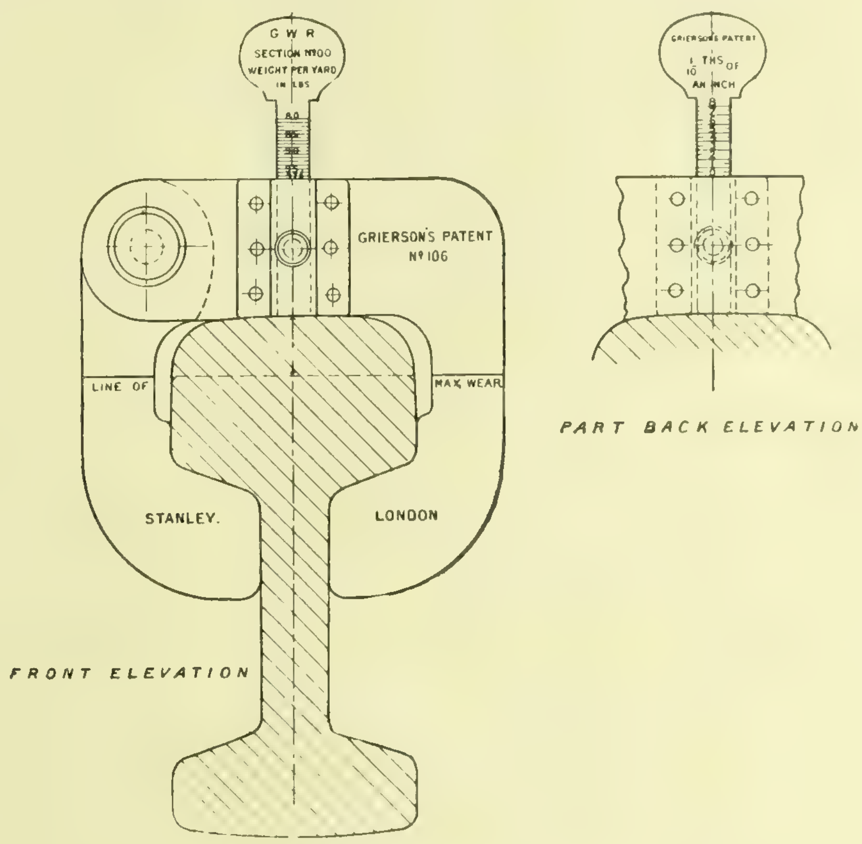
GRIERSON'S GAUGE (Class B) FOR TRAMWAY RAILS.

down, until it touches the head of the rail; it is then clamped by means of a milled head, removed, and the reading, which indicates the number of pounds per yard weight of the rail, taken. This occupies less than a minute. The advantages claimed for the gauge are: (1) The rate of wear and the resulting weight of the rails per yard can be ascertained in a moment, without removing them from the permanent way; (2) rails can be weighed or measured at any time without stopping the traffic or working single line as at present; (3) the life of the rails may be lengthened without any risk, by leaving them in the road until they are worn down to the line of maximum wear shown on the rail gauge; (4) the gauges can be applied to any section of rail and to all kinds of permanent way.



GRIERSON'S GAUGE (Class C), with sliding indicator, for rails subject to irregular wear such as on curves and those of electric railways.

including tramways; (5) in addition to the saving which may be effected by this method, in the maintenance of the permanent way, an increase in the traffic receipts is promoted by dispensing with the stopping of goods and passenger trains



METHOD OF APPLYING GRIERSON'S RAIL GAUGE.

for the purpose of weighing the rails, as at present. The sole manufacturers of the instrument are Messrs. W. F. Stanley & Co. Ltd., Gt. Turnstile, Holborn, W.C.

Engineer Electrocuted.—An electrical engineer was electrocuted at the Dublin Corporation Electrical Supply Works, Pigeon House Fort, Ringsend, on Friday last. He was in the employment of Messrs. Ferranti, Limited, Hollinwood, Lancashire, electrical contractors, and was engaged in connection with some extensions at the Pigeon House Works when he accidentally put his hand on a live terminal and was instantly electrocuted, a current of 5,000 volts passing through his body.

BOOK REVIEWS.

The Portable Steam Engine: Its Construction and Management. A Practical Manual for Owners and Users. By W. D. Wansbrough. London: Crosby Lockwood & Son. 9in. by 5½in. 165 pages. Price 4s. 6d. net.

This little book is like the curate's egg, "parts of it are excellent," but a good deal might be omitted without serious loss, notably the middle chapters, consisting of about one-third of the book, and which is little more than a glorified catalogue with numerous inconvenient folding illustrations obviously reproduced from makers' blocks, and interspersed with trade puffs or remarks in which the average reader has no interest. Against this kind of book-making we wish to enter a strong protest. There is far too much of it at the present day. Who, for instance, cares a fig to know that Messrs. So-and-so claim to have been the first to use steel in their fireboxes, or that Messrs. So-and-so do not now make such and such a type of engine and invite you to compare what they now make with what they used to make. It is mere salesman's chatter and does not interest one reader in a hundred. The author does more justice to himself and gives much more information in the last 60 pages of the book, dealing with the use and management of portable engines, the action of slide valves, &c., than in all that precedes them, if we except the first two chapters dealing with the evolution of the portable engine, and which, with the end portion named, constitute all that entitle the book to any permanent value. The rest gives little or nothing that could not be gathered by a cursory visit to almost any agricultural show.

* * *

Boiler Draught. By Keay Pratt, M.I.Mech.E. London: Constable & Co. 7½in. by 5in. 138 pp. Price 4s. net.

The draught of a boiler is but one of so many features associated with its working that a book specially devoted to its discussion is, we fear, scarcely likely to appeal to a wide circle, especially as the ground here covered contains nothing that can be described as new or specially important, and which is not equally as well dealt with in existing and more comprehensive treatises on boiler working. However, within the limits he has set himself, the author deals with the subject in a clear and simple manner, and to such as seek information only on questions concerning air supply and draught of steam boilers the book may prove of service.

* * *

Diesel Engines for Land and Marine Work. By A. P. Chalkley, B.Sc., Assoc.M.Inst.C.E., with an introductory chapter by Dr. Rudolph Diesel. London: Constable & Co, Ltd. 8¾in. by 6in. 226 pp. Price 8s. 6d. net.

Although the Diesel engine is but a particular type of oil engine in essentials its fuel economy is so superior to the ordinary oil engine, and the difficulties attending its first introduction have been so successfully surmounted in the process of constructional development that it promises, in one or other of its modifications, to be the only acceptable type of oil engine where large powers are concerned. It has already secured a wide adoption in land practice, and its use for the propulsion of steamships is making steady and rapid progress. Indeed it is in this direction that its future commercial triumphs promise the greatest success. The conspicuous feature of the Diesel engine is that the oil is vaporised not by the application of external heat but that developed by the sudden compression of the air within the cylinder while the combustion of the charge of fuel is to some extent under control and can be distributed over the combustion stroke and so give less fluctuation of pressure in the cylinder. It may in fact be regarded as a true internal-combustion engine in which the heat of fuel is transformed directly into useful work in a cylinder without any previous process of transformation. The satisfactory working of the Diesel cycle necessitates much higher pressures for compression and for pulverising the oil supply than have been attempted or are necessary in other internal-combustion motors, and it is this feature which has called forth the distinctive mechanical details in its construction. These are all admirably described and discussed in the work before us, which in view of the rapid and growing interest in this type of motor will, we doubt not, prove interesting to a wide circle of readers. The book is well written, all the details are fully dealt with, and the illustrations are both numerous and excellent. The introduction by Dr. Rudolph Diesel is interesting reading as a summary of past attainments and future possibilities, and also as a warning against rash attempts, of which many will doubtless be made, to build this type of motor without the adequate care required in manufacture. As this warning is important we take the liberty of quoting it. "The Diesel motor," he remarks, "must be constructed with extreme care and the best materials employed in order that it may properly fulfil all its capabilities; only the best and most completely equipped works can build it." These fundamental conditions regarding construction he truthfully observes are no disadvantage, but on the contrary tend to raise the excellence of workmanship. The warning, however, should be taken to heart by both makers and users.

BOOKS RECEIVED.

Four Place Tables of Logarithms and Trigonometric Functions. Compiled by E. V. Huntingdon, Assistant Professor of Mathematics in Harvard University. London: E. and F. N. Spon, Ltd. Price 3s. net.

Transactions of the Liverpool Engineering Society. Vol. XXXII. Edited by T. R. Welton, M.A., Assoc.M.Inst.C.E. Published by the Society, Royal Institution, Colquitt Street, Liverpool.

Brook's Mechanical Engineers' Price Book. London: Messrs. E. and F. N. Spon, Ltd. Price 4s. net.

PROBLEMS OF DEEP MINING.

LECTURING at the Birmingham University on "The Problems of Deep Mining," Professor John Cadman declared that the problems which were connected with the threatened national stoppage in the coal trade were small as compared with some of the great problems relating to deep mining. During the last financial year, the lecturer mentioned that 264 million tons of coal was mined, of which 84 million tons were exported, the quantity consumed in this country amounting to four tons per head of the population. Professor Cadman stated that one of the most difficult problems that remained to be solved in connection with deep mining was the keeping of the mine atmosphere at a livable temperature. Air that was pumped into the mine, he said, was responsible for the oxidation of the coal, and that produced heat that was greater than the rock temperature itself. This difficulty was met by a method of cooling. If deep mining was to be carried on, less dust must be manufactured and prevented from being distributed in the mine. There were many ways of doing this, including the construction of roadways lined with non-oxidisable materials, the conveyance of the coal in dust-tight trams, and the complete filling of the place left after the extraction of the coal. The lecturer referred to the work done in experimental mines, and said that a good deal of knowledge had been obtained in connection with work in hot temperatures. He alluded to the establishment, which had just been announced, of a lectureship endowed by the coal-owners to deal with mine rescue appliances in the Midland Counties. He did not intend expressing any opinion at this stage on the matter, but he might say that the lecturer would have to deal with a very scientific problem in mining. He would be the instructor of the instructors in the various districts, and would inspect the various rescue stations with the view of keeping them in an efficient state.

Interesting Locomotive Boiler Tests. The Jacobs-Shupert U. S. Firebox Company, Coatesville, Pa., has arranged for a series of tests to be conducted under the direction of Dr W. F. M. Goss regarding the efficiency as well as the strength and resistance of the Jacobs-Shupert sectional firebox in comparison with a similar firebox of the standard staybolt type. A special testing plant has been erected for the purpose of the tests. On the conclusion of the efficiency tests the boilers are to be subjected to low water tests. Provision will be made for spectators to observe these tests without danger or injury in case of explosion. The boilers are to be identical in construction except for the fireboxes. The tests will be completed on or about April 1.

NOTES ON TWO-CYCLE OIL ENGINES.*

BY FRANK DUNCANSON, B.SC.

IF the internal-combustion engine is to displace the steam engine for marine propulsion, it must answer to the following requirements: it must have a large shaft horse-power at a reasonably low speed (in order to get propeller efficiency), its weight per brake horse-power must be low, the space taken up must be small, and, most important of all, the fuel consumption must be low. In comparing the advantages of 2-cycle internal-combustion engines with those of 4-cycle engines, we have these important factors to consider.

A 2-cycle engine theoretically should give twice as much power at a given speed as a 4-cycle engine having the same piston displacement. Hence for a given power and speed we should need only half the piston displacement in a 2-cycle engine and consequently should get a lighter and more compact machine. In order to get these ideals realised the mean effective pressure in the cylinders must be the same in a 2-cycle as in a 4-cycle engine, and the mechanical efficiency must be the same in both cases.

The difficulties which must be overcome in the design of a successful 2-cycle engine are: (1) Due to imperfect scavenging, the fresh charge is diluted with inert exhaust gases, and hence combustion is imperfect, consequently the mean effective pressure is low; (2) due to the same cause, weak mixtures, which would otherwise effect an economy in fuel, will not ignite at all, and therefore cannot be used; (3) if the exhaust valve or port is still open when the fresh charge is pumped in, some of the fuel will inevitably escape with the exhaust, and thus the fuel consumption will be high. This applies also to engines which have a "buffer" of scavenging air blown in between the exhaust and the mixture, because it is impossible to avoid diffusion, and mixing of the gases due to eddies; (4) the mechanical efficiency of the 2-cycle engine will be less than that of the 4-cycle engine on account of the auxiliary machinery which must be used in scavenging the cylinder and pumping in the fresh charge.

All these disadvantages will naturally combine in giving an engine which compares unfavourably with the 4-cycle in fuel consumption, weight and bulk. The conditions to be aimed at in the design of a 2-cycle engine are: At the end of the power stroke we must get rid of the exhaust gases, then the cylinder must be scavenged, *i.e.*, the residual gas now at about atmospheric pressure must be swept out of the cylinder, and the cylinder left full of fresh air at or above atmospheric pressure. While this air is being compressed on the return stroke of the piston and the exhaust ports are closed, a small quantity of fuel must be sprayed into or otherwise intimately mixed with the air to form an explosive mixture which may be ignited towards the end of the compression stroke or at the commencement of the power stroke. It would be an advantage if the fuel were not injected until the compression stroke is completed, thus the danger of pre-ignition would be entirely avoided, the extra work in pumping in the small quantity of fuel at compression pressure instead of at slightly above atmospheric pressure being quite negligible. Another advantage of pumping in the fuel at the end of the compression stroke is that the space is much smaller, and therefore the mixing can be more easily effected.

The advantages which we have given to us straight away on the adoption of the 2-cycle principle are: (1) The absence of valve pockets and big valves in the cylinder head renders the design of this very simple, moreover the combustion chamber or clearance space is much more compact, thus giving ideal conditions for the ignition of the charge, because, as is well known, the flame originating at the ignition plug takes an appreciable time to travel to the more remote parts of the combustion chamber, and the more compact the combustion chamber can be made the more rapid the ignition, and hence the better the thermal efficiency of the engine. (2) If scavenging is perfect, then the total volume of the cylinder, *i.e.*, the piston displacement, together with the clearance volume, is filled with fresh air which can be usefully employed in the power stroke, whereas in the ordinary 4-cycle engine the combustion chamber is always left full of exhaust gases, at about atmospheric pressure, which mix up with the fresh charge and dilute it, thus lowering both the capacity and the thermal efficiency of the engine. (3) Much weaker mixtures could be used in well-scavenged 2-cycle engines, thus increasing the thermal efficiency to even more than that of a 4-cycle engine. (4) A more uniform torque can be obtained with a 2-cycle engine because work is done on every downward stroke of the piston. This uniformity of torque, besides enabling a fly-wheel to be dispensed with, also conduces to better propeller efficiency. (5) The dimensions of the engine would be much less than those of a 4-cycle engine of the same power, and this would compensate for the space taken up by the auxiliaries.

By careful design and understanding of the conditions to be aimed at, there is no reason why the all-round efficiency of the 2-cycle engine should not be as good as, or even better than, that of the 4-cycle engine.

Considering now the pumping operations, the suction stroke of the 2-cycle engine differs from that of the 4-cycle only in that it is carried out in a separate pump which is designed for this purpose only. The pump cylinder is not heated up, and the cylinder walls and valves, since they are subject to small pressures only, can be made of proper proportions, and hence they will be light in weight. All these things combine to raise the efficiency of the pumping actions; the volumetric efficiency—*i.e.*, the capacity of the engine—

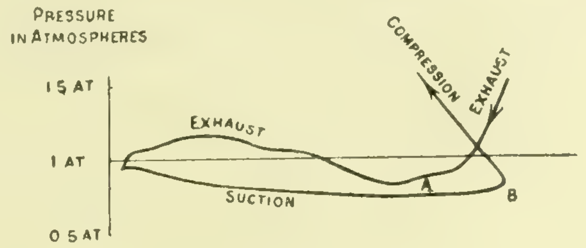


FIG. 1.

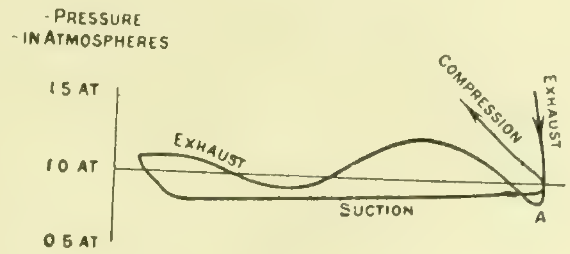


FIG. 2.

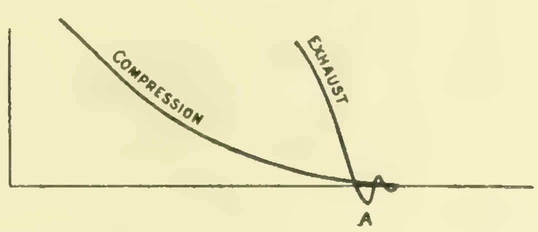


FIG. 3.

increases, due to the fact that for the same piston displacement the power cylinder receives a greater quantity of cold air than if the suction stroke has been carried out in the cylinder itself. The frictional losses and volumetric efficiency of the pump-cylinder should not be far different from those attainable in all good air pumps, say a suction pressure of 14·1 to 14·4 lbs. absolute, and a volumetric efficiency of from ·95 to ·97. Since the most favourable pressure of the scavenging air is from 1lb. to 3lbs. by gauge, the rise of temperature due to compression is negligible, and in any case it disappears during the transfer of the air to the reservoir or the power cylinder.

It is, of course, assumed that the scavenging air and charge is furnished by a separate pump independent of the power cylinder. The conditions are much worse, when, as is sometimes done, the front end of the cylinder is used as a pump, in which case the efficiency is lowered by the strong heat transfer from the power cylinder to the pump cylinder. The conditions are still more unfavourable when the enclosed crank case is made to serve as a pump, but this design is used only in very small powers and need not concern the question of the marine engine at all. The conclusion to be arrived at is, that to utilise to the fullest extent the advan-

* Paper read before the Institute of Marine Engineers.

tages of the 2-stroke cycle, only independent pumps, which may be designed as such without restriction, should be used.

Turning now to the question of scavenging, it is of the utmost importance that all the burned gases should be driven out of the cylinder, for on this depends the efficiency, reliability, and capacity of the engine. Assuming that the cylinder volume is to be cleared out with air, the introduction of some air in excess is indispensable, hence there must be available a volume of scavenging air greater than the cylinder volume, because during the scavenging period some air is certain to be lost through the exhaust ports, and unless some excess air is at hand, some of the burned gases are certain to remain. If independent pumps are used, the supply of air may be made as much as is desired, but when the front end of the cylinder or crank case is used to compress the air, an excess is not obtainable.

It is found that as long as the scavenging air is led from the pump directly to the main cylinder, its proper action is seriously hampered. With the pump and main cylinder cranks at 180° apart, it is possible to scavenge only at the

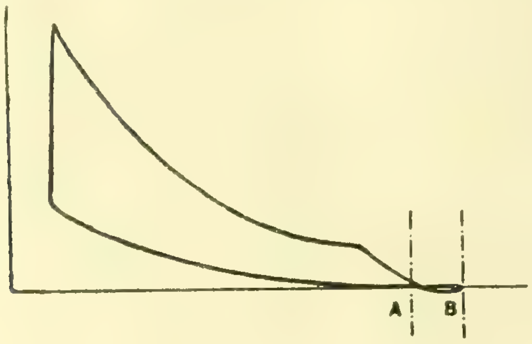


FIG. 4.

dead centre; where the pump crank leads the main crank, the scavenging air must have comparatively high pressure on account of the short time available for transfer. It seems necessary, therefore, to interpose between pump and power cylinder a receiver of such size that, during the entire scavenging period, the air pressure can be maintained without much drop. This pressure should be as low as is consistent with sweeping out the exhaust gases. An abnormally high scavenging pressure not only increases the lost pump work, but, what is worse still, interferes with a thorough driving out of the burned gases. If the air is highly compressed it enters the cylinder with great velocity, and rebounding from the inner walls, causes eddy currents of such magnitude that, from the outset of the scavenging period, burned gases mix with the incoming air, and thus a part of them is retained in the remaining air of the new charge. The perfect scavenging action on the other hand shows very different characteristics. The air should enter the cylinder slowly, avoiding all counter or eddy currents, and should, if possible, in the form of a solid column drive the exhaust gases ahead of itself out through the ports. This action, however, can only be obtained with low pressures and sufficiently large ports.

By carefully timing the introduction of the scavenging air, a great saving in the pumping work might be effected, for the following reason. During the exhaust the velocity of the outflowing gases is very high, in the neighbourhood of 2,600 to 3,000ft. per second, and is independent of port area, so that if the exhaust line is made as straight and as long as possible the kinetic energy of the exhaust gas column may be sufficient to overcome all frictional resistances in the line, so that the pressure in the cylinder, owing to the over-expansion of the gas, may drop to less than atmospheric. This phenomenon can be easily seen by taking a weak spring indicator diagram from an engine. Figs. 1 and 2 show this for a 4-cycle engine, and Fig. 3 shows it for a 2-cycle engine. It will be seen that at a certain point A in the exhaust, the pressure falls well below atmospheric. Now if the introduction of the scavenging air is so timed that it occurs just at the point when the pressure in the cylinder is below atmospheric, then there will be less exhaust gas to be swept out, and the scavenging will be much more perfect. The attainment of these ideal conditions depends a great deal upon the size and form of the inlet and exhaust passages, and a consideration of the points should have a marked effect on their design. The allowable minimum pressure of the scavenging air depends mainly upon the size and frictional resistance of the ports and passages and upon the time available for scavenging.

If β lb. per square inch is the pressure in the receiver or pump, and T is its temperature, and if β'' is the pressure in the cylinder, then the velocity of the air will, in general, be

$$v = 58\,C\sqrt{T\left(1 - \frac{\beta_{''}}{\beta}\right)} \text{ ft. per sec,}$$

where C represents a velocity coefficient.

If the time allowed for scavenging is $t = \frac{1^{\text{th}}}{\text{x}}$ of the time taken for one complete stroke, then the volume of air delivered into the cylinder will be

$$\text{V} = a \;\; \text{V} \;\; t\,f \text{ cubic feet;}$$

where f = area of ports

a = the coefficient of contraction.

In practice it is found that C varies from ·85 to ·95 and a is approximately equal to from ·6 to ·65, but varies with the shape of the ports.

From the above relations it would be quite easy to arrive at the pressure of the scavenging air which would give the best results. When the piston controls the exhaust ports the time taken for exhausting and scavenging should be from 10 to 12 per cent. of the time taken for one stroke, and if the ports are made in a ring round the cylinder a large area is available for the exhaust to get away. The idle part of the stroke, as it were, when the piston is uncovering these ports, A to B, Fig. 4, is not detrimental, since, as compared with 4-cycle engines, the beginning of the compression occurs with full, or above atmospheric, pressure instead of the suction pressure as at B, Fig. 1.

It is desirable to have the pressure drop in the air receiver as small as possible in order that the scavenging may continue with undiminished force to the end of the period. To attain this end the receiver should be made as large as possible. The two diagrams, Figs. 5 and 6, make this point clear. The first is taken from a receiver of too small a volume. The pump delivers air from a to b. From b to c the pressure remains constant at about ·3 atm. (4·21bs. per

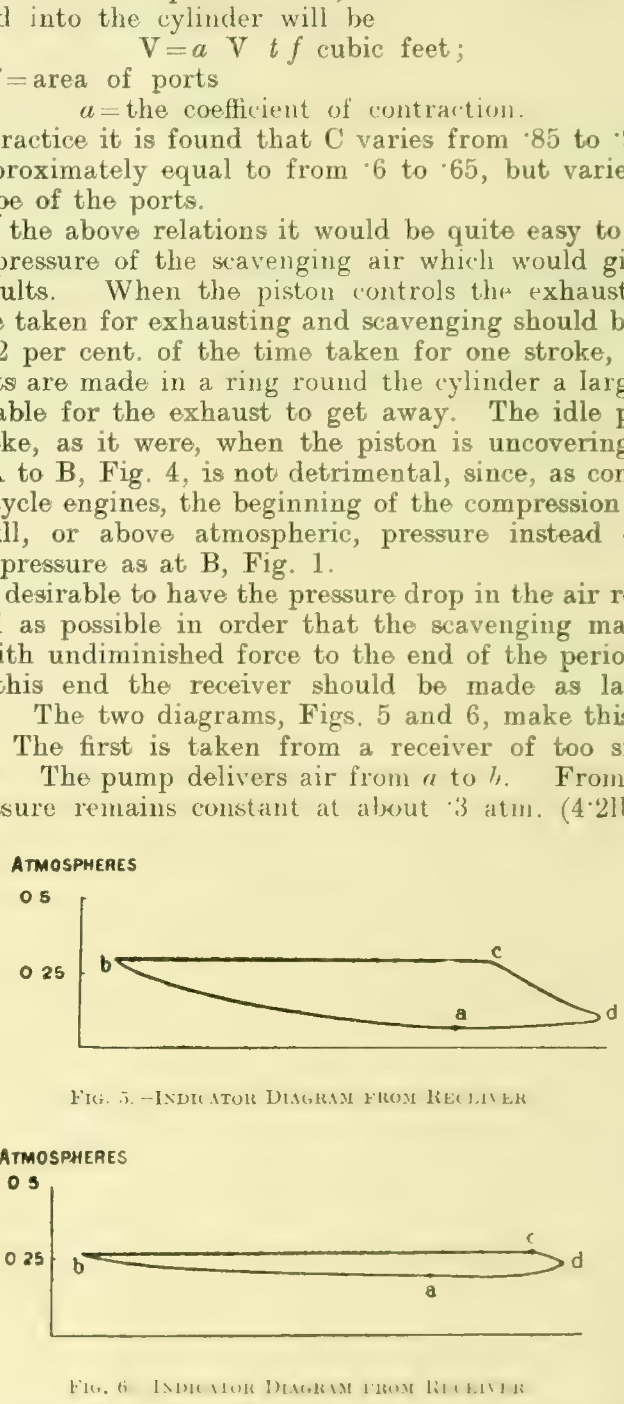


FIG. 5.—INDICATOR DIAGRAM FROM RECEIVER

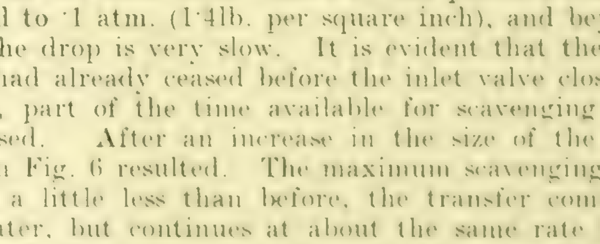


FIG. 6 INDICATOR DIAGRAM FROM RECEIVER

square inch) above atmosphere. Scavenging commences at C, but at the outer dead centre d, the pressure has already dropped to ·1 atm. (1·4lb. per square inch), and beyond this point the drop is very slow. It is evident that the transfer of air had already ceased before the inlet valve closed at a; that is, part of the time available for scavenging had not been used. After an increase in the size of the receiver, diagram Fig. 6 resulted. The maximum scavenging pressure is now a little less than before, the transfer commences a little later, but continues at about the same rate until the closure of the inlet valve, since in this case the receiver pressure does not drop below ·2 atm. (2·8lbs. per square inch) above atmosphere. The pressure at the beginning of compression in the power cylinder is correspondingly higher, and since on account of somewhat later introduction of the air it is less highly pre-heated, there will be a greater charge volume in the cylinder, which finally means greater engine capacity.

By a careful consideration of the facts upon which these

notes are based and with greater improvements in the design of 2-cycle engines, there can be no doubt that a 2-cycle engine can be made just as efficient as a 4-cycle engine, and there are even grounds for hope that in the future, instead of saying "a 2-cycle engine can never be made as efficient as a 4-cycle engine," the tables will be turned and we will say, "a 4-cycle engine can never be made as efficient as a 2-cycle engine."

INDUSTRIAL AND TRADE NOTES.

Order for Locomotives.—The North British Locomotive Company, Glasgow, has received an order to build 20 passenger engines for the North British Railway Company. The contract has come very opportunely, as slackness has prevailed at several of the Locomotive Company's works for a considerable time.

Brown, Bayley's Steel Works, Ltd.—The directors of Brown, Bayley's have decided to recommend to the shareholders the payment of a final dividend of 7½ per cent., making with the interim dividend of 5 per cent., already paid in July last, 12½ per cent. for the year. The dividend is the same as for the previous two years.

New Light Railway.—The Light Railway Commissioners met at York on the 20th ult. to consider an application for the construction of a light railway, nine miles in length, from Haxby Station, four miles from York, on the Scarborough line, to Brandsby, in the North Riding. The Commissioners granted the application.

Further Rise in Scotch Oil Prices.—The Scotch mineral oil companies announce a further advance in their fuel and heavy oils. Prices for Glasgow delivery have been raised 10s. per ton, and for the rest of Scotland 5s. per ton. Within a year these kinds of oil have advanced about 30s. per ton for Glasgow delivery and 20s. for delivery outside of the Glasgow area.

Water Meters.—Messrs. Siemens Bros., Ltd., of Woolwich, have issued a new edition of their water-meter catalogue. The firm manufacture a number of types suitable for all kinds of service. The construction and relative advantages are all clearly illustrated and described, and for those interested in this kind of appliance the pamphlet contains a quantity of collateral information which should make it useful at times for reference.

British Bicycle Factory in Japan.—A British cycle manufacturing firm have established at Kobe a branch factory equipped with the most modern machinery. This factory began work in January. It will be able to turn out complete bicycles, importing only the steel tubing and the chains and certain accessories. The factory has a capacity of from 1,000 to 1,500 bicycles a month with its present plant, which can be enlarged if necessary.

Shipbuilders to Move from the Thames.—Messrs. Rennie & Co., shipbuilders, of Greenwich, announce that on the completion of the work they have in hand they intend closing the works and transferring their business to Wivenhoe, Essex, on the Colne. Messrs. Rennie have built and engined all classes and sizes of ships and floating docks during their long association with the Thames, and are now moving into larger and more modern premises.

Boilermakers at Crewe Works.—Last week the boilermakers in the Crewe works of the L. & N.W. Railway were put on full time. This will affect between 700 and 800 hands who for several years have been on short time. The men recently asked the railway company to put them on full time, but were informed that such a step would necessitate a reduction of the staff, which has since taken place. To those who were discharged the company granted facilities for obtaining other employment by giving them and their families free passes on the railway.

Aluminium Jigs.—In a pamphlet recently issued by the British Aluminium Company they claim that the use of aluminium for the construction of drilling jigs has many advantages over cast iron. Among these is the saving in the weight which it is necessary to move in order to bring comparatively small pieces of work under the various drill press spindles, and the absence of variations in different lots of work carried out at intervals, such variations, owing to change of temperature, being frequent with cast-iron jigs.

Mather & Platt, Ltd.—The report of this company for the past year states that, including £37,600 brought forward, the net profits amounted to £164,756. The directors transfer £40,000 to works removal reserve account, and recommend a final dividend, making 10 per cent. for the year, together with a bonus of 2 per cent., in both cases free of tax, leaving £32,756 to carry forward. The transfer to works account is in view of depreciation and expense incidental to the removal to New Park Works. For the previous year the net profit was £109,721, and the dividend was the same as now.

Big Electrical Machinery Contracts.—One of the most important electrical power development schemes now in hand in any part of the North American Continent is that of the British Columbia Electric Railway Company, which proposes a generating station having a normal output exceeding 100,000 h.p. In this connection negotiations have just been concluded with the Caledonian Ironworks Company, Ltd., for three large water wheels, each developing 14,000 h.p., whilst to Messrs. Dick, Kerr & Co., Ltd., has been awarded a contract for electrical generators, each of 9,000 kilowatt capacity.

Ship-repairing Works for Liverpool.—The Mersey Docks and Harbour Board on the 22nd ult. approved a recommendation of the Works Committee to let on lease for a term of 60 years from the 1st April next, to Messrs. Harland and Wolff, certain premises in Bootle, known as the North Dockyard. The premises with the land attached are of a very extensive nature. This resolution confirms the announcement we made recently that the Belfast firm were in negotiation with the Dock Board for the acquisition of land in the district named, and that the purpose is to construct a large ship-repairing establishment.

Swan, Hunter, & Wigham Richardson.—The better times enjoyed by engineers and shipbuilders during the past year are reflected in the annual report of this well-known Wallsend firm. The company's profits were at a rather low ebb during 1908 and 1909, and only 2½ per cent. each year was paid on the ordinary shares. For 1910 the profits rose to £67,656, the ordinary dividend being increased to 5 per cent. The company now records a net profit for 1911 of £117,000, and the dividend is 7½ per cent., this being the best showing made since the present company was formed in 1903. The company puts £35,000 to the reserve fund, increasing it to £55,000.

Heavy Losses of a Colliery Company.—It is evident from the report of the year's working of the Duffryn Rhondda Colliery Company that all collieries do not make the large profits which many persons are apt to imagine. In the case of this colliery the result of last year's working is a loss of about £18,000, the direct loss on working being £8,500, and the interest, taxes, Coalowners' Association calls, &c., making up the balance. For the year 1907 the company paid 10 per cent. dividend; for 1909 it was 5 per cent.; for 1910 there was no dividend, a loss of £12,900 being carried forward, so that with the loss for the past year the debit balance is now over £31,000.

The Waste Heat and Gas Electrical Generating Stations, Ltd.—The report of this company states that the profits amount to £25,071, against £21,914 a year ago. The directors propose a dividend at the rate of 8 per cent. for the year (same as last), leaving a balance to be carried forward of £7,955. The negotiations for erecting further waste heat generating stations, which were reported to be proceeding at the date of the last annual report, had so far advanced early in the year as to require the issue of further capital to meet the cost of construction. The capital offered was largely over subscribed, and the whole of the issue has now been called up.

Metal and Shipbuilding Industries in Japan.—The metal industries in Japan are not supposed to have any great future owing to the lack of ore sources. The principal foundry, the Wakamatsu Imperial Foundry, is dependent on Chinese mixed with Swedish ore, and the output is limited. Unless new deposits are discovered in any of the Colonial possessions no dangers need be anticipated by foreign exporters. In shipbuilding Japan has made enormous strides, but it must be remembered that in many cases the machinery and parts are imported and only put together in Japan. Even so, foreign built ships average 28 per cent cheaper than Japanese ones, a difference which has, however, been considerably reduced by the shipbuilding subsidies.

South Staffordshire Mond Gas Company.—A meeting of the shareholders of this company was held at Dudley Port, Tipton, on the 19th ult. The chairman, in moving the adoption of the report, said the profit on revenue account had more than doubled. They sold over 30 per cent more gas, which realised over 26 per cent. more than the previous year, and the revenue from residuals was nearly 27 per cent. more. On December 31 last they were supplying 123 works, compared with 102 on the corresponding date in 1910, and there were coupled up to the supply 153 gas engines and over 500 furnaces or heating appliances. To meet the increased demand, which was sure to come, they had ordered the plant at the works to be extended at once.

Oil Tank Steamers.—During the past week contracts were entered into for the building of no less than 21 oil tankers of large dimensions, adapted for the consumption of coal or oil. Several are for American owners. All contracts have been placed on the North East Coast, and 19 of them have been apportioned, we believe, as follows: Sir W. G. Armstrong, Whitworth & Co., Ltd., two of

15,000 tons capacity, one of 9,000 tons; Swan, Hunter, & Wigham Richardson, Ltd., two of 15,000 tons, four of 9,000 tons; Palmer's Shipbuilding and Iron Company, two of 15,000 tons, four of 9,000 tons; Wm. Doxford & Sons, two of 13,000 tons, two of 9,000 tons. At the present there are no fewer than 44 such steamers, of a total carrying capacity of about 370,000 tons, being constructed.

Dunderland Iron Ore.—We understand that Messrs. Krupp, of Essen, are negotiating for the acquisition of a controlling interest in the Dunderland Iron Ore Company. The Dunderland undertaking has up to the present been a disappointing one. The company was formed just over ten years ago to acquire extensive iron ore properties in Dunderland, Norway, and an exclusive license free of royalty to use Mr. Edison's patented processes for the extraction of iron ore. Aims and expectations went askew from the first, and debenture interest fell into arrear in March, 1908, while in September, 1911, it was officially stated that "the plant has been shut down awaiting the raising of the necessary capital to instal new plant." The new capital will be raised in the form of debentures.

Amalgamation of English Tubemakers.—The recent amalgamation of Scottish tube interests has, we learn, been followed by an amalgamation of English firms for co-operative working for the regulation of selling prices, in order to stop the ruinous "cutting" which has been prevalent for three years. Between thirty and forty firms between Birmingham and Warrington, which is practically the whole of the tube-producing area of England, have come into the combine, and first fruits are seen in the withdrawal of former price lists and the substitution of discounts on a basis involving an immediate advance of from 2½ to 5 per cent. The increased prices are held not to be more than is consistent with the higher cost of production. Satisfaction is felt at the termination of the price war.

Employers' Parliamentary Association. — The newly-established Employers' Parliamentary Association was formally constituted on the 21st ult. at a meeting in Manchester. Sir Charles Macara, who was elected the first president, mentioned that 900 firms, among them some of the most important in the country, had joined. Similar organisations had been commenced in London, Scotland, and Ireland, all of which would co-operate. They were also in communication with federations of employers with a view to their becoming affiliated. As to the constitution of the Employers' Parliamentary Association, the policy of the association would be governed by the General Council, consisting of representatives of prominent centres, and the Executive Council would be the central body which would work out that policy.

Canadian Iron Bounties.—The "Montreal Gazette" states that the Government has decided in favour of granting substantial bonuses for the encouragement of ironmaking in Canada. The great smelting industries at Sydney and Sault Ste Marie were established largely by means of bonus aids. The last of these expired in June last. These were the bounties on steel rods. There had previously been bounties on billets and other forms of iron and steel which had expired, and which the late Minister of Finance failed to renew. The Government has decided that the state of the industries and the prosperity of the country warrant a restoration of this bounty aid. Therefore it has been practically decided to give a bounty of a dollar a ton on pig iron produced from foreign ore and a dollar and a half a ton on pig iron produced from domestic ore.

New Turbine Steamers.—Messrs. William Denny & Bros., Dumbarton, launched on the 22nd ult. the turbine steamer "Princess Victoria," which they have built for the Larne and Stranraer Joint Railways. Her principal dimensions are: Length, 300ft.; breadth, moulded, 40ft.; and depth to promenade deck, 24ft. 6in. The propelling machinery consists of three sets of Parsons turbines, supplied with steam from water tube boilers. The turbines were contructed by Messrs. Denny & Co., and the boilers partly by Messrs. Babcock & Wilcox and partly by Messrs. Denny & Co. The turbine passenger steamer "Greenore" was launched on the 20th ult. by Messrs. Cammell, Laird, & Co., Birkenhead, for the London and North Western Railway Company's service between Holyhead and Greenore. The vessel is 305ft. in length and 40ft. in breadth, and she will have a speed of 21 knots.

Engineers and the Demarcation of Work.—At Carlisle on the 21st ult. a conference was held between representatives of the shipbuilding and engineering employers and representatives of certain trades in the two industries, relative to the question of demarcation. In March of last year representatives of 36 trade unions connected with shipbuilding and engineering had a conference with the employers representing these industries respecting a proposal to establish a Demarcation Board to deal with any dispute which may arise regarding the demarcation of work as between one trade and another. In the engine shops the trades chiefly interested in the subject at issue are the engineers and the brass workers, and in the shipyards, boilermakers and shipwrights, while other societies are affected in a lesser degree. Suggested agreements have been considered, but very little progress has been made. The meeting just held was preparatory to another conference with the employers, to be held at an early date.

Accidents on British Railways.—A summary of accidents reported to the Board of Trade as having occurred on railways in the United Kingdom during the quarter ended September 30th last has just been issued. According to this, there were in the period under review 290 killed and 2,291 injured, as compared with 268 killed and 2,407 injured in the corresponding period of 1910, being an increase of 22 killed and a decrease of 116 injured. In addition to the above there were 105 servants of companies or contractors reported as having been killed, and 1,325 injured, whilst the following accidents were reported by railway companies as having occurred during the three months upon their premises, but in which the movement of vehicles used exclusively upon railways was not concerned: 17 servants of companies or contractors and seven other persons killed, and 179 passengers, 5,492 servants, and 171 other persons injured, making a total in this class of accident of 24 persons killed and 5,842 injured, as against 18 killed and 5,268 injured in the corresponding period of 1910.

Novel Power Installation for Steamers.—The Hamburg-American Company have, we are informed, ordered from the Vulcan Company, of Stettin and Hamburg, a steamer of 22,000 tons gross register which is to be propelled by a combination of high-speed turbines with Fottinger Transformers. The power of the vessel is to be 13,000, and she will have one high-pressure and one low pressure turbine each running at about 800 revs. By means of two Fottinger Transformers the revolutions will be reduced to 160 on the propeller shaft, so that large propellers of high efficiency can be used. The Transformer also does the reversing, and no reversing turbines are consequently required. The result is a very large saving in weight (over 600 tons), space, and first cost. The Hamburg-American Company is the first to make the experiment on a large vessel, and the result will be watched with interest. So far the Fottinger Transformer has been used only on a tug belonging to the "Vulcan" in conjunction with a Curtis turbine, and on the gas driven vessel "Holzapfel I." In both cases it has done its work very successfully. We understand that the Holzapfel Marine Gas Power Syndicate are interested in the Fottinger patent rights for Great Britain.

Shipping Prospects.—At the annual meeting of the Chamber of Shipping of the United Kingdom, held in London on Friday last, Mr. Thomas Royder, of the Cunard Line, in his address remarked that 1912 had opened with employment good in every part of the globe. As a necessary corollary, freights had been, and were, on a remunerative level. In looking forward, the most difficult questions with which they were confronted were perhaps those relating to labour. They must, he said, if they carried on their business to the best advantage, satisfy the just claims of the men, but it was equally clear that if they were to continue to find them with employment the men must recognise and respect the employers' rights and responsibilities. In short, they must remain the managers of their own businesses. The meeting carried a motion urging the Government, having regard to the intimidation and violence which had been openly carried on during the recent strikes, and to the serious interference with the supply of food and other necessaries of life to the people, to amend the law fully so as to place trade unions and their members under the same legal responsibility for their actions as other bodies and persons, and so deprive them of the privilege conferred upon them by the Trades Disputes Act, 1906.

Working of the State Telephones.—At a recent gathering of the North East Coast Association of Chartered Secretaries, held at Newcastle-on-Tyne, Mr. H. Shaw delivered a lecture on "The Telephone Question," in the course of which he outlined the history of the telephone installation in this country, adding that, considering the excellent results obtained by Hull and Portsmouth, he had always felt it a great misfortune that the Post Office had strongly opposed proposals for municipalisation. Now that it was perfectly certain that the Post Office intended to keep the telephone system in its own hands the commercial community must combine to obtain reasonable rates with an efficient service. The telephone system had been in the hands of the Post Office for the space of only a few weeks, and even in that short time, especially in London, complaints were rife. The chief were the following. The present service compares unfavourably with that afforded by the National Telephone Company; there is great difficulty in hearing and being heard; conversations are frequently cut off and interrupted; cross communication is more

frequent; there is more difficulty and delay in getting connected with the number required; the present service is not so expeditious as formerly; and wrong numbers are continually being given.

The Economics of Railway Nationalisation.—An interesting lecture on "Railway Nationalisation" was delivered by Mr. W. C. H. Church at a recent meeting of the Newcastle Economic Society. He said there was not a sufficient case for State ownership in respect to this particular country. There were not, for example, the same military reasons as in Germany for a State railway, or for a unification scheme as in Italy, or for developing vast tracts of new country as in America and Australia. In order, indeed, to make out a case for nationalisation in respect of the British railways, he suggested that it ought to be shown either that capital was not forthcoming to build such railways or further railways, or that the railways were not being operated by the present owners to reasonable advantage. They should not only show that the present operation of the railways was defective, but they would require to show that State operation was likely to remedy the defects. Personally, he thought any defects would be added to by State control. The only successful State railway was that of Germany; all the rest would be in the bankruptcy court but for the taxpayer. He compared British railways favourably with railways abroad, and said they wanted to be spared the parochial officialism and the manipulation of wages by the Labour party which had been associated with State railways, especially in Australia. The 30 millions lost by the Government over the working of the telegraphs would, he thought, be a small matter compared with the losses on the working of the railways by the State.

Burdens on the Coal-mining Industry.—At the annual meeting of Messrs. Andrew Knowles & Sons, Ltd., colliery proprietors, held a few days ago at Manchester, Mr. R. M. Knowles, the chairman, stated that during the past sixteen years the company had distributed in dividends £638,137, averaging £1 11s. 11d. per share, or nearly 6¼ per cent. per annum. The highest dividend was 13½ per cent. in the years 1900 and 1901, and the lowest 3 per cent. in the year 1898. During the same period they had paid in workmen's wages £3,619,752; income tax, £55,770; local rates, £129,968; workmen's compensation in twelve years, £47,245. These figures showed that the concern, along with other colliery concerns, was contributing more than its due share towards imperial and local taxation, and it would have been thought that no further legislation would have been passed which would have put new burdens upon an industry on which the livelihood of such a large number of men depended. Parliament, however, passed last year two Acts which would place further burdens and responsibilities upon them, namely, the National Insurance Act and the Coal Mines Act. Why employers should be called upon to contribute towards the cost of national insurance it was difficult to understand, but the measure could not but have the effect of putting an end to many struggling concerns. To the shareholders in that company it would be equal to an income tax of 2s. 9d. in the pound on the profits of last year. The effect of the Mines Act would be seriously to increase the cost of the production of coal, but they were not yet in a position to estimate what that would amount to. The report, declaring a dividend of 4 per cent. for the year, was adopted.

The Workmen's Compensation Act and Temporary Recoveries from Incapacity.—The House of Lords, in unanimously dismissing the appeal in Taylor v. The London and North Western Railway Company on the 19th ult., discussed at length questions arising from temporary recovery from incapacity under the Workmen's Compensation Act. The Lord Chancellor said that their lordships in this matter were bound by the decision in Nicholson v. Piper. It was thus settled that when a county court judge was satisfied that the incapacity resulting from an injury had finally disappeared he could so adjudge and finally end the weekly payment beyond revival. He did not think that there was anything in the decision of Nicholson v. Piper which prevented the county court judge from adjudging that the weekly payment be ended until further order. The same result was, they were told, attained by a practice of ordering a merely nominal payment in order to keep the question alive. In his view, either of these methods might be lawfully adopted—an ending of payment might be either temporary or permanent. Lord Shaw agreed that it was competent to the judge to end the compensation for ever. But he was of opinion that the words "ended, diminished, or increased" in the Act included not merely ending the compensation for ever but ending it for a time. The language and meaning of the Act were to the effect that compensation was to be made for and during the incapacity. Cases might easily be figured in which the capacity for work might for a time return and then incapacity might again recur. The careful prognosis might indicate a certain periodicity of illness with intervals of fitness for work, or it might suggest such an uncertainty of a continuance of health as to cloud the workman's whole future with peril. These were just cases in which the county court judge might feel bound to end the payment, not for ever, but for a time. In the fear apparently of the word "ended" being more literally construed the course had been sometimes taken of a nominal payment being adjudged, so as to preserve a form of continuity and, so to speak, to keep open the compensation account. Lords Atkinson and Mersey concurred, and the appeal was dismissed, with costs.

Time Rates of Wages in the Engineering Trades.—The Labour Department of the Board of Trade has just issued a return showing the standard time rates of wages in the United Kingdom as at January 1 last. The rates of wages of turners, fitters, and smiths, and a number of other departments in the engineering trades are given at 40s. per week in London, whilst millwrights received 42s. 6d., and patternmakers 44s. 6d. The number of hours forming a week vary from 48 to 54. On the Tyne the rate comparable with the 40s. in London is 37s., and in some instances drops as low as 31s. 6d. for a week of 53 hours. At Leeds patternmakers get 39s. for 53 hours, smiths 36s., and most of the other trades 35s. per week, although borers and slotters, and planers and millers get 31s. Sheffield rates were 41s. for patternmakers, and 38s. in all other branches of engineering, except brass finishers, planers, borers, and slotters, who received 35s., the week being one of 53 hours. Nottingham wages are hardly as good, 39s. being paid for millwrights, smiths, and patternmakers, and 37s. for most of the others; but here die-sinkers or press tool makers receive 43s. per week of from 51 to 54 hours. Newport takes the lead for wages in Wales in the engineering trades, the rate being 44s. per week of 53 hours in marine shops and 37s. in collieries. In Scotland at Glasgow patternmakers' wages are 40s. 1½d. for 54 hours, coppersmiths and other smiths receive 38s. 3d., and all other trades 37s. 1½d. Belfast wages range from 43s. per week for patternmakers to 39s. for fitters and smiths, a week's work being from 54 to 56½ hours. Ironfounders in London district are paid from 38s. 6d. to 43s. per week of 54 hours, whilst patternmakers get 44s. to 45s. In the northern counties, including Middlesbrough, the payment is from 40s. to 41s. for 53 hours. The North Midland counties range from 39s. at Derby to 31s. at Gainsborough, and at Birmingham 1s. per week less is paid for 53 hours. Liverpool rates are good, ironfounders receiving 42s. and 44s. for 53 hours, Manchester being about the same, and Warrington slightly lower for the same number of hours. In Sheffield ironfounders receive 42s. and patternmakers 41s. for a week varying from 48 to 53 hours. The wages of boilermakers and steel shipbuilding in London range from 54s. for angle iron smiths and platers to 36s. for riveters and 30s. for holders up. The hours of work vary from 48 to 54 per week. The Clyde district pays 42s. down to 28s. 1½d. for the various classes of trades for 54 hours per week. Shipwrights on the Thames receive 42s., as against 39s. 9d. at Glasgow and 40s. 6d. at Belfast. Sheffield angle iron smiths receive 43s., platers 41s., riveters and caulkers 37s., and holders up 33s. for a 53 hours week. Electrical workers in London are paid 9½d. per hour, Bristol, Cardiff, and Liverpool paying 9d., and Sheffield 8½d., the average week being 53 hours.

METAL QUOTATIONS.

TUESDAY, FEBRUARY 27TH.

Aluminium ingot		65/- per cwt.
,, wire, according to sizes, &c.	from	102/- ,,
,, sheets ,, ,,	,,	120/- ,,
Antimony	£27/10/- to	£28/-/- per ton
Brass, rolled		7¾d. per lb.
,, tubes (brazed)		9⅞d. ,,
,, ,, (solid drawn)		8d. ,,
,, ,, wire		7¾d. ,,
Copper, Standard		£64/2/6 per ton.
Iron, Cleveland		49/6 ,,
,, Scotch		55/6 ,,
Lead, English		£16/3/9 ,,
,, Foreign (soft)		£15/18/9 ,,
Mica (in original cases), small		6d. to 2/- per lb.
,, ,, ,, medium		2/6 to 4/- ,,
,, ,, ,, large		4/6 to 8/6 ,,
Quicksilver		£8/7/6 per bottle.
Silver		$26\frac{15}{16}$d. per oz.
Spelter		£26/12/6 per ton.
Tin, block		£195/15/- ,,
Tin plates		13/6 ,,
Zinc sheets (Silesian)		£29/10/- ,,
,, (Stettin; Vieille Montagne)		£30/-/- ,,

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1910.

Manufacture of iron and steel. Elektrostahl Ges. 25581.

1911.

Connecting rod connections for internal-combustion engines. Grice. 1296.
Mining machines. Lake. 2498.
Controlling gear for steam engines and winding engines. Galloways, Ltd., and Pilling. 2613.
Valve gear for reversible internal combustion engines. Vollmer. 2791.
Safety devices for lifts. Greenhalgh. 2822.
Cooling the cylinders of explosion engines. Rogers. 2938.
Low pressure steam heating systems for railway trains. Sawyer. 2980.
Joint making packing. Beldam & Beldam. 3106.
Control of reciprocating machine saws. Wicksteed & Wicksteed. 3107.
Means for controlling or regulating the supply of steam to gas-producer plant. Alston & Houston. 3114.
Driving and reversing gear. Soprounoff. 3319.
High speed reciprocating engines. Lanchester. 3682.
Reversing mechanism for metal planing machines. William R. Dell & Son, Ltd., Richards, and Stewart. 3809.
Utilising the waste heat of internal combustion engines. Bellamy. 4254.
Gas producers. Smith & Atkinson. 4556.
Internal combustion engines. Miller. 5014.
Drying of steam. Wild. 5303.
Miners' safety lamps. Lautzsch. 6051.
Fluid pressure engines. Groves. 6508.
Bearings or mountings for flywheels. Waller. 6621.
Two-stroke internal-combustion engines. Morrison. 6825.
Mercurial vacuum gauges. Robinson, and Brady & Martin, Ltd. 6938.
Apparatus for raising liquids by means of steam, or compressed air. Bowen. 6950.
Apparatus for water cooling and condensing. Dean. 8563.
Process for uniting metal parts by brazing. Pugh. 9104.
Governing mechanism for prime-movers. Warwick Machinery Company (1908) and Samuelson. 9245.
Drilling, boring, and analogous machines. Bambridge. 9373.
Flexible shaft couplings. Wilce. 9602.
Coal cutting machines. Garforth & Bousfield. 9708.
Arrangement for operating the controlling valves in fluid pressure power transmission gear. Lentz. 10261.
Feed motion of rope-driven coal cutters. Spence. 11770.
Vaporising and mixing devices for internal combustion engines. Yardley. 12416.
Internal-combustion engines. Wood. 12420.
Reversing gear for internal combustion engines. Jorgensen. 12725.
Method of producing cast articles of copper and its alloys. British Thomson Houston Company. 12920.
Shackles for haulage ropes. Keep. 14211.
Chucks. Wahlstrom & Burchardi. 14226.
Pneumatically operated valves. Edwards. 14363.
Apparatus for smoke prevention and fuel economising in connection with steam generators. Rothwell. 14544.
Means for pumping liquids. Badger. 14884.
Means for lubricating internal combustion engines. Best and Lloyd, Ltd., and Carpmael. 14909.
Speed and distance indicating apparatus. Behrens. 15308.
Wrenches. Rogers. 15985.
Means for measuring stresses and strains. Wazau. 15999.
Screwing stocks and dies. Pass & Peart. 16118.
Production of cores of any desired cross section for metal casting purposes. Kurze. 16696.
Briquettes of metal parings and the like metal scrap. Allgemeine Briketierungs Ges. 16802.
Percussion tools. Siemens Schuckertwerke Ges. 16998.
Chloridising roasting of ores. Helsingborgs Kopparverks Aktiebolag. 16957.
Rotary engines. Touiller. 17003.
Wind engines. Perry. 17005.
Fluid pressure operated hammer tools. Lake. 17019.
Valve gears for internal combustion engines. Heuer & Bruhn. 17054.
Means for lubricating internal combustion engines. Best and Lloyd, Ltd., and Carpmael. 17295.
Process for the production of steam for gas generators. Frambs, and Bender & Frambs Ges. 17770.
Tool steel retainers for percussive tools. Newton. 17974.
Adjustable spanner. Fitzpatrick. 18472.
Charging apparatus for mechanical roasting furnaces. Hardingham. 19314.
Ratchet drills. Lowden, Byrd, and Inventions and General Syndicate. 19437.
Toothed gearing. Humphris. 19936.
Steam generators. Steinmuller. 20466.
Manufacture of fuel briquettes. Furse. 21192.
Valves and valve seats. Knowles & Goreham. 21236.
Stay for boiler plates. Ward & Ward. 22226.
Ball grinding machines. Norma-Compagnie Ges. 22325.
Spanners. Cook. 22563.
Valves. Rothchild. 22932.
Cushioning or shock-absorbing means for driving mechanism. Bateman & Bateman. 23100.
Centrifugal pumps. Geb. Sulzer. 23374.
Miners' safety lamps. Hailwood. 26091 and 26092.
Compound steam engines. Schmidt. 28382.
Construction for fixing blades in turbines. Bergmann Elektricitats-Werke Akt.-Ges. 29199.

1912.

Valves of internal combustion engines. Reeves. 41.

ELECTRICAL, 1911.

Miners' electric safety lamps. Hailwood. 436.
Apparatus for the manufacture of electric resistances. Hirst and Brook. 2926.
Electric lighting systems for railway carriages. Electric and Ordnance Accessories Company, Langley, and Price. 3238.
Electrical influence machines. Morris & Lister, Ltd., Morris, and Watson. 3701.
Voltage regulators. Burnham. 3703.
Electrical apparatus for the manufacture and welding of metal articles. Jevons. 3838.
Transmitter for signalling by electro magnetic waves. Chambers. 4488.
Telegraphic systems. Faiella. 4920.
Electric motor control. British Thomson-Houston Company. 5620.
Electric cut-outs. Schweitzer & Conrad. 6443.
Automatic regulating devices for electric supply systems. Lake. 7528.
Electrically controlled valves. Nicholson & Brooking. 8899.
Electro magnetic lifting appliances used with cranes. Steel, Peech, & Tozer, Ltd., and Bowen. 8951
Electric switches. W. T. Henley's Telegraph Works Company, and Judge. 10747.
Dynamos. Newton. 10758.
Electric arc lamps. Boardman, Boardman, & Boardman. 11872.
Systems of electric distribution. British Thomson Houston Company, and Whitaker. 12918.
Generation of alternating electric current. Rosenberg. 13099.
Automatic switches or cut outs for use in charging secondary batteries. Midgley & Vandervell. 15039.
Electro magnetic circuit-breakers. Compagnie des Compteurs Aron. 16962.
Tumbler switches. Lake. 18881.
Methods of and apparatus for cooling electrical machinery. Baum. 19760.
Electric incandescent lamps. Euler. 20643.
Electric switches. Lucas & Lucas. 21495.
Sparking plug for internal combustion engines. Mills. 21616
Protective devices for electric lamps. Perry & Davies. 23781.
Lighting and regulating of electric arc lamps. Harle et Cie 25138.
Electrically actuated and controlled apparatus for operating railway semaphore signals. O'Donnell and British Pneumatic Railway Signal Company. 25345.
Secondary or storage batteries. De Karavodine. 28867.
Electric ignition devices for internal combustion engines. Robert Bosch. 29368.

Conservation of our Coal Supplies.—In the House of Commons a few days ago Mr. McKenna, the Home Secretary, stated that in view of the importance of economising our coal supplies generally he is considering whether a Government inquiry could with advantage be made in two directions:—(1) What measures are possible to prevent waste in the getting of coal, *e.g.*, by wasteful methods of working or by leaving unnecessary barriers between royalties. (2) What economies can be effected by stopping waste in the consumption of coal and by its more scientific use in the production of energy.

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The Inspection and Working of Agricultural Traction Engines.

Several formal enquiries recently held by the Board of Trade into explosions of traction-engine boilers used for agricultural purposes disclose an amount of ignorance and recklessness in connection with their working which is disquieting to the public in agricultural districts, where they wander about the high roads from one farm to another for employment under the hiring system. It is only a few weeks since (see p. 124 ante) that we gave an account of an enquiry held at Winchester into an explosion of this kind at Crawley, which resulted in the death of two men. In that case the boiler was owned by a firm who made a practice, apparently, of purchasing and doctoring up second-hand boilers, which were let out to third parties, who contracted to do ploughing and similar work at various farms. The boiler had changed hands several times, and although over 30 years old, was worked at a pressure 20lbs. higher than it was originally constructed for. Further, it was dangerously wasted by corrosion. The Board of Trade Commissioners held that the explosion would have been averted by reasonable precautions and the exercise of ordinary care, and as a consequence of the negligence displayed, they ordered the firm who worked the engine to pay £50, and the firm who let it out on hire £25 towards the costs of the enquiry. They commented also on the imperfect character of the inspection frequently observable in connection with boilers of this kind, and the consequent danger to the outside public. These lessons are further emphasized in a report of a Formal Investigation, just issued, on an explosion which occurred at Cheltenham on September 12th, 1910. This case resembled the other in several particulars. The boiler belonged to a firm who owned a number of similar engines, and let them out under hire-purchase agreements to third parties. It was 24 years old, and originally constructed for a pressure of 100lbs. on the inch, but after changing hands several times, and after certain repairs were made, it was finally let out on hire at a working pressure of 150lbs., or nearly 10 per cent. higher than the pressure for

which the boiler was originally constructed. The owners in this case had taken the precaution to have the boiler examined and tested by the Ocean Insurance Company, who, after an hydraulic test to 230lbs., and data supplied to them, issued a certificate that they considered "the boiler safe and satisfactory for a safety-valve load of 150lbs. per square inch." Some six months after this, the engine was let out on a hire-purchase agreement to a man who worked the engine himself, and to whom, on the basis of their previous examination and test, the Ocean Company issued a policy in the sum of £1,000, insuring him against (*a*) loss or damage to the locomotive, (*b*) liability of the assured to pay damages for injury to property of any person, and (*c*) liability of the assured to pay compensation for fatal or non-fatal injuries received by any person. Three months after this the boiler burst with great violence. The subsequent investigation by the Board of Trade Surveyor and the enquiry of the Commissioners led them to the conclusion that the explosion was due to excessive pressure, and "that the springs of the safety valves were either jammed or screwed down, possibly with the object of getting a pressure exceeding 150lbs. to do the heavy work required by the locomotive." For this state of affairs, they held the man who had "hire-purchased" and worked the engine responsible, and ordered him to pay a sum of £100 towards the expenses of the enquiry. At the enquiry, the superintending engineer of the insurance company advanced the theory that the explosion was caused by some high explosive inside one of the smoke tubes, but the Commissioners did not accept this fantastic explanation, and in view of the facts, it is not worth discussion, for as they remarked, "there was no direct evidence to support it, while the nature of the explosion was quite consistent with an explosion caused by over-pressure of steam." There are some other features, however, in connection with the explosion on which, in the public interest, it appears desirable to comment. While the Commissioners exonerated the Ocean Company, and its superintending engineer from any blame for the explosion, they, nevertheless, expressed the opinion that "the arrangement between this company and the firm who sold the boiler, if carried out without a thorough examination of the boiler and the greatest care and precautions, might be detrimental to the safety of the public," an opinion with which we entirely agree, and which makes it desirable to examine the arrangement a little more closely. Its precise terms were outlined in the following letter addressed by the Ocean Company to Messrs. Lewis and Sons, of Reading, the firm who supplied the boiler:—

Messrs. H. Lewis & Sons,
Reading. October 22nd, 1909.

Dear Sirs, Referring to your Mr. Lewis' interview with our Mr. Petheram, on the 21st inst., we have pleasure in submitting the following propositions for your consideration.

To thoroughly examine and witness hydraulic pressure tests on not less than, say 60 boilers, our fee would be 10s. per boiler, it being understood that not less than four boilers would be ready on each day appointed for our engineer surveyor to attend. The fee would include a separate certificate in each case, stating briefly that the boiler had been thoroughly examined and tested with satisfactory results, and that we were willing to insure it at a certain pressure. It would be understood that in each case we should give you the highest pressure for which we considered the boiler safe and suitable. We would further send you a brief report on the condition of each boiler for your own private information, and we would advise you as to how long the certificate would hold good without a further examination being made. This, as personally explained, would essentially depend upon the age and condition of the boiler. If after your present stock of boilers have been examined you require an odd one examined and tested now and then, our fee, if we had to send specially at short notice, would be one guinea per boiler. But if you gave us a week's notice we would charge the same fee as quoted above for the large number of boilers. We feel sure that we thoroughly understand your requirements, and the scheme you have in mind, and the fee quoted above is really most reasonable having regard to the work to be undertaken.

Yours faithfully,
GENERAL MANAGER AND SECRETARY.

The examination of the boiler in question, as revealed by the enquiry, and which was described in the Ocean Company's report as "a thorough examination as far as practicable," was of a very partial character. The interior was not accessible, and as none of the smoke tubes were drawn, inspection of it could only be made by looking through the manhole and several mud holes in the water space, while of the exterior surface even less was discernible, as the lagging was not removed. Had it been, there is no doubt the seriously laminated condition of the plate which gave way would have been discovered. It ought in fairness to be added that this incomplete examination was supplemented by an hydraulic test on the following day to a pressure of 230lbs. on the inch; and in view of the importance which in the past the Board of Trade have attached—in our opinion unduly—to the value of the hydraulic test as a means of discovering boiler defects, the insurance company were, perhaps, to some extent justified in assuming that after such a test the boiler might reasonably be considered safe for a working pressure of 150lbs., although, as already stated, this was nearly 40 per cent. higher than the pressure for which the boiler was originally constructed 24 years ago. An hydraulic test is a very useful means of determining the tightness of riveting in the case of new work or of repairs, or the sufficiency of flat surfaces, or abnormally-shaped parts, the strength of which may be in doubt, but, as is well known to all familiar with boiler inspection, it is a poor substitute for visual examination in discovering the great majority of defects that occur in boilers, and which, if neglected, lead to failure. Instances have occurred again and again where a defect has developed into a rupture shortly after the hydraulic test has been applied. In the present case, having regard to the age of the boiler and its history, as well as to the great increase beyond the original working pressure—the amount of which, it seems to us, was as open to ascertainment by the insurance company as it was subsequently by the Board of Trade—we cannot help feeling that the company should not have been satisfied with anything less than an examination which was "thorough" *in reality*, and not "*as far as practicable*." In commenting upon this aspect of the case and the certificate that was issued, the Commissioners rightly took exception to this qualifying phrase, pointing out that the removal of the lagging for the purpose of external examination could have been easily effected, and that without the removal of some of the tubes the lower part of the interior could not be seen. Boiler owners, we are aware, are often reluctant to make the preparation necessary for a thorough examination on account of the trouble and expense, but there are times when it is necessary, and should be insisted upon by inspecting authorities if they are to do their duty to their clients and to the public, and this should be realised by all concerned. There is, however, we regret to say, an unfortunate tendency on the part of some inspecting companies to cut down fees to a point at which it is difficult, if not impossible, to render honest and efficient service except at a loss, and under such circumstances it is needless to say the service is liable to suffer. It is not for us to suggest what is a reasonable fee, but speaking with intimate knowledge of what efficient boiler inspection means in the way of trouble and expense, the fee of 10s. per boiler, for which the Ocean Company undertook to make an hydraulic test with its attendant examination, and to include, as stated in their letter to Messrs. Lewis, quoted above, a certificate stating briefly that the boiler had been thoroughly examined and tested with

satisfactory results, and that they were willing to insure it at a certain pressure, strikes us as being extraordinarily low, and we are not surprised that in commenting upon this arrangement the Board of Trade Commissioners should remark that "if carried out without a thorough examination of the boiler and the greatest care and precautions, might be detrimental to the safety of the public." It is cheaper, as a rule, to make an hydraulic test than an efficient thorough inspection, and it is desirable this fact should be impressed upon the minds of steam users. Further, they should clearly recognise that if inspecting authorities are to perform the service which is necessary to arrive at a reliable opinion respecting the condition of a boiler, or its suitability for the working pressure, they must be willing to make suitable provision for *a real "thorough"* inspection, and to pay for it.

NEW MELTING POINT DETERMINATIONS.

THE reason why the melting points of many substances that are used in iron and steel metallurgy have not been accurately determined is because a suitable furnace, with temperature control, has not been designed. Careful work at the University at Aachen has developed an electric vacuum furnace in which temperatures can be reached and controlled far in excess of those possible of attainment in the iridium furnace designed by Nernst, and used by the Bureau of Standards at Washington as well as other institutions. This new furnace uses the resistance of carbon as the heating element. A full description and some very interesting results obtained are given in a recent issue of "Metallurgie," and recorded in "The Iron Age." The temperatures are measured altogether by optical methods, two Wanner pyrometers being used. In the following table are given some results obtained by the experimenter, E. Otto Goecke :—

Melting Points of Various Metals, Determined by the Use of a Vacuum Furnace.

Material.	Melting Point.	Pressure.	Remarks.
Gold	1071°C	2 mm.	
Manganese	1247	4 mm.	
Chromium	1514	5 mm.	
Platinum	1750	2 mm.	
Iridium..................	2224	5 mm.	
Uranium Carbide, UC_2	2425	5 mm.	Sintered at 2360°.
Vanadium Carbide, V_4C_3	2750	5 mm.	In order to prevent reduction by carbon the oxides were placed on platinum.
Ferrous Oxide, FeO	1419	5 mm.	
Ferric Oxide, Fe_2O_3	1548	4 mm.	
Magnetic Oxide, Fe_3O_4	1538	4 mm.	
Oxide of Chromium, Cr_2O_3	2059	Nitrogen, 1 atmos.	The crucible was made of ZrO_2.
Alumina, Al_2O_3	2020	Nitrogen, 1 atmos.	
Uranium Oxide, UO_2	2176	Nitrogen, 1 atmos.	Melting began at 2098°.

A complete series of determinations was run on the well-known Seger cones both in a vacuum and in an atmosphere of nitrogen. The following short table shows the good agreement obtained :—

Seger Cone. No.	Pressure	Temperature Given.	Temperature Found.
28	Vacuum, 4 mm.	1630°C	1627°C.
30	Vacuum, 4 mm.	1670	1672
32	Vacuum, 5 mm.	1710	1715
35	Vacuum, 5 mm.	1770	1780
37	Vacuum, 7 mm.	1825	1837
28	Nitrogen, 1 atmos.	1630	1631
29	Nitrogen, 1 atmos.	1650	1651
32	Nitrogen, 1 atmos.	1710	1718
33	Nitrogen, 1 atmos.	1730	1729
34	Nitrogen, 1 atmos.	1750	1747
36	Nitrogen, 1 atmos.	1790	1793
38	Nitrogen, 1 atmos.	1850	1844
39	Nitrogen, 1 atmos.	1880	1882
40	Nitrogen, 1 atmos.	1930	1926
41	Nitrogen, 1 atmos.	1960	1963
42	Nitrogen, 1 atmos.	2000	2009

Tests were also made on five clays of well-known brands which had melting points given in terms of Seger cone numbers. The agreement was exact.

Very careful experiments were then made with alumina, lime, and magnesia. When working in a vacuum the alumina began to vaporise somewhere between 704° and 1,739° C. This action was very active at 1,905° C.; at 2,020° C. the exide began to melt, and at 2,035° C. it was completely molten. Another series was run in nitrogen at atmospheric pressure. At 1,947° C. it began to sinter; this was very noticeable at 2,009°, and at 2,020° C. it was completely molten. In this latter case no vapour was noticed.

The test with lime in a vacuum could not be carried to a much higher temperature than 2,400° C., for then the heating tube of carbon burned through, probably because of a reaction between the carbon and oxide vapour. At 2,102° there was noticeable a rounding of the sharp corners of the sample of lime, which could only be due to the formation of vapour. It strongly sintered at 2,320° C.; and at the highest temperature reached, 2,348° C., was not melted, but had almost passed into vapour. The series run in a nitrogen atmosphere showed the presence of vapour comparatively early, namely, at 1,742° C. At 1,900° C. it melted, and began boiling at 1,994° C. The temperature of the furnace remained constant until practically all the lime had boiled away. It then increased, and at 2,009° C. nothing was left. The difference in the results obtained in a vacuum and in nitrogen are so great that they must be due to the formation of an easily volatile compound of lime and nitrogen.

The experiment with magnesia in the vacuum was carried to 2,513° C., but no melting could be observed. The heating tube then burned through. Lively vaporisation was first noticed at 2,039° C. In a nitrogen atmosphere this was distinctly noticed at 2,009° C.; but if ampere numbers and temperatures are used as ordinates it is seen that it begins at 1,805° C. At 2,455° the heating tube burned through, but the sample was not melted.

If these results are brought together we see that alumina melts at from 2,020° C. to 2,035° C. both in a vacuum and in a nitrogen atmosphere. The melting point of lime in a vacuum was not reached, but on the other hand it melted at 1,990° C. in an atmosphere of nitrogen. This is undoubtedly due to a reaction between the lime and nitrogen. Finally the melting point of magnesia was not reached in either a vacuum or a nitrogen atmosphere.

£1,000 Prize Award for an Aerial Engine.—A meeting of the joint committee of the aeronautical bodies, representing the Aeronautical Society, the Royal Aero Club, and the Aerial League of the British Empire, was held on the 14th ult. to consider the report of the Testing Committee and the results of the above competition, which was open to world makers of aeroplane and airship engines. The prize of £1,000 offered by Mr. Patrick Y. Alexander was unanimously awarded by the joint committee to the Green Engine Company. The Green engine entered for this competition developed 61·6 horse-power at 1,150 revolutions per minute in two non-stop runs of twelve hours each. The test was carried out at the Government Aircraft Factory.

The British Association.—For the meeting of the British Association for the Advancement of Science, which is to take place this year at Dundee, on September 4th and following days, under the presidency of Prof. E. A. Schäfer, LL.D., F.R.S., the following presidents have been appointed to the various sections: Mathematical and Physical Science, Prof. H. L. Callendar, LL.D., F.R.S.; Chemistry, Prof. A. Senier, M.D., Ph.D.; Geology, Mr. B. N. Peach, LL.D., F.R.S.; Zoology, Mr. P. Chalmers Mitchell, D.Sc., F.R.S.; Geography, Sir Charles M. Watson, K.C.M.G., C.B., R.E.; Economic Science and Statistics, Sir Henry H. Cunynghame, K.C.B.; Engineering, Prof. A. Barr, D.Sc.; Anthropology, Prof. G. Elliot Smith, M.D., F.R.S.; Physiology, Mr. Leonard Hill, M.B., F.R.S.; Botany, Prof. F. Keeble, Sc.D.; Educational Science, Prof. J. Adams, M.A.; Agriculture, Mr. T. H. Middleton, M.A. Agriculture will form the subject of a full section for the first time. Prof. W. H. Bragg, F.R.S., and Prof. A. Keith, M.D., have been appointed to deliver the evening discourses.

STRUCTURE AND HEAT TREATMENT OF TOOL STEEL.*

BY J. V. EMMONS.

Tool steel consists essentially of iron and carbon. There are, however, four other elements always present, two of them, phosphorus and sulphur, being injurious impurities, while the other two, manganese and silicon, have some more or less valuable effect when present in certain proportions. The gases, oxygen and nitrogen, are also present in small amounts as injurious impurities, but are not usually taken into account. Frequently other elements are added to produce a special grade of steel for certain purposes. The principal metals added include nickel, chromium, tungsten, vanadium,

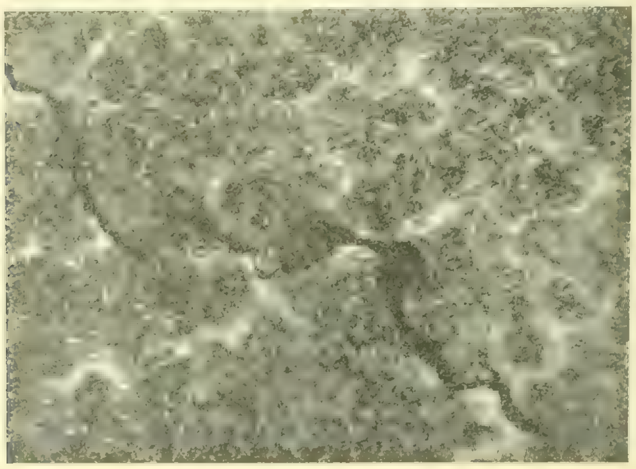


FIG. 1 FIRECRACK IN STEEL, FOLLOWING THE LINES OF CEMENTITE

and molybdenum. The carbon in tool steels varies from about 0·8 to 1·50 per cent., according to different requirements. An analysis which is widely used for cutting tools and which may be taken as typical, follows:—

	Per cent.
Carbon	1·20
Manganese	0·30
Silicon	0·15
Phosphorus less than	0·020
Sulphur less than	0·020

In the last few years it has been recognised that the structure of tool steel has fully as much to do with its properties as the chemical composition. This has led to the establishment of microscopic equipment in all well-equipped steel laboratories.

Ferrite is pure iron. It is usually recognised by its irregular hexagonal-shaped grains. It is soft, ductile, has little strength, and cannot be hardened. It occurs in tool steel normally only when mixed with cementite to form pearlite. It is found, however, in connection with certain abnormal conditions such as bark and graphite. These will be considered later.

Cementite is a carbide of iron containing 6·6 per cent. carbon. It is very hard and brittle, resembling glass in these properties. Cementite is contained in small quantities in all tool steel over 0·80 per cent. in carbon.

Pearlite is a mechanical mixture of cementite and ferrite, the two being arranged alternately in very thin plates. It contains 0·80 per cent. carbon and is soft and tough. Pearlite is the chief constituent of annealed tool steel.

Martensite in tool steel contains from 0·70 to 0·90 per cent. carbon and is produced by quenching in water or some similar bath from a temperature above the critical point. It consists of interlacing needles, which structure gives it great strength and hardness. Martensite is the principal constituent of hardened steel. A micro-photograph of it is illustrated in Fig. 3.

Sorbite is a transition from between martensite and pearlite. It may be formed by fairly rapid cooling from above the critical point or by drawing the temper of hardened steel. It is harder than pearlite and has great strength. Sorbite is the principal constituent of tool steel as it comes from the rolls or forge. Several other constituents and transition forms are known, but the above are of the greatest practical interest.

* Paper read before the Metal Trades Superintendents' and Foremen's Club, of Cleveland, February 15th, 1912.

The inspection of tool steel is one phase to which the consumer frequently gives too little attention, and to this fact a large majority of the difficulties encountered in heat treatment may be attributed. Two methods of inspection are employed. The first is by chemical analysis and microscopic examination, which is available only with laboratory equipment.

The second is by the examination of the surface of the bars, plates, &c., and of the hardened fracture by the naked eye or the hand magnifier. The former method is the most accurate known, and to it we owe most of our present knowledge of tool steel. The latter method is much less accurate when used alone, but in skilled hands it gives most valuable indications of the condition of the steel. It has the advantages of being inexpensive and available even in small shops. It is possible to detect in this way surface cracks, the presence of bark, pipes, overheated structure, graphite, and bad cases of segregation of cementite as illustrated in Fig. 2. Microscopic examination shows, in addition to the above, the amount and condition of the bark, the exact amount of segregation, the approximate amount of graphite, and the precise amount of overheating, all of which are necessary for the intelligent handling of tool steel.

The first step in the process of heat treatment is annealing. There is no best way to anneal tool steel. It is impossible for any one method to satisfy all conditions. Every consumer has his own especial problem of annealing to solve, the answer to which depends on the grade of steel used, the condition of the steel before annealing, and the results desired.

Plain carbon steels are divided by the manufacturer into several grades ranging from 0·70 to 1·50 per cent. carbon. In addition to these there are numerous grades of alloy steels coming into wide use known as chrome steel, nickel steel, tungsten steel, vanadium steel, chrome-tungsten steel, chrome-vanadium steel, &c. These special grades have widely different properties and frequently require special treatment.

The low limit below which it is not practical to anneal tool steel is about 1,200° Fah. The high limit above which it is not safe to anneal tool steel is about 1,500° Fah. In this range of 300° practically all annealing operations are carried on. This great variation in heats is required mainly because of the previous condition of the steel or because special results are required. Steel as it comes from the mill is said to be in the natural state, but this is very indefinite as it may be in any one of a variety of conditions due to a lack of uniformity of melting, soaking the ingot, rolling, &c. The normal condition for unannealed steel is sorbite, containing in the case of steels over 0·80 per cent. carbon, a fine, well-distributed network of cementite.

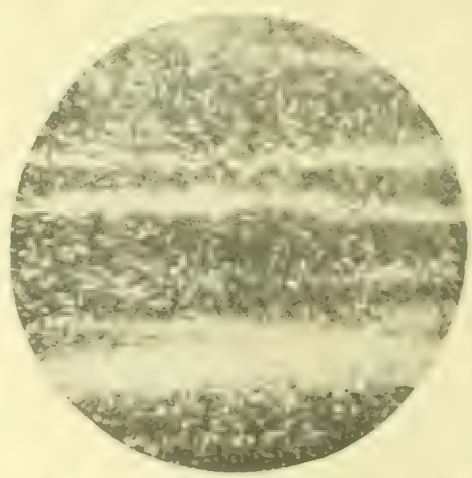


FIG. 2 LONGITUDINAL SECTION, SHOWING SEGREGATION OF CEMENTITE.

For the proper regulation of annealing temperatures a knowledge of the critical point of the steel is necessary. The critical point in tool steel, or, as it is sometimes called, the recalescence point, is the point in heating steel where the cementite is dissolved by the iron, and is the point in cooling where the cementite crystalises out of the iron. This might be roughly compared to water at about the freezing point. For the sake of comparison we will refer to the freezing point of water as its critical point. If you cool the water slightly below the critical point needles of ice at once begin to form. If we heat it above the critical point the needles at once melt or are dissolved. The cementite in tool steel behaves in the same way. If we heat it above the critical point, which is about a cherry red or 1,375° Fah., the cementite melts or is dissolved in the iron, but as soon as it cools again the cementite at once crystalises out. This separation of the cementite takes a certain amount of time. The hardness and toughness of hardened steel are due entirely to the fact that the steel is cooled so rapidly from above the critical point that some of

the cementite is trapped in the iron by the sudden stiffening of the cooling metal, forming martensite or hardened steel. But if the cooling from above the critical point is prolonged, the iron and cementite separate and lie side by side in the form of pearlite, or annealed steel. The critical point is marked by a number of interesting phenomena, among the most important of which, from a practical standpoint, is the loss of magnetism. The critical point may be roughly determined as the temperature in heating at which steel no longer attracts a magnet, and the temperature in cooling at which it begins to attract a magnet.

The varied results which it is necessary to accomplish by annealing demand a wide range of treatments. The principal purposes for which tool steel is annealed are: (1) To put it in

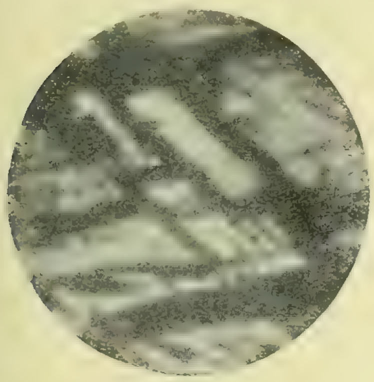


FIG. 3.—MICRO-PHOTOGRAPH OF MARTENSITE.

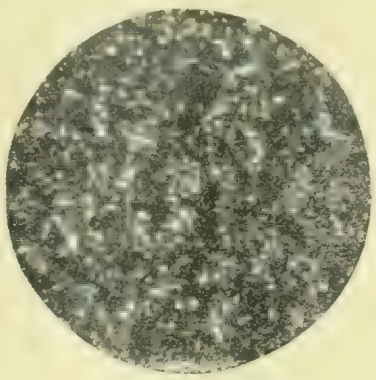


FIG. 4. CEMENTITE BROKEN UP, NOT LIABLE TO FIRECRACK.

condition to harden properly. (2) To put it in condition to machine. (3) To put it in condition to draw into wire.

To put steel in condition to harden, it is necessary to give it the finest possible structure and at the same time the best possible distribution of cementite in case the steel is above 0·90 per cent. carbon. It is generally recognised that this may be best accomplished in steels which have no abnormal conditions present, by annealing at a temperature slightly above the critical point. If a laboratory and pyrometers are available the critical point for each grade of steel used may be determined accurately. If these facilities are not at hand the critical point may be determined roughly by means of a magnet.

To put steel in condition for machining it is necessary to take into account the different machining operations. The three principal operations on tool steel are turning, milling, and threading. The turning operation requires steel as soft as it can be obtained. The milling operation requires steel slightly harder in order that the metal will not drag, making the work rough and gumming-up the cutter. The threading operation requires steel still harder in order that the metal will not drag nor the threading tool throw up a burr. Steel that will thread perfectly will frequently cause great difficulty in turning. Where only one of these operations is necessary the annealing may be adjusted with little difficulty, but if two or three of the operations must be performed upon the same work the only solution of the problem is to endeavour to strike the happy medium where all of the operations can be performed at least fairly well.

In drawing tool steel into wire it is necessary to anneal after each draft, in order to soften the steel and restore the low elastic limit destroyed by the stretching as it was drawn through the dies. This wire is annealed by heating to a temperature considerably below the critical point for a considerable length of time, the low temperature being necessary to avoid the formation of bark and graphite.

Some of the abnormal conditions which may be present in unannealed tool steel are coarse structure, due to overheating or a high finishing temperature under the rolls; segregation of cementite, and bark. The refining of the coarse structure due to overheating usually requires a double treatment involving first an annealing at a temperature from 100° to 150° above the critical point. This annealing completely breaks up the over-heated structure. It is then given a second annealing slightly above the critical point to still further refine the structure left by the first treatment.

The segregation of cementite caused usually by prolonged soaking is in danger of being increased by annealing. If it is not too far advanced, it may be improved by a treatment similar to that for overheated structure. Bark and graphite are the two most undesirable products of annealing.

Bark is the completely or partially decarbonised layer of steel near the surface. It is due chiefly to the oxidising action of air and other gases upon the steel while it is at a high temperature. It has been observed in depths varying from 0·001in. to 0·125in. All steel has more or less bark unless it has been removed by pickling or grinding. The principal cause of its production in annealing is an oxidising condition which may be due to air, a large quantity of scale or rust on the steel, or some packing material which contains oxygen. A micro-photograph of bark on steel is illustrated in Fig. 7.

It is very important that all of the bark be removed from the steel for the reason that it will harden only in proportion to the amount of carbon it contains, which in any case will be less than that of the interior of the steel, and may be so low that it will not harden at all. Difficulty caused by bark is in the turning operation. In a high-carbon steel containing from 1 to 7·50 per cent. carbon, a large part of the bark will approximate 0·70 to 0·80 per cent. carbon. The critical point of steel containing 0·70 per cent. to 0·80 per cent. carbon is very low. Therefore, when the steel is annealed at its appropriate temperature the bark is considerably overheated, with a resulting coarse structure.

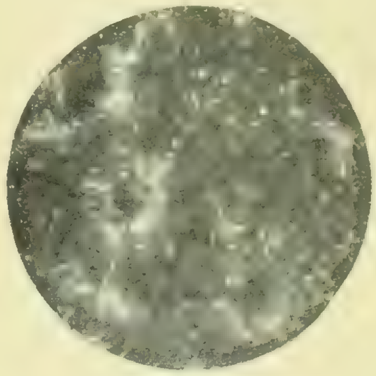


FIG. 5 CROSS-SECTION, SHOWING SEGREGATION OF CEMENTITE.

On round bars this forms a ring of hard, overheated steel which is extremely difficult or even impossible to turn accurately. The best remedy for this condition is to anneal in such a manner as to produce no bark, but if it is necessary at any time to soften a bark so that it may be machined, it may be done by re-annealing at a temperature varying from 1,330° to 1,375° Fah., depending on the grade of steel used.

The second by-product of annealing is graphitic carbon, sometimes known as black fracture or black centre. In this condition part or all of the carbon has been driven out of combination in the form of graphite. This practically amounts to changing the tool steel into a high grade of malleable cast iron. It is caused by either repeated annealings or prolonged annealing at a temperature below the critical point. Once formed, the only remedy is to remelt the steel.

FIG. 6—CEMENTITE NETWORK, LIABLE TO FIRECRACK.

When it is desired to anneal steel which has already been hardened, annealing at a temperature just below the critical point is usually satisfactory. High-speed steels may be annealed at temperatures varying from 1,325° to 1,400° Fah. in a manner similar to plain carbon steel. Greater care is usually taken to pack the steel in such a manner as to prevent bark.

There is a method of quick annealing high-speed steel which is useful where it is necessary to anneal a single tool as quickly as possible. It consists simply in heating the tool to 1,300° Fah., allowing it to cool in the air, reheating to 1,300° Fah. and holding it at that heat for 30 minutes, when it is allowed to cool in the air. This will be found successful for most high-speed steels now on the market, making the tool soft enough to machine and putting it in condition to reharden perfectly.

Tool steel to be hardened must be heated to a temperature above the critical point and cooled rapidly in some quenching bath such as water. The degree of hardness depends upon the rapidity of cooling and also upon the amount of carbon present. The higher the percentage of carbon and the faster the

cooling the harder the steel will become. When tool steel is quenched at a temperature slightly above the critical point, it has the finest structure that it is possible for it to attain. The higher the heat above the critical point the coarser the structure becomes. The hardening temperatures for most tool steels in use to-day lies between 1,360° and 1,450° Fah.

Closely connected with hardening is the drawing operation. For most purposes it is found necessary to draw or temper hardened steel in order to relieve strains and increase the toughness. This is accomplished by reheating the hardened steel to a low temperature varying from 400° to 600° Fah., according to the degree of hardness and toughness it is desired to obtain.

One of the principal difficulties encountered in hardening steel is the liability to firecrack. Firecracks are especially liable to start from sharp corners, sharp angles, or deep recesses. These should be avoided in the design of tools whenever possible.

The two principal causes of firecracks are high sulphur content and bad distribution of cementite. The amount of sulphur can only be detected by a chemical analysis. The condition of the cementite can only be determined by microscopic examination. The effect of the condition of the cementite upon the hardening of tool steel cannot be too highly estimated. In hardened steel the cementite contains that portion of the carbon which is in excess of 0·80 per cent. The amount of it present is of little importance compared with the condition in which it is present. It should be remembered that cementite is extremely hard and also extremely brittle. If it is present in a network, long plates, or connected masses, it forms a line of weakness which is easily fractured under the hardening strains. These lines of weak-

FIG. 7.—MICRO-PHOTOGRAPH OF BARK ON STEEL.

ness are shown in Fig. 1. If the cementite is properly broken up by the annealing or previous heat treatment it will be present in small, rounded particles, each one isolated from the others. Such a structure gives the maximum strength to the steel. If the sulphur analysis of a steel is known to be satisfactory, the relation of the condition of the cementite to firecracks may be expressed briefly as follows.

If the cementite is present in plates or large masses the tool will firecrack. This network is illustrated in Fig. 6. If it is present finely broken up in round particles the tool will not firecrack, this structure being shown in Fig. 4.

The effect of the condition of the cementite upon the cutting qualities of the steel tools is of even greater importance. To understand the action of a cutting tool take the example of a lead lap. If a piece of lead charged with diamonds the size of shot were held against a rapidly-revolving piece of metal the diamonds would start to cut, but would be instantly torn away from the soft lead in which they were embedded. The result would be that the lap would be rapidly spoiled, while the work was only roughened. If the lap is charged with fine diamond dust each particle of diamond takes a very small cut and is held firmly by the lead until it is worn away. Such a lap cuts almost as fast as an emery wheel and produces a smooth, finished surface with very little wear of the lap.

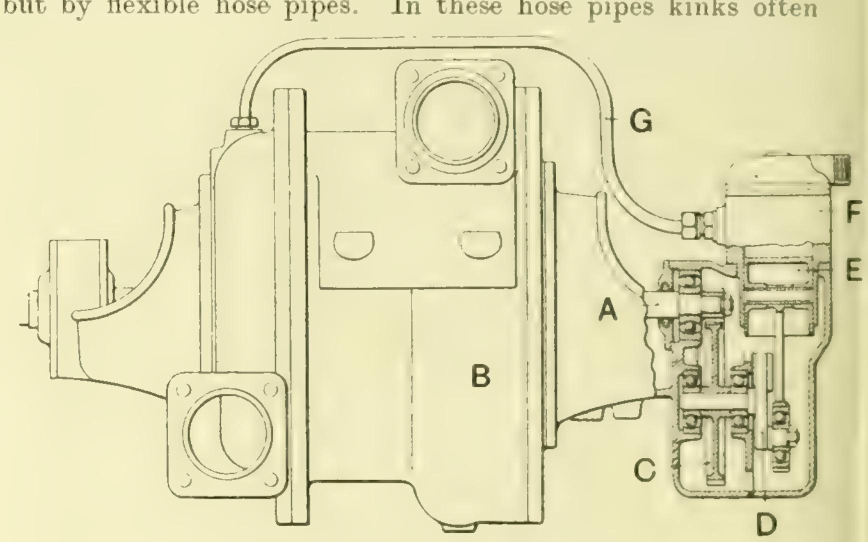
In a steel-cutting tool, if the particles of cementite are large they are rapidly torn away, exactly as in the lead lap, causing the cutting edge to crumble and wear away rapidly. But if the cementite particles are small and uniformly distributed, they are held firmly and stand a large amount of wear. This fact is so important that it may be stated that for tools of the same analysis and degree of hardness, the amount of work done will be in proportion to the fineness of distribution of the cementite.

It may also be stated that for finishing tools the better the distribution of the cementite the finer the finish it is possible to obtain. In this connection it is sometimes asked: "Why is it that high-speed steel does not make good finishing tools?" This can be best explained by a comparison. If you wish to saw a piece of wood in such a way as to leave the smoothest possible surface you naturally select a saw with the finest possible teeth. If you wish to saw very rapidly without regard to the roughness of the work you select a saw with very coarse teeth.

Applying this same principle to steel. A high-grade carbon steel, properly made into a finishing tool, has the cementite distributed in very fine, uniform particles in a martensite matrix so fine as to be almost structureless. Such a tool produces a very smooth finishing cut. On the other hand, high-speed steel consists of fairly large grains which break apart, producing a rough edge which will cut very rapidly, but not smoothly.

SULZER'S CENTRIFUGAL PUMP FOR FIRE SERVICE.

CENTRIFUGAL pumps have the disadvantage of drawing badly. Consequently disturbances in the suction pipe may lead to the suction column of water breaking off and to the delivery being interrupted. This is more likely to occur in pumps for extinguishing fires or for use in other circumstances where the suction piping is not constituted by rigid pipes, but by flexible hose pipes. In these hose pipes kinks often



SULZER'S CENTRIFUGAL PUMP FOR FIRE SERVICE.

form whereby the delivery is disturbed, and if a continuous water column is to be obtained again, it is necessary to produce a good vacuum, for which purpose the suction of the centrifugal pump is insufficient.

In order to obviate these difficulties, the arrangement illustrated has been designed and patented by Sulzer Bros., Winterthur, in which a piston vacuum pump is connected to the suction pipe of the centrifugal pump and driven with the centrifugal pump for rendering the working as reliable as possible. The initial suction may also be produced by the piston pump, whilst the centrifugal pump propels the water or delivers it under increased pressure. Referring to the illustration, the piston E of a vacuum piston pump F is driven from the spindle A of the centrifugal pump B by a gear C and a crank disc D. The vacuum pump is connected by a pipe G to the suction side of the centrifugal pump, and is driven together with the latter. As soon as for any reason there is a disturbance in the suction piping, affecting the vacuum, the piston pump at once re-establishes the vacuum necessary to obtain the continuous water column again.

Status Prize.—The Council of the Society of Engineers may award in 1912 two premiums of books or instruments to the value of £8. 8s. and £4. 4s., for approved essays on the subject of "How to Improve the Status of Engineers and Engineering, with special Reference to Consulting Engineers." The competition is open to all, but application for detailed particulars should be made to the Secretary before entering

THE BALANCING OF LOCOMOTIVES.—III.

BY JAS. DUNLOP.

COUPLED DRIVER ENGINES.

INTRODUCTORY to the consideration of engines with coupled driving wheels and to make quite clear the points previously commented upon regarding reciprocating parts moving in different planes, also the difference in inertia effects due to the connecting rods of 4-cylinder so-called "balanced locomotives" being on the same sides of their driving axles, the 4-cylinder locomotive illustrated in Fig. 24 is taken as an example. This engine was designed for the Lancashire and Yorkshire Railway by Mr. Geo. Hughes, the locomotive superintendent, and was very fully described by him in a paper he read before the Institution of Mechanical Engineers. This paper was printed in these pages in July and August, 1909, and in addition to disclosing the fact that the mean weight of the reciprocating parts on each side of the engine is 485lbs., it contains the interesting statement that "the reciprocating parts on the inside of the frames, moving in an opposite direction to the outside, counteract each other, and the engine is balanced so far as reciprocating parts are concerned, except for a horizontal swaying couple, which is inconsiderable."

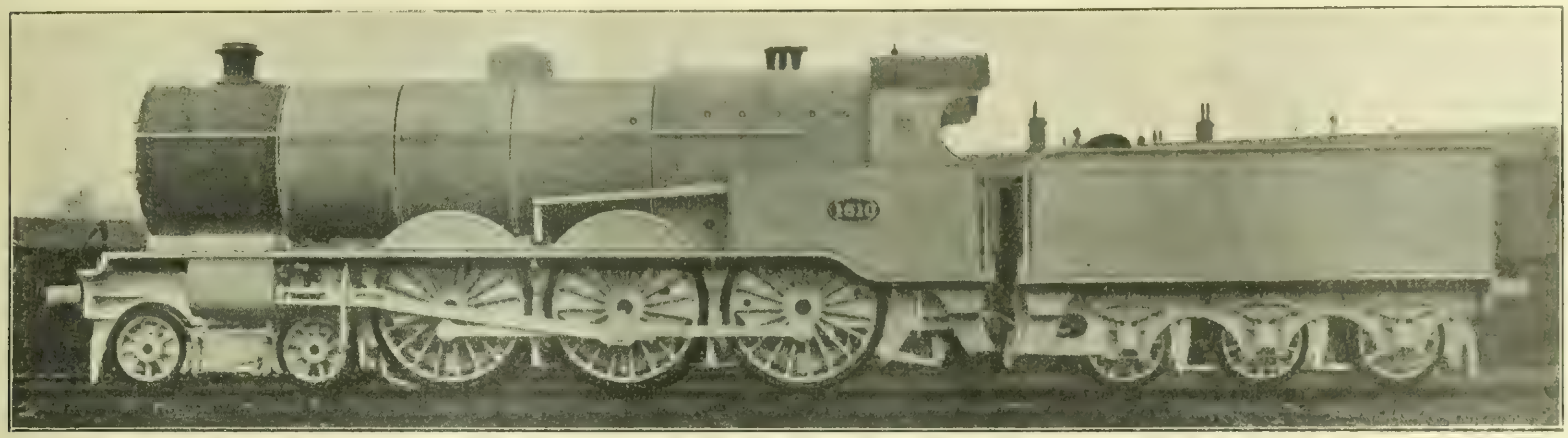


FIG. 24. LANCASHIRE AND YORKSHIRE RAILWAY 4-CYLINDER LOCOMOTIVE.

It is, no doubt, because of this interesting statement that the balance weights of this engine have the unusually square relation to each other on opposite wheels, shown by the balance-weight arrangement illustrated in Fig. 25. To anyone with only a superficial knowledge of balancing, the positions of these weights at once excite questions why with inside cylinders the balance weights are all opposite the coupling cranks, and why they are directly opposite. The answer to the first question is because the inside revolving parts are completely balanced by the tail weights on the inside cranks. The answer to the second question is because the reciprocating parts are not balanced at all, and the inconsiderable swaying couple above mentioned amounts to no less than 72 per cent. of the weight of the reciprocating parts for one cylinder.

One of the virtues possessed by a 45° set-square is that it cannot make mistakes, and the following use of it will demonstrate quite clearly the relation between the weight of the reciprocating parts and the amount of the swaying couple set up by them. Fig. 26 illustrates the cross-section drawing of the engine. Project downward, from the cross-section drawing, the centre lines of the cylinders and of the (approximate) centres of gravity at which the balance weights are placed in the wheels. At right angles across these lines draw the line A B, cutting the balance-weight centres at C and D. With C as centre, describe a small circle to indicate the crank axle. Describe also, as shown, small circles to indicate the inside and the outside crank-pin positions. Through D draw D F at an angle of 45°, cutting the cylinder centres at E F G and H. Join these points to C and it will then be seen the joining lines are the separate balance weights for the inside and outside cylinders, as previously demonstrated in the constructions shown in Figs. 6 and 9. Also E F and G H represent these weights on each side of the engine combined in one. This latter fact may not at first sight be quite clear, but as the actual positions of C F and C G in relation to C E and C H are the dotted prolongations C K and C J, it will be seen that, by drawing the parallelograms C K M E and C J L H, the resultant weights C M and C L are, by the nature of the construction, equal and parallel to E F and G H. Then if C D—the distance between the centres of gravity of the balance weights—represents to any scale the weight of the reciprocating parts for each cylinder, C M and C L represent to the same scale the horizontal swaying couples which are said to be inconsiderable, and the angles N C M and A C L are the angles in relation to the outside cranks at which the equivalent balance weights must be placed in the wheels.

The scale of Fig. 26, as here printed, is too small to measure accurately the proportions of C D and C L, but an arithmetical comparison may be made as follows: The centres of the cylinders are 23in. and 83in. respectively, and the centres of gravity of the balance weights = C D are approximately 58in.

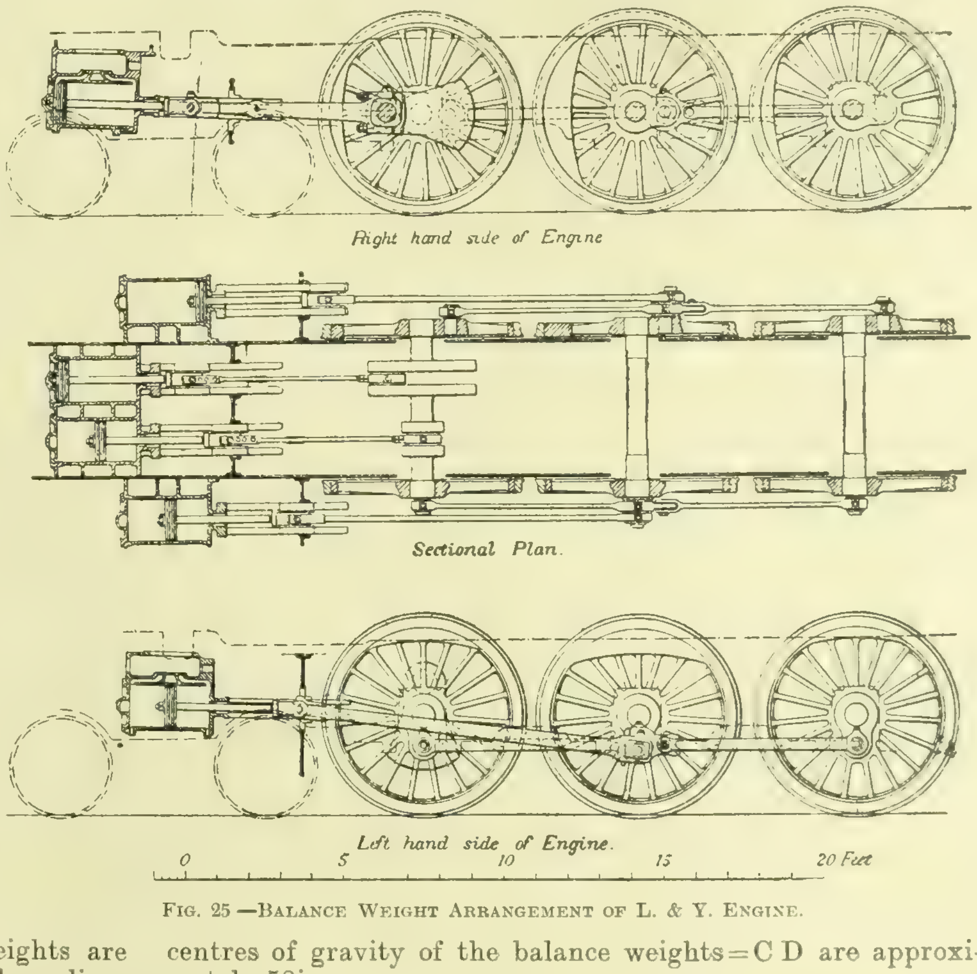


FIG. 25.—BALANCE WEIGHT ARRANGEMENT OF L. & Y. ENGINE.

$$\text{Then } \sqrt{2}\,\frac{83-23}{2} = CL = 42\text{in. say.}$$

The mean weight of reciprocating parts for one cylinder is 485lbs.

$$\frac{485 \times 42}{58} = 351\text{lbs.}$$

$$\frac{351 \times 100}{485} = 72 \text{ per cent.}$$

An ordinary inside 2-cylinder engine with reciprocating parts twice the weight for each cylinder and having two-thirds balanced in the usual manner would have no greater horizontal swaying couple than this 4-cylinder so-called "balanced locomotive."

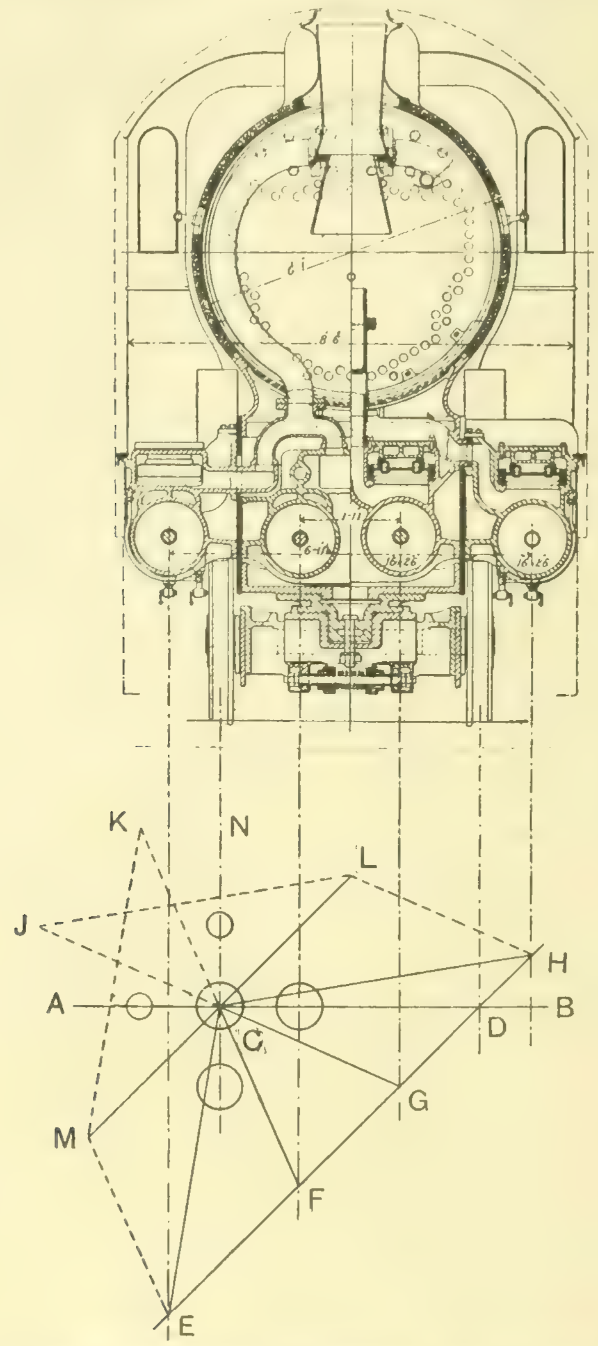


Fig. 26.—Balancing Diagram. 4-Cylinder L. & Y. Locomotive. Reciprocating Parts Only.

One important point demonstrated by this construction is that, so long as the inside and outside reciprocating parts are of equal weight, the angle of the balance weight is always 135° from the outside crank, and is quite independent of the amount of the weight or of the distance between the centres of the cylinders. If the outside parts are heavier than the inside, the angle becomes greater. If the inside parts are the heavier, the angle becomes less. Finally, of course, the balance weights for reciprocating parts are combined with the balance weights for the revolving parts, and the ultimate angle is determined by the relative positions and amounts of these weights in parallelogram construction. It is this latter fact that prompts anyone looking at Fig. 25 to doubt the accuracy of the balancing carried out on the engine in question. For purpose of comparison, Fig. 27 illustrates a 4-cylinder engine similar in all balancing essentials to the Lancashire and Yorkshire engine. The angles at which the various balance weights are placed at once indicate the attention that has been given to the horizontal swaying couples, and, as a whole, this engine may be taken as a good example of what a correctly-balanced engine of this construction looks like.

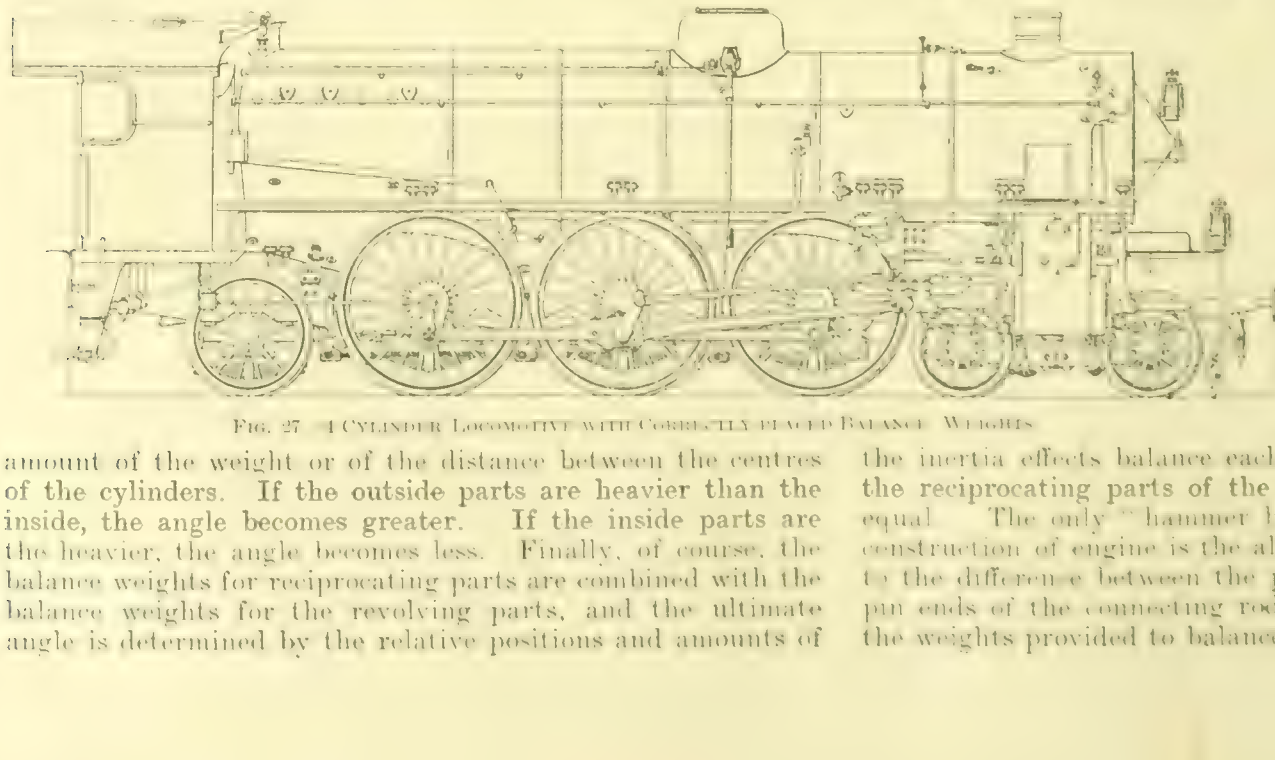


Fig. 27.—4-Cylinder Locomotive with Correctly Placed Balance Weights.

In this engine, however, as in all similar type engines, there are swaying couples that no balance weights can eliminate. These couples arise from the fact that all four connecting rods are operating on the forward sides of the driving axles, so that while one connecting rod is making a forward stroke, the adjacent connecting rod is making a backward stroke. There is, consequently, a maximum difference between the inertia effects of the reciprocating parts at the end of each stroke. This difference is clearly illustrated in Fig. 28, which shows the inertia effects of equal reciprocating weights attached to adjacently-moving connecting rods jointed to cranks set at 180° apart. The figure is drawn for a 6 to 1 ratio of connecting rod to crank, and 15° crank angles, and shows that at the end of each stroke the difference in the inertia effects amounts to one-third of the weight of reciprocating parts attached to one connecting rod. The reason why balance weights cannot eliminate this difference is because each connecting rod alternately sets up the maximum effect, and any weights used for the purpose would merely oppose each other without affecting the balance of the engine in any way. Even were it supposed that the connecting rods moved in one and the same plane, this difference in inertia effects would still occur.

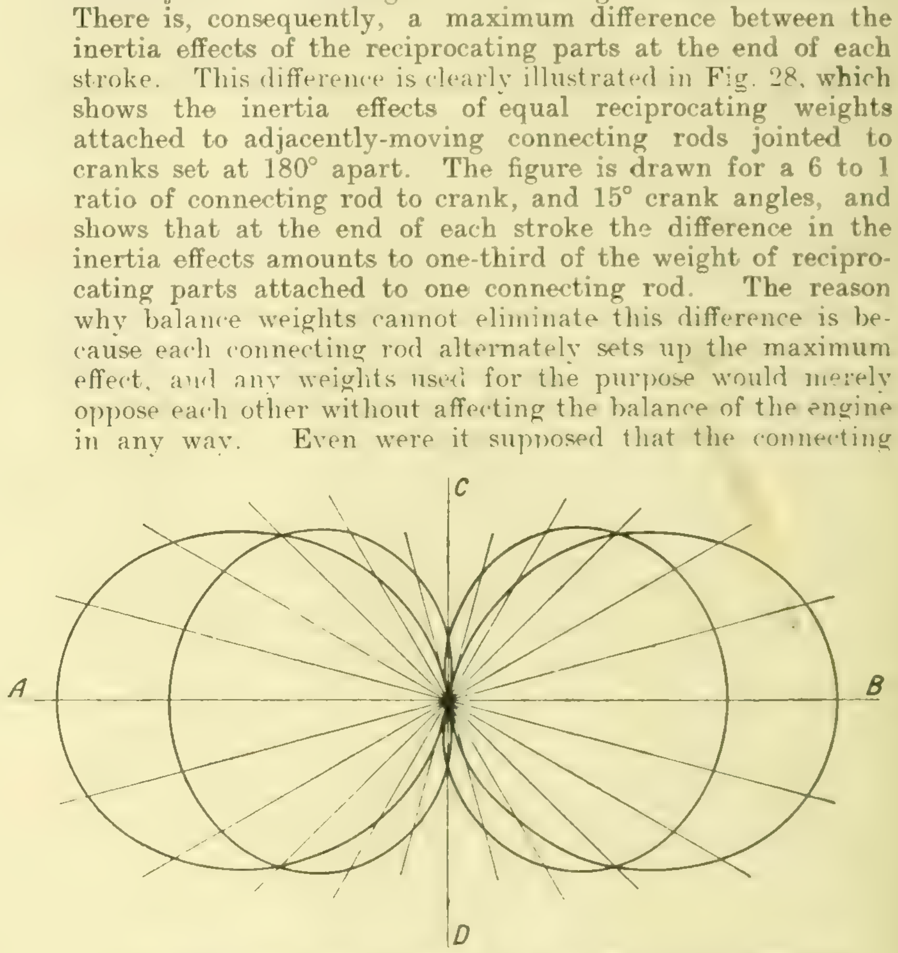


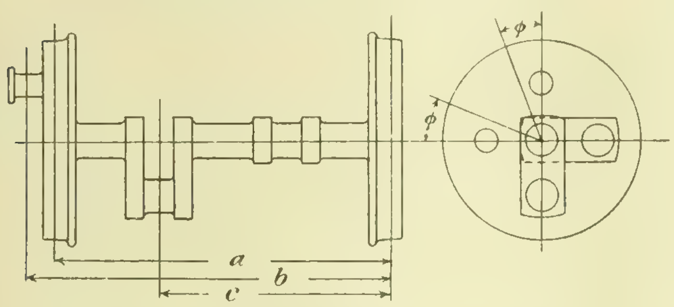
Fig. 28. Showing Inertia Effects of Equal Reciprocating Weights, for Cranks Set at 180° apart, 6 to 1 Ratio of Connecting Rods to Cranks, and 15° Crank Angles.

The only more or less normal construction of locomotive in which this difference can be eliminated along with all horizontal swaying couples due to reciprocating parts is illustrated in Fig. 29, which shows a design of 10 coupled driver engine perfectly practicable, although not actually constructed. The cylinders are arranged outside in pairs at each end of the engine, so that the connecting rods of the front and back cylinders on either side make inward and outward strokes simultaneously. This is brought about by the balance cranks on the central pair of coupled wheels, and, as a consequence, the inertia effects balance each other at all times, provided the reciprocating parts of the front and back cylinders are equal. The only "hammer blow" effect possible with this construction of engine is the almost insignificant amount due to the difference between the pendulum action of the crank pin ends of the connecting rods and the revolving action of the weights provided to balance these parts of the connecting

rods. A consideration of the coupling arrangement of this engine, along with that of Fig. 2, will show that any number of pairs of driving wheels, from two upward, may be coupled, and at the same time have an engine that is practically perfect in its balance.

There are, no doubt, many engineers who have an antipathy to performing calculations graphically, just as there are others who make use of a formula without really understanding at all what the formula implies. For the benefit of the latter especially, it may be as well to explain that the following arithmetical calculations, although very simply expressed, are perfectly exact, and give just the same results as the more roundabout expressions generally used.

Inside Cylinder Engines.
Form of Balance-weight Calculations.



Let a = distance between centres of gravity of balance weights.

b = distance between coupling rod centre and far balance weights.

c = distance between connecting rod centre and far balance weights.

W_1 = weight of crank arm with included part of crank pin acting at distance a.

W_2 = weight of revolving masses, *i.e.*, part of coupling rod, with included part of crank pin acting at distance b.

W_3 = weight of revolving masses, *i.e.*, half connecting rod with included part of crank pin and crank arms acting at distance c.

W_4 = weight of reciprocating masses to be balanced in each wheel and acting at distance c in all cases.

W_P = primary balance weights.

W_S = secondary balance weights.

C = combined balance weights.

Driving Wheels.

$W_{P1} = W_1$

$W_{P2} = W_2 \frac{b}{a}$

$W_{S2} = W_{P2} - W_2$

$W_{P3} = W_3 \frac{c}{a}$

$W_{S3} = W_{P3} - W_3$

$W_{P4} = W_4 \frac{c}{a}$

$W_{S4} = W_{P4} - W_4$

$W_P = W_{P3} + W_{P4} - W_{P1} - W_{P2}$

$W_S = W_{S2} + W_{S3} + W_{S4}$

$C = \sqrt{(W_P)^2 + (W_S)^2}$

$\frac{W_S}{W_P}$ = tan of angle of convergence ϕ

Leading or Trailing Wheels.

$W_{P1} = W_1$

$W_{P2} = W_2 \frac{b}{a}$

$W_{S2} = W_{P2} - W_2$

$W_{P4} =$ } same as for driving
$W_{S4} =$ } wheels

$W_P = W_{P1} + W_{P2} - W_{P4}$

$W_S = W_{S2} + W_{S4}$

$C = \sqrt{(W_P)^2 + (W_S)^2}$

$\frac{W_S}{W_P}$ = tan of angle of divergence as for outside cylinder engines.

NOTE.—All weights are taken at crank pin radius—*i.e.*, inch-pounds—and are to be reduced in ratio according to balancing moment of crescent found.

It will be perceived from these calculations that primary weights are placed in the wheel nearest the particular masses that are being balanced, while secondary weights are placed in the opposite wheel, and that when the various weights are combined, it is the primary weights of one side of the engine

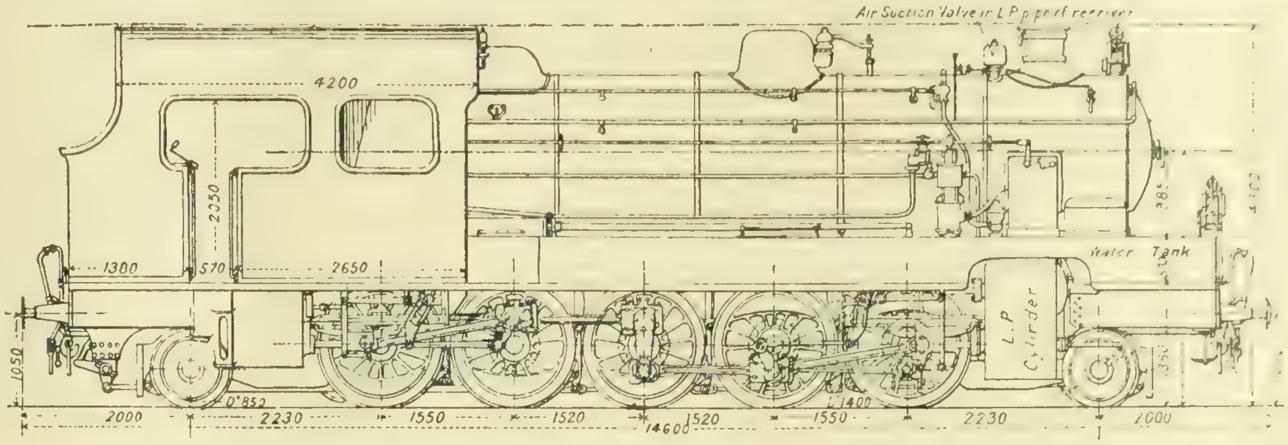


FIG. 29.—OUTSIDE 10-COUPLED DRIVER 4-CYLINDER LOCOMOTIVE WITH PERFECT BALANCE.

that are combined with the secondary weights of the opposite side.

The relative positions of the various combined weights for a correctly-balanced 6-coupled inside-cylinder locomotive, coupled forward and backward, are illustrated in Fig. 30, the inside revolving as well as the reciprocating parts being balanced in the wheels.

As an alternative to the arithmetical calculations, the proportional scale illustrated in Fig. 7 may be used to produce the same results with the certainty that any false steps made will be quickly evident and much more easily retraced than is the case with arithmetical calculations.

The method of using the scale is illustrated in Fig. 31, which shows the cross section drawing of Fig. 30, combined with the scale so that the cylinder centres, the centres of gravity of the balance weights, and the coupling rod centres may be projected across the scale in the downward direction, as shown. It will be seen that, according to the horizontal line on the scale along which it is read off, any weight W from 8lbs. to 500lbs. can be found. Then along the same horizontal line the corresponding primary weights W_P or the secondary weights W_S, whether for inside or outside parts, can be read off direct, thus performing at a glance the arithmetical calculations previously given. By drawing two lines at right angles and along these lines marking off to any desired scale the various primary and secondary weights, as shown in Fig. 32, the ultimate amount and angle of the combined balance weights are found without calculation of squares and roots or consulting tables of tangents, &c. It will be understood that, for inside-cylinder engine balancing, primaries oppose primaries, but secondaries add to secondaries, and that the lesser is taken from the greater primary before the line is drawn to form the triangle, the hypotenuse of which represents to the given scale the amount and angle of the combined weight.

Fig. 32 shows approximately the various weights of the driving wheels of Fig. 30, and it is to be noted that the balance weights for the reciprocating parts of coupled engines are divided equally between all the coupled wheels. It is, of course, understood that the weights of the parts to be balanced can only be ascertained by direct weighing or by careful calculation, but in either case these weights tabulated against their various symbols on the left of Fig. 32, along with the scaled primaries and secondaries, would form a useful and reliable record against any future questions regarding the balancing of an engine.

Readers interested in the use of the proportional scale will find that a scale 30in. long will meet all requirements. A third row of figures giving a maximum reading of 750lbs. may be added at the top.

Junior Institution of Engineers.—The following meetings of this Institution have been arranged: Tuesday, March 12th, at the Institution of Electrical Engineers, Victoria Embankment, at 8 p.m., paper on "Railless Electric Traction," by Mr. Bertram D. Fox, B.A., Assoc.M.Inst.C.E.; Friday, March 15th, at 39, Victoria Street, Westminster, at 8-15 p.m., Mr. A. H. Weston, on "Crude Oil Engines." On Saturday, March 16th, at 10 a.m., a visit has been arranged to the Lots Road Generating Station, Chelsea.

BRITISH ENGINE, BOILER, AND ELECTRICAL INSURANCE COMPANY, LTD.

At the annual meeting of the shareholders of the British Engine, Boiler, and Electrical Insurance Company, Ltd., held at the offices of the company, 12, King Street, Manchester, on Friday, March 1st, the Chairman (Mr. Longridge) remarked that while increased competition from accident insurance companies had not interfered with the usual steady increase in the volume of business, the claims for the year 1911 had been abnormally heavy. This was not to be accounted for either by lack of vigilance in the selection of risks or by diminished efficiency in the matter of inspection, and though he might be accused of frivolity in making the suggestion, he was inclined to think that climatic conditions affected the result. It was an admitted fact that boiler claims were unusually heavy in a year when there was a dry summer and the supply of feed water was deficient both in quality and quantity. It was not so easy to trace a connection between the weather and the breakdowns of either engines or electrical plant, except that a sudden frost, such as had recently been experienced, would certainly increase the claims for breakdowns among gas engines, but, be the cause what it might, the claims ratio for 1911 had been unusually high. The percentage of breakdowns among insured plant did not vary much, and it was higher than either owners or makers were disposed to admit, but with the spread of the company's business their costs both for periodical inspections and for the supervision of repairs were proportionately reduced. Out of the disposable balance of £17,025 it was proposed to carry £7,000 to reserve fund, to write off £250 from furniture and instruments, and, after declaring a dividend of 5s. per share with a bonus of 3s. per share (less income-tax in both cases), there would be £2,091 to carry forward to next account. After re-election of the retiring directors (Mr. W. E. Barrett and Sir Frank Hollins, Bart.) and the auditors (Messrs. P. & J. Kevan), the meeting closed with a vote of thanks to the chairman and the staff.

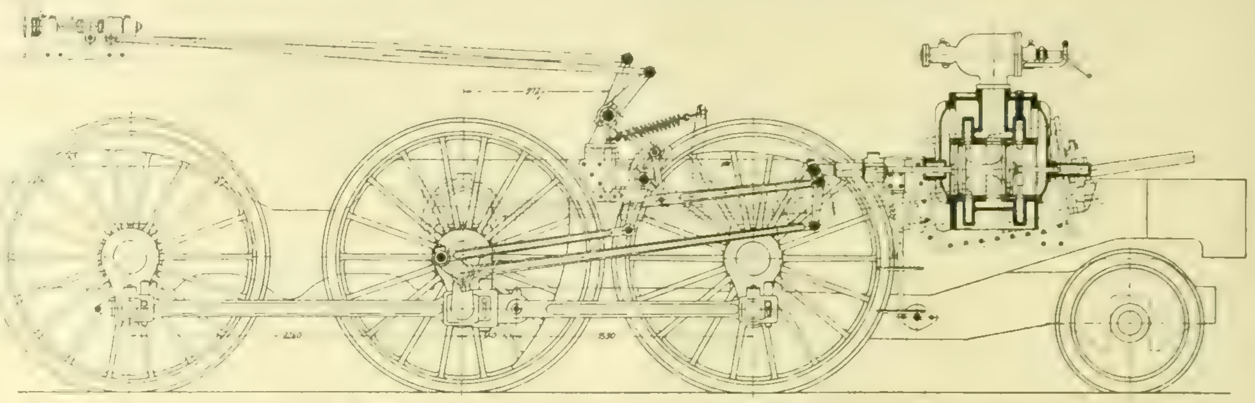
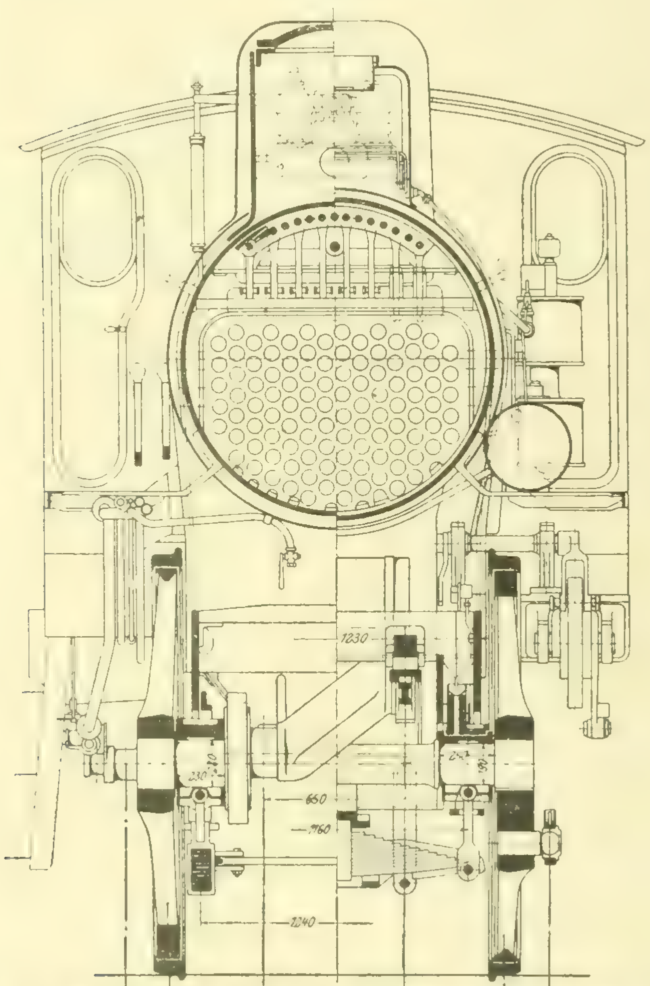


Fig 30.—Relative Positions of Balance Weights, Six-coupled Inside Cylinder Locomotive. (See page 289.)



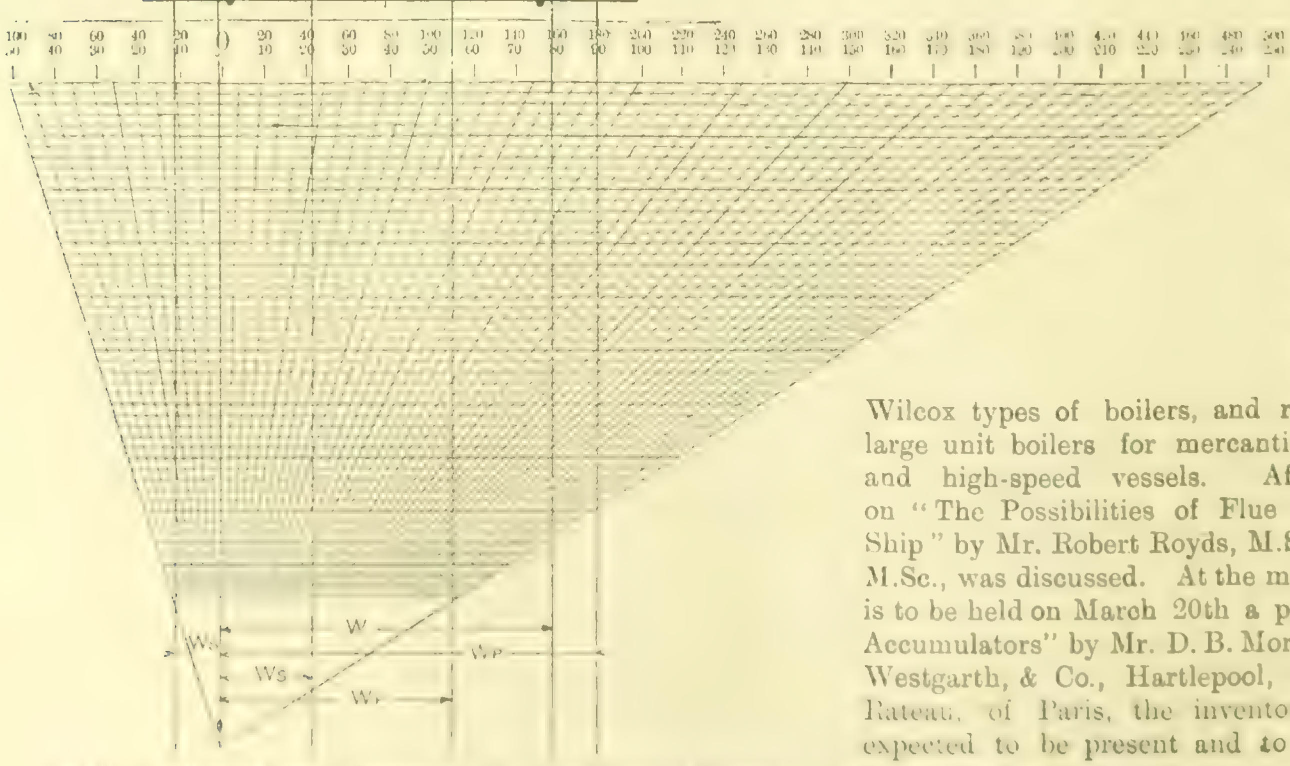


Fig. 31.—Method of Using Proportional Scale to Perform Counter-balancing Calculations. (See page 289.)

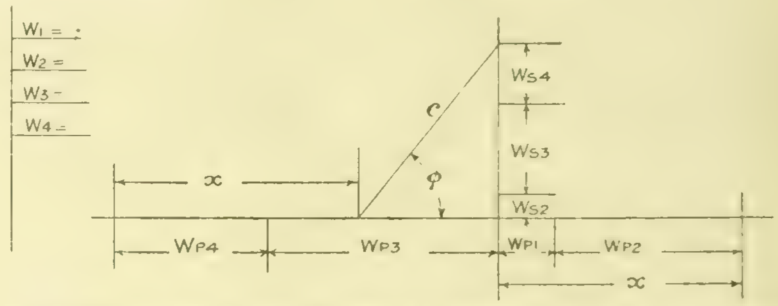


Fig. 32.—Method of Finding Combined Balance Weight in Conjunction with Proportional Scale. (See page 289.)

Institution of Engineers and Shipbuilders in Scotland.—At a meeting of this Institution, held on the 20th ult. at Glasgow, a paper entitled "On the Wider Adoption and Standardisation of Water-Tube Boilers" by Mr. E. M. Speakman, was read. Mr. Speakman dealt principally with the Yarrow and the Babcock and Wilcox types of boilers, and recommended the adoption of large unit boilers for mercantile service and for Channel and high-speed vessels. Afterwards the recent paper on "The Possibilities of Flue Gas Economisers on Board Ship" by Mr. Robert Royds, M.Sc., and Mr. J. W. Campbell, M.Sc., was discussed. At the meeting of the Institution which is to be held on March 20th a paper on "Regenerative Heat Accumulators" by Mr. D. B. Morrison, of Messrs. Richardsons, Westgarth, & Co., Hartlepool, will be read, and Professor Rateau, of Paris, the inventor of the Rateau turbine, is expected to be present and to speak on the subject of the paper.

STURTEVANT STEAM TURBINE WITH REVERSING BUCKETS.

A NEW type of steam turbine which employs reversing steam buckets and introduces a new design of lubrication for the main bearings and which has also a floating packing box arranged to serve as a relief valve has been brought out by the B. F. Sturtevant Co., Hyde Park, Mass., U.S.A. It is designed for direct connection to machinery not demanding relatively high speeds yet requiring good efficiency, such as blowers, ventilating fans, gas exhausters, mechanical draught installations, electric generators, and centrifugal pumps. We are indebted for the accompanying illustrations, which show the main points of the turbine, to our contemporary "The Iron Age."

The steam enters an annular steam chamber in the casing of the turbine through a balanced throttle valve. From this chamber it passes through nozzles to the rotor or bucket wheel. These nozzles expand the steam to a pressure equal to the exhaust pressure in the turbine, so that the steam leaves the nozzles at a very high velocity, impinging against the semi-circular rotor buckets and imparting the impulse to the rotor and leaving the buckets in a reverse direction to that of entry. In leaving, the steam enters the semi-circular reversing buckets made in one piece with the nozzles. The action is to again reverse the direction of the steam and drive it back into the rotor. Thus the steam enters and

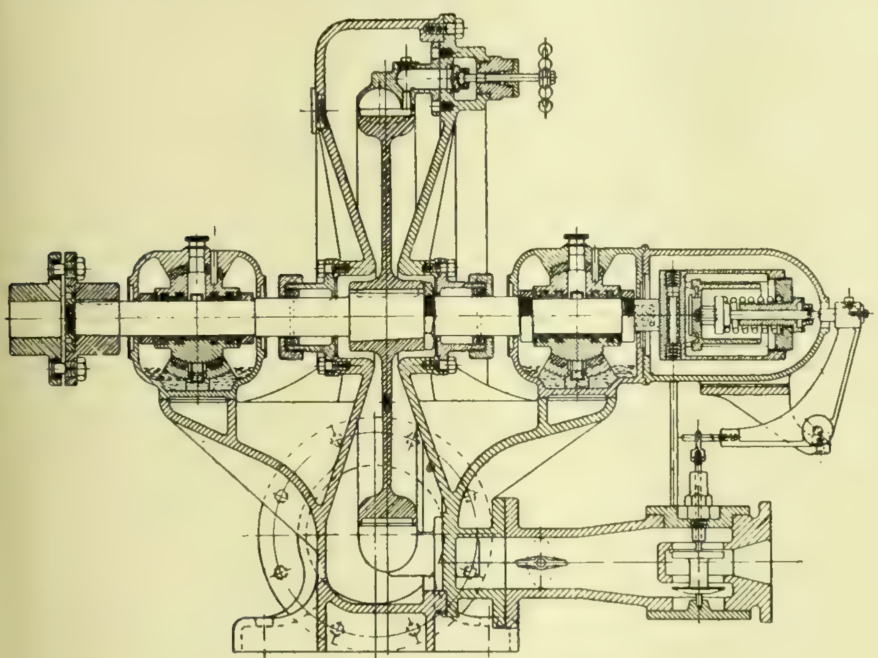


FIG. 1.—STURTEVANT STEAM TURBINE. Longitudinal Section.

leaves the rotor three times before its kinetic energy is absorbed and its velocity drops to nearly that of the rotor. It then passes out into the exhaust. In the illustration (Fig. 2) of the rotor and nozzle sections the vanes of the rotor straddle the edges of the nozzle. It has been demonstrated that when the steam from the nozzle enters the bucket it strikes the upper edge of the lip just entering the jet of the steam nozzle and the semi-circular turn at the bottom and spreads out over the whole area of the bucket before making its exit. The speed of the steam being 15 times greater than that of the rotor, the greater part of it has time to leave the bucket through the supplementary port or reversing bucket shown immediately below the nozzle section. From this port the steam is redirected into the rotor, and the remainder enters the succeeding bucket shown just coming into the compass of the drawing. By this time the bucket mentioned has advanced so that the steam is next caught in the buckets alongside of and beyond the nozzle.

The rotor is a solid forging of open-hearth steel, the buckets being of semi-circular form milled into the rim. The method of cutting these buckets is of exceptional mechanical interest, and is shown in Fig. 3. The cutter is a gear with cutting edges on the back of the teeth and driven by a similar gear, the work being done in an especially designed and patented machine. The former method, using an ordinary shank cutter, necessitated the cutting away of a part of the bucket to give clearance for the shank, which necessarily weakened the rotor construction and was found to reduce efficiency. The new method cuts faster and also smoother, the peripheral drive being more powerful and resulting in no chatter. The rotor buckets are protected by the rim of the wheel, which is raised above them, and the construction of the wheel and stationary buckets is such that if by any chance they should come in contact none of the buckets would be injured. It goes without saying that the solid wheel is practically indestructible, and danger of buckets working loose is eliminated.

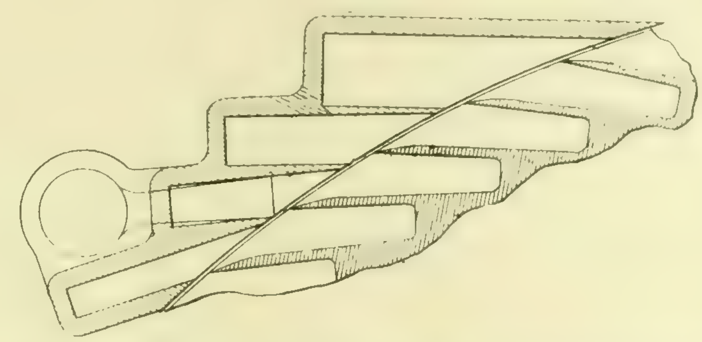


FIG. 2.—SHOWING METHOD OF REVERSING STEAM BETWEEN THE ROTOR AND THE STATIONARY BUCKETS.

The Tobin bronze nozzles and reversing buckets are cast together in segments. The nozzles can be separately closed by hand valves on the exterior of the casing. When the engine is to be operated continuously on a light load one or more of the nozzles may be closed to secure economical operation. Where the demand for power varies widely this feature offers a distinct advantage.

The only parts requiring lubrication are the main bearings, which removes the possibility of oil in the exhaust steam. This is, of course, an important point when the steam is to be used for heating systems or feed-water heaters. A channel oiling ring is used to obtain positive lubrication without the use of a pump. The oil is taken from the oil pocket by the rapidly revolving channel-shaped oiling ring, and is held within the ring by centrifugal force until it is diverted to the bearings by means of a scoop. The ordinary oiling ring, it is held, has a tendency to throw the oil from the bearings instead of concentrating it where it is needed. The channel scoop produces a positive pressure which forces the oil to the bottom of the bearing, where the greatest pressure and consequent need of lubrication exists.

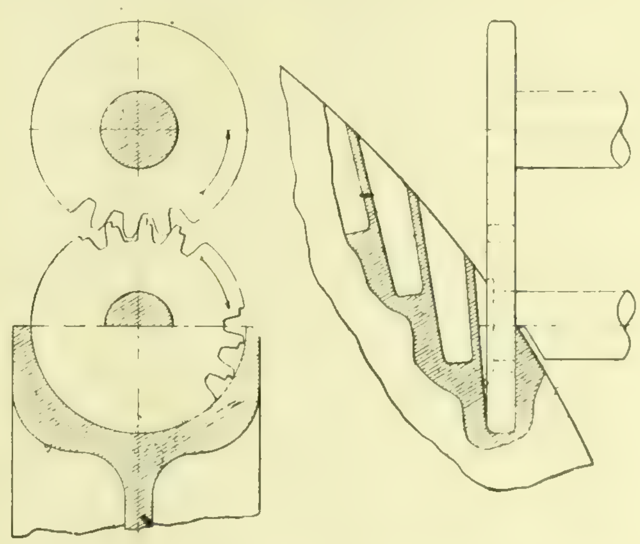


FIG. 3.—SHOWING HOW BUCKETS ARE FORMED IN THE ROTOR.

The speed of the turbine is regulated through a balanced throttle valve by means of a powerful governor of the centrifugal type. In addition to the main governor an emergency governor is set at a predetermined maximum speed. If for any reason the main governor loses control a separate emergency valve is instantly and automatically closed through an entirely distinct mechanism.

The new turbine is built in five sizes, with standard rotor of 12in., 18in., 24in., 30in., and 36in. diam. By suitably combining the size of a rotor, rotative speed, nozzle capacity, and steam pressure, a range of from 5 h.p. to 200 h.p. may be covered by the unit best adapted to the work.

THE INSTITUTION OF CIVIL ENGINEERS.

At a meeting of this Institution held on the 5th inst. two papers by Prof. John Goodman, M.Inst.C.E., were read, of which the following are abstracts:—

Roller and Ball Bearings.

For the past 15 years the author has been investigating the behaviour of both roller and ball bearings, in order to find the load and speed at which such bearings may be allowed to run. The object of this communication is to lay before the Institution the results of a large number of tests of bearings, together with an attempt to reduce the mass of information obtained to a definite law. Two distinct types of testing machines were used; one for roller and ball bearings running on a cylindrical journal, and the other for thrust and collar bearings. These are described.

The common types of roller bearings are then referred to, and their relative advantages and disadvantages are discussed. Emphasis is laid on the serious troubles that arise from the end-thrust on the rollers. The reason for the existence of end-thrust is dealt with, and proposals are made for minimising its ill effects. The machines used for measuring the friction of bearings and the end-thrust are described, and the results are tabulated. The tests show that the friction of roller bearings is much lower than that of ordinary bearings as commonly lubricated; the coefficient of friction is also more constant than with a plain bearing, being practically independent of speed and temperature. The starting effort of a roller bearing is little, if any, greater than the running resistance, which is a very important feature in machines which are constantly stopped and started. No satisfactory expression has been found for the safe load under which a roller bearing may be run. The various frictional losses that occur in a roller bearing have been analysed, and expressions are given for each.

Ball bearings are found to possess a great many advantages over roller bearings; the friction is less, there is no end-thrust, and they occupy a much smaller length of shaft than either plain or roller bearings. Hertz's theory of the compression of perfectly elastic spheres and the stresses which occur in them when loaded is cited, and its application to the ball-bearing problem is pointed out.

Very early in the author's experimental investigation it was found that the speed of rotation of the shaft and the balls makes a great difference to the working load that may be imposed on a ball bearing. It is shown that the centrifugal force acting on the balls does not materially increase the load upon them, hence the speed effect is not due to that cause. It is believed to have some relation to the well-known effect of very rapid reversals of stress. The effect of running balls on flat and on grooved surfaces is dealt with, the experiments largely corroborating theoretical investigations.

The extreme importance of having all the balls in one race of exactly the same size, also of obtaining perfect truth and freedom from scratches in the ball races, is insisted upon. Expressions based on experimental data are given for the limiting working load of ball bearings of both the thrust and radial types; and curves are plotted to show how the author's experiments agree with the tables found in makers' catalogues.

The question of finding the load which will ultimately bring about failure in a ball bearing is one which presented some difficulty. Bearings which appear to be perfect to the naked eye after running for several months may ultimately fail if allowed to run for years. It is obviously out of the question to run test bearings for this length of time. Other methods, therefore, for detecting impending failure were tried, but without success, until the microscope was used for the examination of the balls. This method proved to be very valuable, and is believed to give entirely satisfactory results. The results of tests of ball bearings of different makes and designs are tabulated in an appendix. The design of bearings is also dealt with.

The author is of the opinion that modern ball bearings, as turned out by the best makers, are entirely satisfactory and reliable, and there is no reason to apprehend trouble with them. Reasonable care, of course, must be taken in mounting the bearings, and in ensuring that they are not allowed to run under higher loads than are given by the author's expressions. Ball bearings are more expensive to purchase than plain bearings fitted with ordinary lubrication, but the friction is about one-tenth as great, and the oil required is almost nil. When these qualities are taken into account, the ball bearing for almost every purpose is considered to be vastly superior to plain bearings.

The Testing of Antifriction Bearing Metals.

The author points out in this paper that very few data have been published on the various methods of testing the antifriction properties of bearing metals. In the testing machine used in early experiments the bearing under test was loaded with dead weights, but this becomes very irksome and laborious when large weights are employed. The author therefore designed a machine in which loads up to 10 tons could be applied to the bearing by means of levers, and yet leave it free as regards rotation through a small arc about the centre line of the shaft. The machine is described in detail, special attention being called to the method employed for keeping the temperature of the bearing constant during the test; also of ensuring a small relative to-and-fro motion of the bearing and shaft in order to prevent them from wearing in grooves. The preparation and bedding of the bearing to the shaft is discussed, and the methods of lubrication and other details of the tests are dealt with. The results of two typical tests are given; in the one case the temperature of the bearing was controlled and in the other case it was not.

PREVENTION OF COAL-DUST EXPLOSIONS.

Mr. G. H. Winstanley, M.Sc., F.G.S., president of the National Association of Colliery Managers, in a recent speech said that a professor of Liverpool University had recently put forward a rather startling proposition for the prevention of mine explosions. It was suggested that they should proceed on lines entirely opposed to those adopted for generations. Instead of further improving ventilation, it was rather suggested that they should have deficient ventilation, and that the oxygen percentage should be reduced from 21 to about 17, because with 17 per cent. lights would not burn. Of course, if a light would not burn, they could not very well cause an explosion. No safety lamp was so safe as the one which was not lighted. Of course, from the scientific point of view there was nothing new in the statement that they could not have an explosion unless they had an explosive mixture, but there was something startlingly novel in the suggestion that collieries should be ventilated with air that did not contain a proper proportion of oxygen. Providence had ordained that they should breathe an atmosphere of certain composition. It was a well-known fact that human beings could breathe and live in an atmosphere containing less than 21 per cent. of oxygen; but he did not know that the experiment had been carried so far as to ascertain how long a man might so continue—not merely to sit down in a chair, but to work at the coal face or push tubs about day after day in such an atmosphere. Until professors would submit themselves to such a practical test, he thought they must regard the proposal with a good deal of suspicion.

The Institution of Mechanical Engineers' Examination Test.—A a meeting of the Institution of Mechanical Engineers, held on the 16th ult., the proposals of the Council to institute an entrance examination for admission to the institution was discussed, and the following resolution adopted: "That this meeting generally approves the proposal that each candidate (of an age at present fixed at 30 years and under) for class up to associate membership should (in addition to requirements embodied in the present by-laws) afford satisfactory evidence of training either by suitable educational tests or by passing an examination initiated by the Council on behalf of the Institution; and that the Council be requested to draw up any alterations in the by-laws which may be necessary for submission to the members at a future annual general meeting."

The Northampton Institute Engineering Society.—The 10th annual dinner of Northampton Institute day students (past and present) will be held at the Holborn Restaurant, Kingsway, London, W.C., on Saturday, March 16th, 1912, at 7.30 p.m. Reception 7 p.m. Past students are requested to note the change of date.

SOME GENERAL PRINCIPLES INVOLVED IN THE ELECTRICAL DRIVING OF ROLLING MILLS.*

BY C. ANTONY ABLETT, B.SC.

(*Concluded from page 231.*)

Intermittent-slip Regulator.—Fig. 9 shows a type of intermittent-slip regulator suitable for direct-current motors. This consists of a small motor relay which sets in operation a number of relays which successively connect resistances in parallel with the resistance placed in series with the shunt field of the motor. The field of the motor relay is excited by the main current passing through the mill motor armature. If the mill motor is small the main current passes through this field, but if the main current is too big the field is placed across a shunt placed in the mill motor circuit.

The armature of this motor relay is excited by a pressure winding which is placed across the mains supplying the main mill motor. The armature is restrained from moving by means of a spring, so arranged that when the current in the main circuit exceeds a certain value, the turning moment of the armature of the motor relay overbalances the spring, so that the armature makes a slight movement. This movement of the armature successively makes contact with a number of fingers, which energise the relays, which successively connect resistances in parallel with the resistance in the main motor shunt field.

Fig. 10 shows a form of intermittent-slip regulator adapted for use with 3-phase motors. This consists of three liquid resistances with movable plates, one placed in each phase of the rotor circuit. A motor relay is provided in this case, the windings of the motor stator being either in series with the mains supplying the main mill motor or else supplied through a current transformer.

The rotor of this motor relay is prevented from moving, either by a spring or by a weight slung from a band passing over a pulley on the motor shaft. When the current in the main motor exceeds a certain predetermined value the turning movement given by the motor relay overbalances either the spring or the weights, allowing the armature to turn a certain amount, thereby raising the plates in the liquid resistance by means of a belt passing over another pulley on the motor shaft. The raising of these plates increases the resistance in the rotor circuit of the mill motor, thereby causing it to fall in speed.

Such intermittent-slip regulators do not find much application, because they are not rapid enough in their action to deal with the extremely rapid fluctuations in power occurring in most rolling mills. The action of the intermittent-slip regulator is very different from that of the continuous-slip regulator. This intermittent regulator comes into action when the power given by the motor attains a certain value, and when this point is reached a very slight increase in power indeed will cause the intermittent-slip regulator to act to its fullest extent. Theoretically speaking, therefore, the power can be maintained at its average value with a deviation of perhaps less than 1 per cent., so that the power curve is practically a straight line, and does not rise and fall in accordance with logarithm curves, as is the case with the continuous-slip regulator.

Further, it has been shown that with such variations in speed of the motor and flywheel as are permissible in practice, the stored energy given out by the flywheel is proportional to the fall in speed. Assuming, therefore, that constant power is required throughout the pass when a bar is between the rolls, and as the power given by the motor is practically constant, the power given by the flywheel will also be practically constant. That is to say, in each small interval of time the same amount of stored energy is to be given out by the flywheel. The speed will therefore fall during the pass in accordance with the straight-line law, and will rise again in the interval between passes, also in accordance with the straight-line law, and there will be no logarithm curves for the rise and fall in speed as is the case with the continuous-slip regulator.

Fig. 11 is drawn to show the theoretical behaviour of the motor and flywheel when provided with the automatic-slip regulator, supposing, as in the case of Fig. 4, that a power of 500 horse-power is demanded for 5 secs., followed by a 5-second interval, and then succeeded by another pass demanding 500 horse-power for 5 secs. Three curves of speed are also shown for flywheel weights of 50 tons, 25 tons, and $12\frac{1}{2}$ tons, from which it will be seen that the variation in speed is proportional to the weight of the flywheel.

The above considerations of the behaviour of the intermittent-slip regulator are based on purely theoretical grounds, and on these theoretical grounds it appears to be a very ideal mechanism as compared with the continuous-slip regulator. Engineers who have taken account of the theoretical behaviour without paying sufficient attention to the practical side, are tempted to think that the intermittent-slip regulator is the proper mechanism to use in every case of a motor in conjunction with a flywheel driving a rolling mill.

In practice one may say that the great difficulty with the intermittent-slip regulator is that it is comparatively slow in coming into operation on account of the inertia of the various moving parts. Such slip regulators often take from 1 sec. to 2 secs. to come into operation, and as the power demanded from a rolling mill motor increases practically instantaneously when the rolls bite the bar, the power will rise to its maximum value before the intermittent-slip regulator can come into operation. Thus, instead of reducing the power to the mean value, as would appear to be the action of the automatic-slip regulator from theoretical considerations, it actually is the means of producing very bad peaks indeed.

Fig. 12 illustrates the practical operation of the intermittent-slip regulator under the same conditions as shown in Fig. 11, which is drawn from theoretical considerations, and Fig. 12 serves to show how the intermittent-slip regulator

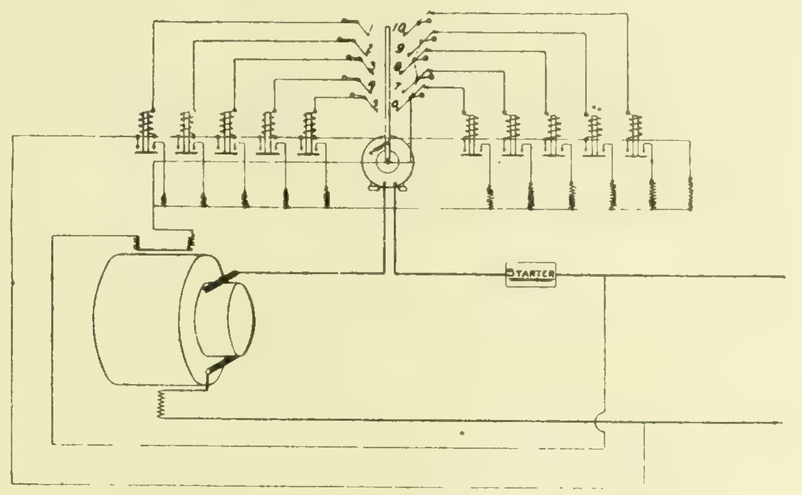


Fig. 9.—Diagram of Type of Intermittent-slip Regulator Suitable for Direct-current Motors.

can allow the power given by the motor to rise to the maximum value that is demanded by the rolls, thereby producing very bad peaks.

In many cases, particularly that of the earlier passes of a roughing mill, which is roughing down billets in order to feed an ordinary merchant mill, the passes are of much shorter duration than the 5 secs. shown in Fig. 12, and may easily be of less than 1 sec. duration. In such a case the intermittent-slip regulator would be absolutely useless, and unless a very large motor were provided the circuit breaker would be continually coming out.

The case of a looping-mill rolling-wire rod, which is shown in Fig. 2, would be a good one for the installation of the intermittent-slip regulator, because the power demanded from the motor does not rise suddenly, but gradually, as the rod is looped into the various pairs of rolls, and the power demanded also increases gradually, so that it gives time for the intermittent-slip regulator to come into operation. The intermittent-slip regulator also finds application for regulating the speed of the flywheel motor-generator set for supplying an electrically-driven reversing rolling mill on the Ilgner system.

Where a 3-phase rolling mill motor is used, and where the continuous-slip regulator consists of a resistance permanently in the rotor circuit, while the intermittent-slip regulator consists of a resistance which is inserted into the rotor circuit after the power reaches a definite value, the use of these resistances entails a certain waste of power proportional to

* Paper read before the Institution of Electrical Engineers.

the amount by which the speed falls, and it would appear at first sight that the waste of power should be less with the intermittent-slip regulator than with the continuous-slip regulator, because with the intermittent-slip regulator the resistance is not always in circuit. Careful tests have shown that this is not the case, and that there is practically no difference between the loss of power taking place in either form of slip regulator.

A little consideration will show that this must be so, because in the case of the intermittent-slip regulator the resistances are brought into circuit where the powers are large, and where a considerable fall in speed is desired, and also that when the resistances are brought into circuit there is a greater fall in speed with the intermittent-slip regulator than with the continuous-slip regulator, so that when the intermittent-slip regulator is in operation it causes a larger loss of power than the continuous-slip regulator, but the intermittent-slip regulator only cuts the resistances out of circuit, when the power, and, consequently, possible loss of power, is small.

Arrangement of Motor and Flywheel to Suit Power Supply.—The choice of the power of a rolling mill motor and of the weight of the flywheel used in conjunction with it, so as to

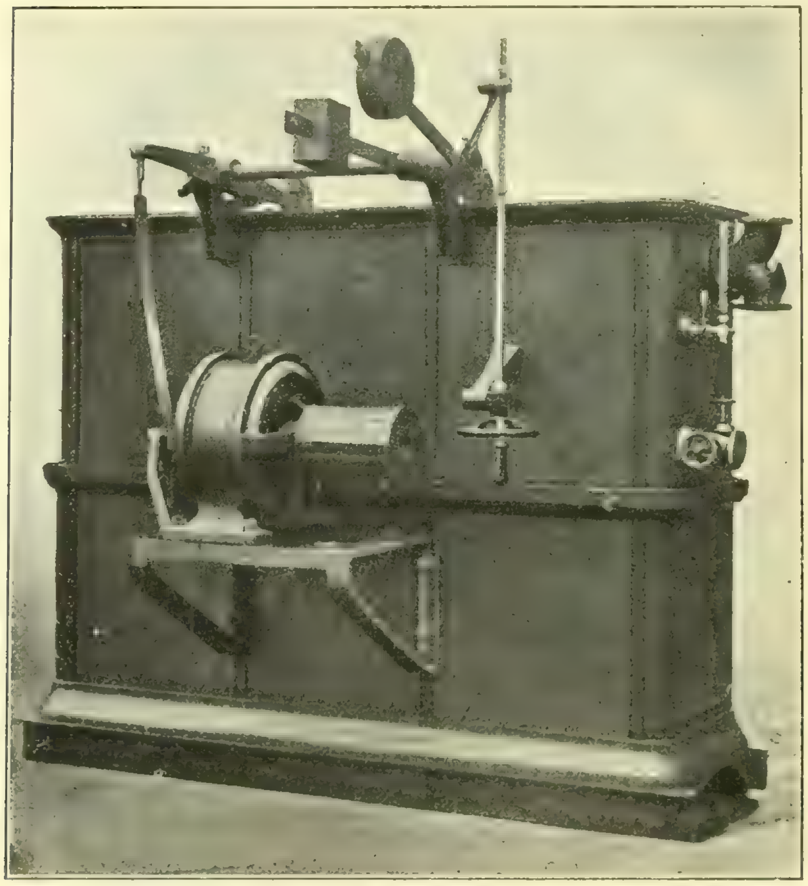


FIG. 10.—INTERMITTENT-SLIP REGULATOR FOR USE WITH 3-PHASE MOTORS.

obtain that relation between motor power and weight of flywheel that will reduce the cost of power to a minimum, depends on whether power is being generated in a power house in the works, or whether power is being purchased from outside; and in the latter case there are various systems of charging for power which materially affect the most favourable proportions between motor and flywheel to be adopted. Some typical cases showing how the system of payment affects these proportions will be considered.

Attention must also be called to the case where there are a number of rolling mills in one works, all of which are doing somewhat similar work, and which will usually all be working together. Here the probability is greatly in favour of the variations in the power taken by the various rolling mill motors balancing one another, so that the total power required remains at a fairly constant value, even although flywheels of quite moderate weight are used with the mill motors. This fact of natural balancing is fully borne out by practical experience, and such a case is an ideal one for cheap electrical driving.

1. *Power generated within Works.*—In this case the power to be supplied by the power station should be kept as constant as possible. If there are only one or two rolling mill motors and a considerable amount of small machinery of which the power demand will keep fairly constant, the rolling mill motors will tend to cause considerable fluctuations of power, and to ensure that power is being generated cheaply in the power station these fluctuations must be reduced as far as possible by using heavy flywheels with the mill motors, and by arranging the slip regulators so as to allow as much fall in speed as is consistent with obtaining the output from the mills, so that as much of the stored energy of the flywheels as possible may be available for reducing fluctuations in the power.

There is a definite economic limit to the weight which may be adopted for the flywheels because increase in the weight increases both the frictional losses and the capital charges on the plant, and a point will be reached where the increase in running costs due to these frictional losses and increased capital charges will balance the saving effected by running the generating plant at constant load. If, on the other hand, there are a large number of rolling mills, all of which are likely to be working simultaneously, it would be advantageous under certain conditions to proceed to the other extreme and to reduce the flywheel weight, relying on the natural balancing effect to keep the load constant.

Theoretically it would be possible to dispense with flywheels altogether, but this would require that the size of the driving motors should be considerably increased, and it would be found cheaper to install a moderate size motor with a moderate weight of flywheel rather than a large motor and no flywheel at all. This reduction in the weight of the flywheels would reduce the capital charges on the plant, and by reducing the frictional losses would reduce the total power required.

In some special cases where there is a large number of mills working simultaneously, natural balancing is very difficult to obtain, as in the case of hot mills for rolling tinplates, where the motors are only giving their maximum power for a very small fraction of the total time, and in such cases it is necessary to use heavy flywheels.

2. *Power purchased from a Supply Authority on the Maximum Demand System where Instantaneous Peaks are Registered.*—This case is similar to the above, as means must be adopted for keeping the power as near to the average value as practicable. The following example will show the saving to be effected by keeping the power to the average value: At a certain works where a small mill is being driven, the maximum instantaneous demand is about 260 kw., while the average number of units taken per month is about 25,600. Payment is made reckoning the maximum demand over 75 hours per month at 1d. per unit, and the remainder of the power at $\frac{4}{10}$ of 1d. per unit. The total cost of power therefore works out at £91. 3s. 4d. per month. If, however, the power during the working hours was reduced to the average—that is to say, to 53 kw.—payment would be made for 53×75 units at 1d. per unit and for 21,600 units at $\frac{4}{10}$ of 1d. per unit, so that the cost of power per month would be £52. 12s. If, therefore, it were possible to keep the power at the average value, a saving of £38. 11s. 4d. per month would be made, or £462. 16s. per annum.

While this case is rather an extreme case, it shows that if a suitably heavy flywheel and a slip regulator were installed to reduce the power to the average, a very large saving would be made after paying the capital charges on this flywheel, &c.

3. *Power purchased from a Supply Authority at a Flat Rate for the Number of Units Consumed.*—In this case all friction losses should be kept as low as possible in order to reduce the total number of units consumed, while there is no object in attempting to prevent variations in the power. If motors large enough to deal with the largest power required by the rolling mill should be installed without any flywheel at all the friction losses would be reduced to a minimum, giving the cheapest possible power costs, while the maximum possible output could be obtained from the mill on account of the steady speed at which it would run. Such large motors, however, would prove more expensive in capital cost than a more moderate size motor used in conjunction with a flywheel of moderate weight, and it could not be generally stated that the saving in power costs due to the reduction of friction by doing without a flywheel altogether would justify the additional capital outlay, although if a

large tonnage from the mill were considered essential the extra capital outlay might then easily be justified. It may be said, however, that in such a case the general tendency would be to reduce the flywheel weight and to increase the motor power.

4. *Power purchased from a Supply Authority on the Maximum Demand System where Peaks of several Minutes Duration only are taken account of.*—This system of charging is much in favour with the various supply authorities, and the remarks made with regard to case 3 apply to this case also.

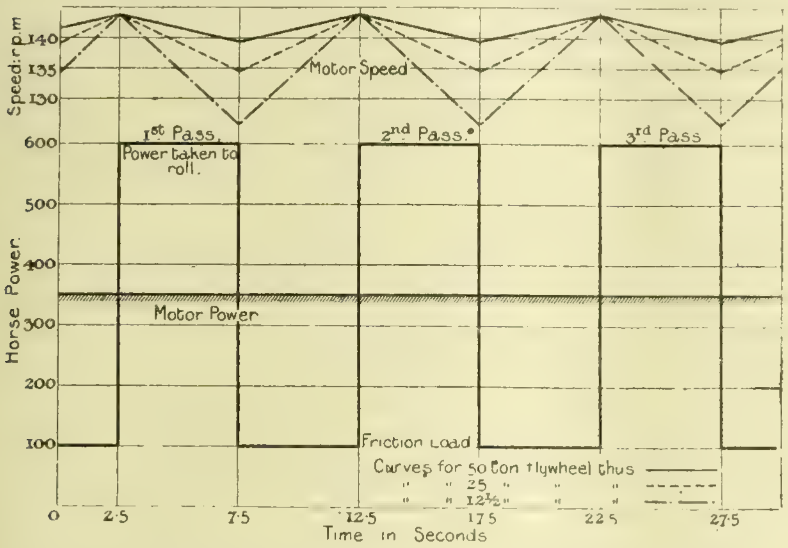


FIG. 11.—INTERMITTENT-SLIP REGULATOR—THEORETICAL ACTION.
Variation of Motor Power and Speed for 50, 25, and 12½ ton Flywheels.
Pass, 5 seconds; interval, 5 seconds.

The variations in power required by most rolling mill motors are very rapid, and the peaks last for a matter of a few seconds only, so that they will not be registered by the maximum demand indicator. Care should be taken that the hourly output of the mill is kept as steady as possible, for if the mill were worked rapidly for an hour or two and then there was a long wait for billets to heat in the furnace, or for some other cause, this period of rapid rolling would be found to affect the cost of power very adversely. This, however, is a matter for the mill manager, and does not affect the arrangement of the driving plant.

The Ilgner System for Driving Large 3-high Mills.—In the preceding section of this paper, reference has been made to the necessity for a mill motor, when used in conjunction with a flywheel, to fall in speed when the power demand is large, so as to enable the flywheel to give up some of its stored energy, and attention has been drawn to the fact that this causes a diminution in the tonnage which the mill can roll.

The speed of a rolling mill is settled by the first passes in the roughing rolls, because in these passes the billet is very short, and if it is thrown out at a high speed it becomes very difficult for the men to catch it. During these passes, while the actual power taken may be large, the time of the pass is short, so that the amount of energy consumed is comparatively small and the flywheel does not have to give up much stored energy, and so the speed of the mill is maintained practically at full speed.

In the later passes, where the bar has become elongated to a considerable length, the time taken by the pass is considerable—half a minute or so—and while the power may not be very great the amount of energy consumed is considerable, and the flywheel will have to vary considerably in speed to give up the necessary amount of stored energy. In these last passes, where high speed is most desirable to get the bar through the rolls quickly on account of its great length, the speed of the motor has fallen to the lowest limit, and this causes the reduction of the tonnage which it is possible to roll. The reduction of tonnage due to this cause is more marked where the mill is engine-driven than where it is motor-driven.

To overcome this difficulty several steel works have adopted the Ilgner system for driving large 3-high mills—that is to say, the same type of electrical plant is used which is generally employed for driving reversing rolling mills. In this system the flywheel is not coupled to the mill, but is coupled to a motor-generator set which supplies current to the mill motor. As the mill motor runs at a constant speed whatever power it is required to give, there is no reduction in tonnage owing to reduction in speed in the mill, but the motor-generator set, instead of the rolling mill motor, varies in speed so that the flywheel can give up its stored energy when the power demand is great, and absorb energy when the demand is small, so as to reduce the variation in power taken from the supply system to a reasonable value.

In such a case, the motor driving the motor-generator set and the flywheel show variations of speed and power similar to those described in the earlier part of this paper for a mill motor and flywheel, except that in this case the variations in power are very much reduced; partly because the motor-generator set runs at a comparatively high speed, so that the stored energy of the flywheel is very much increased, although its weight and cost may be much reduced, and partly because a much larger variation in speed is permissible, as there is no fear of reducing the tonnage of the mill by allowing the variations in speed to be too great, so that a much greater proportion of the stored energy of the flywheel can be utilised to reduce power variations.

It is obvious that by regulating the field current of the generator of the motor generator set, the voltage of this machine may be varied, causing the speed of the mill motor to increase or decrease correspondingly, and as there is no flywheel coupled to the mill motor the speed of the mill motor may be increased or decreased very rapidly. In rolling down a billet or bloom, therefore, it is possible to drive the mill at such a speed that while the first passes are being made the billet can easily be caught, and then to increase the speed considerably for later passes where the billet has been rolled into a long bar, and where each pass takes a considerable time, so that the times of these long passes can be reduced.

In this way the total time for rolling down each billet can be reduced, and the tonnage can be increased. The time taken by these later passes can still further be reduced by increasing the speed after the bar has entered the rolls, and then decreasing the speed again before the bar leaves the rolls, so that it is not thrown out at too high a speed.

By using the Ilgner system, therefore, the possible output from the mill can be increased beyond that which may be obtained if the mill motor were driven at a constant speed. The capital cost of the electrical plant for the Ilgner system of driving is considerably more than that of a plain motor and flywheel, but as the cost of the electrical plant is small in comparison with that of the mill and its various accessories, the use of the Ilgner system for driving such a 3-high mill may not increase the total capital cost of the plant much. As this increase in capital cost enables a much larger output to be obtained, the use of the Ilgner system in such a case cheapens the cost of production by reducing the capital charges per ton rolled.

The use of the Ilgner system increases the losses of power taking place in the electrical machines per day, because there

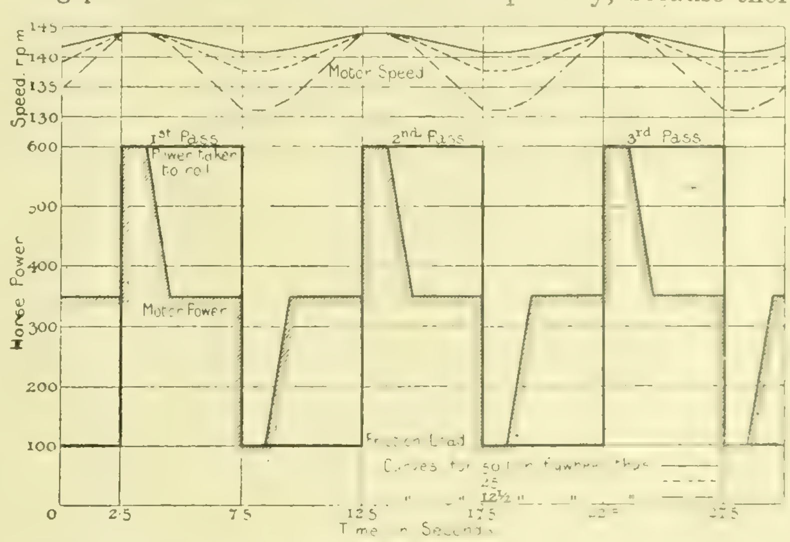


FIG. 12.—INTERMITTENT-SLIP REGULATOR—ACTION IN PRACTICE.
Variation in Motor Power and Speed for 50, 25, and 12½ ton Flywheels.
Pass, 5 seconds; interval, 5 seconds.

are the electrical losses in the motor and the generator of the motor-generator set to be considered as well as those in the mill motor itself, but as a larger tonnage is being rolled in the day, and the bars are rolled so rapidly that they have not time to cool much, the units of electricity per ton rolled may be actually decreased in spite of this additional loss of power

which is introduced. Where the Ilgner system is adopted, it is always possible to use the mill as a reversing mill if a section has to be rolled which is difficult to manage in a 3-high mill.

The Ilgner system has been adopted up to the present for driving :—

(1) 34½in. 3-high mill having three stands of rolls and rolling heavy beams, driven by a direct-coupled motor of 12,600 horse-power normal output. The maximum speed of the motors is 180 revs. per minute, and the speed at which the maximum turning moment is given is 70 revs. per minute. The flywheel motor-generator set, which is provided with a 55-ton flywheel, runs at a maximum speed of 428 revs. per minute, and is driven by a 2,600 horse-power motor.

(2) 29½in. mill having three stands of rolls and rolling beams and light rails, driven by a direct-coupled motor of 8,400 horse-power normal output. The maximum speed of the motor is 180 revs. per minute, and the speed at which maximum turning moment is given is 62 revs. per minute. The flywheel motor-generator set, which is provided with a 55-ton flywheel, runs at a maximum speed of 428 revs. per minute, and is driven by a 1,500 horse-power motor.

(3) 29½in. mill having five stands of rolls and rolling beams and rails, driven by a direct-coupled motor of 7,300 horse-power normal output. The maximum speed of the motor is 180 revs. per minute, and the speed at which maximum turning moment is given is 52 revs. per minute. The flywheel motor-generator set, which is provided with a 75-ton flywheel, runs at a maximum speed of 428 revs. per

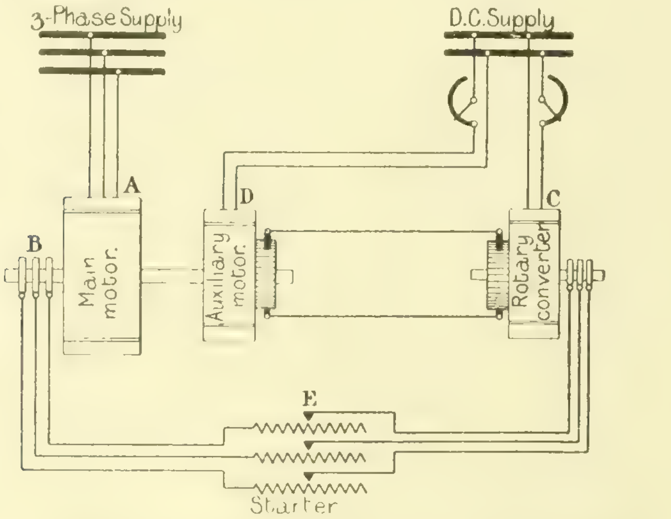


FIG. 13.—DIAGRAM OF CONNECTIONS OF HIGH-EFFICIENCY VARIABLE SPEED 3-PHASE ROLLING MILL MOTOR SET

minute. This 3-high mill motor is supplied from a generator attached to a flywheel motor-generator set, which is supplying an electrically-driven reversing rolling mill at the same works.

(4) 23½in. mill having three stands of rolls and rolling rails, beams, and sections, driven by a direct-coupled motor of 6,000 horse-power normal output. The maximum speed of the motor is 180 revs. per minute, and the speed at which maximum turning moment is given is 140 revs. per minute. The flywheel motor-generator set, which is provided with a 50-ton flywheel, runs at a maximum speed of 500 revs. per minute, and is driven by a motor of about 1,200 h.p.

(5) 22in. 3-high mill having three stands of rolls and rolling rails, sections, and rounds, driven by a direct-coupled motor of 2,400 horse-power normal output. The speed at which maximum turning moment is given is 120 revs. per minute, and the motor is arranged to run at very considerably higher speeds with a correspondingly less turning moment. This 3-high mill motor is supplied with power from a generator attached to a flywheel motor-generator set which supplied a large reversing mill in the same works.

(6) 20½in. 3 high roughing mill, rolling billets, driven by a direct-coupled motor of 3,800 horse-power. The maximum speed of the motor is 180 revs. per minute, and the speed at which maximum turning moment is given is 100 revs. per minute. This 3-high mill motor is supplied with current from a generator coupled to a flywheel motor-generator set which supplies a large reversing rolling mill in the same works.

There is also a seventh 3-high mill which is driven on the Ilgner system, of which no particulars are available.

Three-phase Current for Merchant Mill Driving.—The roughing rolls of a merchant mill should be run at the highest speed at which it is found practicable for the men to catch the comparatively short billet, and as in most cases about the same size of billet is being rolled the speed should remain constant. The finishing rolls, on the contrary, should be capable of running at a large number of different speeds according to the shape and weight of section being rolled. Light sections which cool rapidly must be rolled at a high speed so as to finish them while hot, but with heavier sections the rate of cooling is slower, so that there is not the necessity for rolling at a high speed, while there is the advantage that better material is obtained if the speed of rolling is lower. The slowest speed is required for "hand rounds," where the roller has to guide a bar of oval section with his tongs through a round hole, so that the biggest diameter of the oval stands upright, and unless the speed is low the roller cannot follow up the bar.

If the roughing and finishing mills are coupled together and driven by one motor, it will not be possible to run at a sufficiently high speed for the light sections on account of the roughing mill, so that the roughing mill will restrict the output of light sections, while, on the other hand, when rolling "hands round" the low speed of the finishing mill will require that the roughing mill should also go at a low speed and the output be also restricted. With such a mill the proper outputs can only be obtained at the medium speeds. The ideal drive, therefore, is to provide a constant-speed motor for the roughing mill and a separate variable-speed motor for the finishing mill, and when this is done the roughing mill is usually placed in tandem with the finishing mill.

Where the power available is direct current, this arrangement presents no difficulty, but where 3-phase current must be used the means of providing a variable-speed drive for the finishing mill needs some consideration. The simplest arrangement would be to provide an ordinary 3-phase motor, and to reduce its speed when required by inserting resistances in the rotor circuit. This entails such a large waste of power in the resistances when the lower speeds are required that the arrangement is not practicable commercially. In addition, when the power diminishes in the interval between passes or in the interval between the finishing of one billet and entering the next, the speed tends to increase up to the maximum speed, so that, when the next billet is entered, it is very difficult to handle the material.

Another arrangement which can only be used where a rope drive can be employed is to provide an ordinary 3-phase motor having three rope pulleys of different sizes on its shaft, and to change the ropes from one pulley to another when different speeds are required for the mill. To enable this to be done the motor bedplate has to be made to slide in two directions, so that any one of the three pulleys can be brought opposite the main rope pulley which is coupled to the mill, and so that the motor can be slid away from this pulley in order to tighten the ropes.

This arrangement only enables three possible speeds to be obtained, which is insufficient to meet most requirements, and it has also proved itself to be very wasteful in power, and on this account it cannot be considered where economy is any object. Another arrangement which is much more satisfactory is to convert the 3-phase current to direct current, and then to provide a direct current rolling mill motor, so that the speed can be varied to any required speed in order to suit all conditions without wasting any power, and with the exception of that variation in speed which is necessary to enable the flywheel to give up and regain part of its stored energy the speed remains constant at the required value.

As the 3-phase current must be converted to direct current, a transformer and a rotary converter would be needed for this purpose, so that the capital cost of the plant is increased, and there is a certain loss of power in converting from 3 phase current to direct current. This loss of power in conversion, however, is very small compared with the losses of power in the two arrangements mentioned above, while the extra capital cost is fully justified by this saving in power.

A still more economical arrangement for obtaining variable speed has been adopted for three merchant mills in this country (Fig. 13). This consists of employing a 3-phase motor direct coupled to a direct-current motor for driving the mill. A rotary converter is connected to the rotor circuit of the 3-phase motor, so that when the set is run at reduced speed the power which would otherwise be wasted in resistances in the rotor circuit is converted by the rotary converter from 3-phase to direct current, and then used usefully to supply the direct-current motor.

Comparing this scheme with that of converting all the 3-phase power to direct current and installing a direct-current rolling mill motor, it should be pointed out that in this latter scheme the rotary converter and the direct-current motor do not have to deal with the entire power, but with a power proportional to the amount that the main 3-phase motor is running below synchronous speed. The conversion losses are therefore reckoned on a fraction of the power, and not of the entire power, so that the arrangement is much more efficient. Further, the rotary converter and the direct-current motor are proportioned for a fraction of the power instead of the whole power, so that they can be small machines. The arrangement, therefore, is cheaper in capital cost.

With this arrangement the direct-current motor is provided with a compound winding to act as a continuous-slip regulator, and the combination behaves like an ordinary compound-wound direct-current motor, the speed being varied by altering the resistance of the shunt field circuit of the direct-current motor, while with the exception of that variation in speed necessary to enable the flywheel to give up and regain part of its stored energy, the mill motor set runs at the required speed and does not give trouble by attempting to increase in speed up to the maximum speed between the passes.

Generally speaking, where there is a choice between direct current or 3-phase for driving a mill for which variable speed is desirable, and there is little or no difference in the cost of current, the adoption of direct current will be found the most economical.

Friction Losses.—Particular care should be taken to reduce as much as possible the friction losses, or other such losses which have a constant steady value independent of the power which the rolling mill may be giving, because, generally speaking, the power taken by a motor driving a rolling mill varies between wide limits, so that the average power taken is very much less than the rated output of the motor, and any losses such as those due to friction which go on continuously very considerably increase the number of units of electricity used in a given time.

This is a point which is very liable to be overlooked, because such losses are usually stated as a percentage of the rated output of the motor, and so appear small, but if the average power of a rolling mill motor is one-third of its rated output, as is often the case, a friction loss which may be only 10 per cent. of the rated output will increase the total units consumed in a given time by 30 per cent. Such friction losses may be caused by the friction in the flywheel bearings, or by the windage of the flywheel itself, or in the drive used to transmit the power of the motor to the mill in those cases where the mill motor is not direct coupled.

These remarks apply particularly to rope drives when used for rolling mills, as it is usually stated that a rope drive involves 10 per cent. loss of power, but this only applies to the case of a motor which is constantly transmitting its full power through the rope drive. It would be much more exact if the statement were made that the use of a rope drive involves a loss of 10 per cent. of the power which the ropes are capable of transmitting normally, and that this loss remains constant whether the motor is giving its full normal output or not.

To take a practical example, the case of some tin-plate mills may be considered which require a 450 horse-power motor, where the power varies between very considerable limits, and where there is a choice between installing a high-speed motor driving the mills through a rope drive or installing a slow-speed motor direct coupled to the mill. It may be assumed that the loss in the rope drive is 10 per cent. of the full-load power of the motor, that the efficiency of the slow-speed motor is 2 per cent. less than that of a high-speed motor, and that the actual power consumption required by the mill, apart from the drive, is 15,000 units per week. If a slow-speed motor be installed, 2 per cent. must be added to the 15,000 units on account of the low efficiency, so that the units consumed in the week will be 15,300.

If the 450 brake-horse-power motor ran steadily at its full power, making due allowance for 5 per cent. loss in slip resistance, &c., the steady input would be 385 kw.; therefore if the motor ran steadily at its full power for a week of 120 working hours it would consume 45,000 units. Ten per cent. of this, or 4,500 units, are wasted in the rope drive, so that if the high-speed motor with the rope drive be installed, the total units consumed per week will be 19,500, or 4,200 more than if a slow-speed motor be used.

Supposing that the cost of power is 0·5d. per unit, the extra 4,200 units used per week will cost £8. 15s., or £437. 10s. per annum. This saving would justify a very considerable extra capital expenditure on a slow-speed motor.

While any discussion of the details of construction of rolling mills is outside the scope of this paper, the author holds the opinion that insufficient attention is paid to the question of friction in the pinion housings or on the roll necks, and thinks that improvements might be effected which would reduce this friction, and that any such improvements would materially reduce the cost of rolling. In many mills the power consumed by the friction of the mill itself is about one-fifth or one-sixth of the normal rated output of the motor which is installed to drive the mill, so that nearly 50 per cent. of the units of electricity used per ton rolled are wasted in friction. This shows how great an opportunity there is for improvements for effecting economies in the cost of rolling.

The foregoing observations regarding the large waste of power caused by rope drives where the friction is independent of the power transmitted does not apply to the same extent to the gear drive, because the pressure between the teeth, and hence a greater part of the friction, is dependent on the amount of power transmitted. When a small power is transmitted the friction loss is reduced, so that with a gear drive the units of electricity consumed on the overcoming friction do not form so large a proportion of the total number of units consumed as with a rope drive. In certain mills, particularly in brass and copper sheet mills, long trains of gearing are usually used for transmitting the power of the motor to the rolls, and are so arranged that the power for the more distant mills is perhaps transmitted through ten different pairs of gear-wheels. A more wasteful way of applying power could hardly be imagined.

Economy.—The question of electrical driving is seldom raised without comparisons being made between the cost of driving rolling mills by steam or by electricity, but it is outside the scope of this paper to revive this well-worn subject. Various economies can be effected by the electrical driving when properly applied, but one of the principal economies is that of the cost of power. The electrical drive often enables cheap power to be used when it could not be transmitted or applied in any other way, and also in many cases it affords a means of enabling power to be generated cheaply, so that in planning an electrical drive every care should be taken to make use of its natural advantages as far as possible.

In a large city where land is expensive, and where facilities for generating power in each individual works are far from the best, it is generally found to be most economical to buy power from the supply authority where the amount required is not very large, because power can be generated in bulk in a power station and distributed to the various works more cheaply than the works can generate themselves. Where works are not situated in a city, and where the cost of ground, &c., is much less, it is generally found that the works themselves can generate more economically unless the amount of power required is very small.

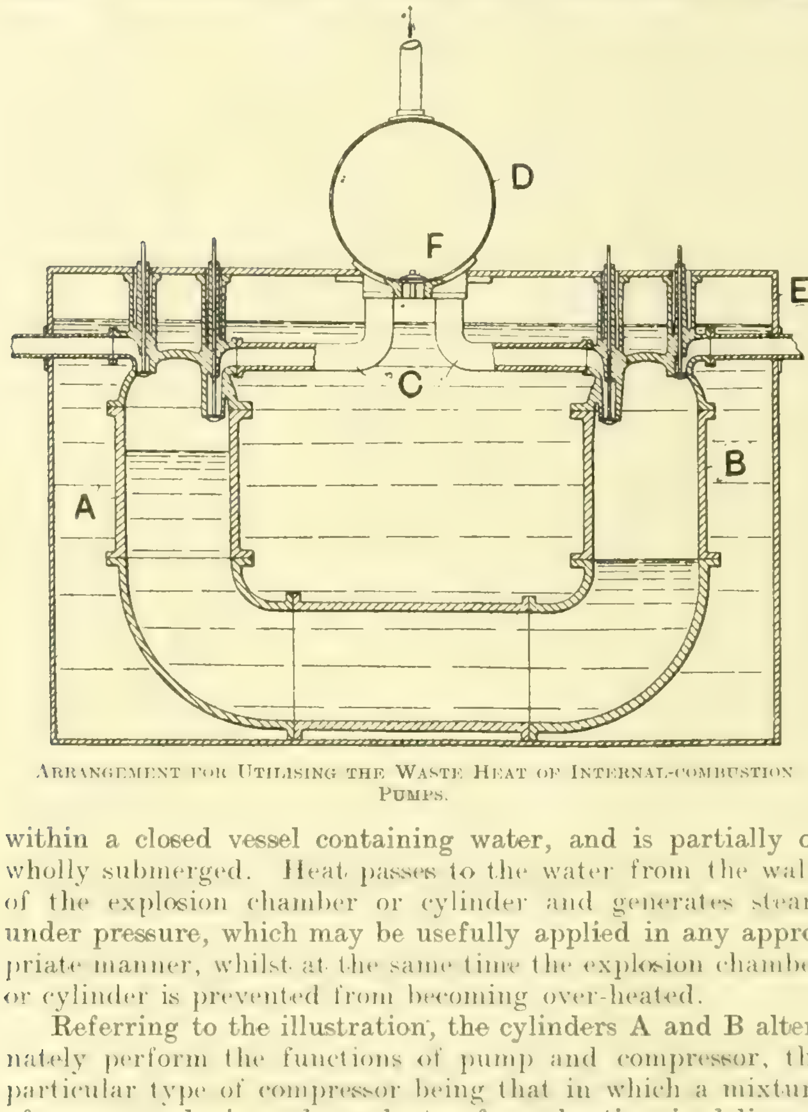
Where cheap power is available it must be applied as economically as possible, and it will be seen from what has been said in the foregoing that considerable care must be exercised in applying a motor and flywheel to a rolling mill in order to ensure that the power is utilised as cheaply as possible if it is desired to obtain economy in working.

There is much reliable information at present available about the units per ton taken to roll various sections, some of

which has been given by the author in other places, so that there is no need to repeat these figures here. Attention should, however, be particularly drawn to the inaccurate results which will be obtained if any attempt is made to arrive at the proper size of the motor by multiplying the units per ton by the tonnage which it is desired to obtain from the mill on the average. Any such figure which is obtained in this way would be far too small, because a rolling mill always works more or less intermittently, as either it is a physical impossibility for the men to stand up to the work continuously—that is to say, to keep up the maximum rate of rolling at which they could roll one bar, or else the mill has to wait for hot billets from the furnace, for the finished material to be cleared away, for roll changing, or for other reasons.

UTILISING THE WASTE HEAT OF INTERNAL-COMBUSTION PUMPS.

A METHOD of utilising the waste heat of internal-combustion pumps or compressors of the Humphrey type has recently been patented by H. M. Bellamy, Welby Gardens, Grantham, Lincoln. With this arrangement, which is shown in the accompanying sectional view, the heat hitherto wasted in the operation of cooling the walls of the explosion chamber is utilised, while more effective use is made of the heat of the exhaust gases. The whole or part of the pump or compressor is placed



ARRANGEMENT FOR UTILISING THE WASTE HEAT OF INTERNAL-COMBUSTION PUMPS.

within a closed vessel containing water, and is partially or wholly submerged. Heat passes to the water from the walls of the explosion chamber or cylinder and generates steam under pressure, which may be usefully applied in any appropriate manner, whilst at the same time the explosion chamber or cylinder is prevented from becoming over-heated.

Referring to the illustration, the cylinders A and B alternately perform the functions of pump and compressor, the particular type of compressor being that in which a mixture of compressed air and products of combustion is delivered through the pipes C to the reservoir D. The whole of the compressor is positioned within a closed vessel E. This vessel is wholly or partially filled with water. The steam evolved by the action of the heat from the walls of the cylinders A and B on the water causes the evolution of steam, which is allowed to pass to the reservoir D by the non-return valve F, there mixes with the compressed gases, and is utilised with them to produce useful work, as, for instance, by being passed through a turbine. The valve F may, if desired, be weighted or acted upon by a spring, so that steam is only delivered to the reservoir at a predetermined pressure.

By thus mixing the steam and compressed air with the combustion products, some of the heat of the latter is given up to the other constituents and the whole mixture is brought to a temperature at which it can satisfactorily be employed to produce power. The water constituting the piston of the compressor is kept within appropriate limits of temperature by any suitable means: thus, it may be renewed constantly or from time to time, the supply being obtained either from the enclosing vessel or from an outside source, and the surplus being rejected into the vessel or outside of the same.

THE REPAIR OF MOTOR-CARS.

AT the first meeting of the North of England branch of the Institution of Automobile Engineers held at Manchester on Wednesday last week, a paper was read by Mr. David J. Smith on the repair of motor vehicles. By taking the average of a large number of cars in the five years 1906-10, Mr. Smith came to the conclusion that the cost of repairs in that time was equal to 25 per cent. of the first cost, apart from tyres and accidents. He remarked that the repairer's lot is not an enviable one, as he is often merely a buffer between the maker and an unreasonable owner. The number of really skilful repairers, he said, was limited, and very often manufacturers felt uneasy when they knew into whose hands their car passed for repair. The manufacturing firm doing its own repairs was, he proceeded, in a peculiar position. Many owners expect that all repairs, adjustments, and so on for a long time after purchase should be done by the maker, either free or on rather one-sided terms. A refusal or even a merely reasonable charge, may bring about a rupture with the customer, but in "mothering" such cars on the terms the customer expects, it is possible to lose a high proportion of the net profits.

To the repairer who is not also the builder there sometimes falls a task which is really nothing short of remedying a faulty design. In this he can hope for very little help from the makers, although cars which are a few years old can, even by a repairer who cannot be expected to know the synthesis of their design, be greatly improved, and if the maker cared to co-operate the improvement, he thought, would be even greater.

However serious for our manufacturers, the influx of imported cars is certainly to be viewed by repairers with equanimity, if not, indeed, with satisfaction. As a class he meets with little or no opposition, and if there is delay in getting parts from abroad his is not the responsibility. The alternative to waiting is for the repairer to make the parts. He may not make them quite like the original ones, but he may occasionally improve, and Mr. Smith argues that it would be advantageous if those who design cars could spend some time in a repair shop where all makes of cars come in, and where he may see the pet theories of all sorts of designers and owners treated with a brutal but perfectly sane revision. Such a training might tend to check originality, but would also tend to soundness of design.

Referring to the equipment and organisation of a motor repair works, Mr. Smith said the demand for good men for this work exceeded the supply. While skilled mechanics could be drawn from the general engineering trades, it needed a considerable time to get their motor-car sense, and the process of acquiring it was apt to be expensive for the employer. As for the rising generation, he urged that all boys, apprentices, and improvers should attend good evening classes, and in his own works he encouraged this by paying the youths' fees.

Electrical Plant in Collieries.—At a meeting of the East of Scotland Branch of the Association of Mining Electrical Engineers recently held in Edinburgh, Mr. R. H. Willis, the branch secretary, delivered an interesting lecture on "The Mechanical Design of Electrical Plant Usually Found in Collieries." The lecturer maintained that all electrical plant which was to be used in collieries should be characterised by extreme robustness. Personally he had seen many plants which, while they had been perfect electrically, had failed mechanically. In the long run it would undoubtedly pay to instal a machine with the heaviest shaft, longest bearings, and stiffest brush gear. Intimation was made that the examinations applicable to Scottish members for certificates of competency granted by the association would be held on March 16th and 23rd in Glasgow.

PRACTICAL HINTS ON MOULDING AND CASTING ALUMINIUM.

THE comparatively low price, bulk for bulk, of aluminium, as compared with the copper alloys, is directing the serious attention of engineers and other users to the lighter metal. The high tensible strength of the aluminium alloys renders them useful for a great variety of purposes. They have found considerable employment in the motor-car industry, and are used for crank cases, gear boxes, carburetters, radiators, and a number of other parts and details. General engineers are also becoming more partial to aluminium castings for many purposes, on account of their lightness, quite apart from the cost; in fact, alloys of aluminium are largely employed at the present time in various branches of engineering work. Brassfounders, therefore, frequently find themselves called upon to handle the metal on a more or less extensive scale. By those who have studied the question it is acknowledged that aluminium castings are best produced in a foundry devoted entirely to that metal and its alloys; for the slightly different procedure in moulding and melting, due to the nature of the metal, when compared with brassfounding, is often a stumbling block to the founder who does not properly realise these differences. But since there are many brassfounders who could with advantage undertake aluminium work, a few hints on the matter may prove useful.

If normal precautions are taken, suitable aluminium alloys should not be difficult to cast. The melting point (about 650° C.) is far below that of iron and even that of the brasses, and the same trouble should, therefore, not occur in regard to gases in the mould and the scabbing of the mould. With a sand fairly free from gas-producing substances and of the right texture there should be a comparatively small amount of gas generated when pouring; and since the heat of the metal in the mould is little more than half what a mould for cast iron will stand, it is fairly obvious that scabbing would indicate bad moulding.

Moulding. — The principles governing moulding for aluminium castings, while broadly the same as for brass, are different in certain respects. Some founders consider that the sand for aluminium moulds should be rather finer than for brass moulds, though not too close in texture, as that would give trouble with the escape of gases. In opposition to the claim that has sometimes been made that the facing sand particularly should be very finely sieved, practical experience shows that very fine sifting does not give the best results. The procedure for ordinary green-sand work is nearer the requirements for aluminium, and the sand used for the former is generally fine enough for the latter. In fact, green-sand moulding, with some differences as regards ramming, &c., is the usual practice for aluminium.

The metal during cooling is subject to considerable shrinkage, and consequently a flexible mould is necessary. For this reason the sand must not be rammed hard, or the result will be strained or cracked castings. This, of course, does not so much apply to simple designs where unrestricted shrinkage is possible, as to more or less intricate castings where a more yielding mould is necessary to accommodate the shrinkage. For the latter, it will be readily seen, the hardness of the dry-sand mould would prove objectionable; while at the same time the dry-sand mould would give little advantage and be more expensive. Certainly a somewhat more skilful moulder is required for green-sand work, for any excess of water may spoil the mould, while the texture of the face also is required to be not only smooth but open-grained. The lightness of the ramming, too, may necessitate a more extensive use of gaggers to prevent the mould dropping in overhanging portions. The essentials are, the mould must be just sufficiently firm to retain its form and receive the metal—more than that is unnecessary in the way of hardness and stiffness.

Having made the moulds with the desired grade of sand, say a fine floor sand for the facing and the rest of the mould rather coarser in texture, it may be dusted with French chalk or lycopodium powder if a clean surface is desired. Tub or bench moulding in the ordinary brass-foundry flasks is usual for the general run of aluminium castings, though large work may be moulded in the floor as with other metals.

A noteworthy feature is the ease with which aluminium castings may be cored. Owing to the lightness of the metal (the specific gravity being little more than that of the core) chaplets to prevent lifting by the metal pressure are not required. The core has only to be held in place for the pouring, and does not show any tendency to lift when the fluid metal surrounds it. This feature greatly assists in obtaining sound castings of designs that would require a number of chaplets with the heavier metals.

The cores require special attention. They should be well vented to allow the ready escape of any gases generated, and should also allow the full and unrestricted shrinkage of the metal surrounding them. The mixture must give a core with a hard, clean face that will not require a core-wash, as this latter treatment closes the pores too much, and is not necessary with a metal having such a low melting point as aluminium. The core, however, should not be of a consistency which will require considerable heat to disintegrate it, for in such case it would remain hard and spoil the casting. It should be just strong enough to stand the pouring of the metal, and no stronger. It is not difficult amongst the various mixtures and binders now available to find a material suitable for fulfilling these requirements; in fact, the writer has seen cores for aluminium work, which, after being baked, could be sharply struck against metal without suffering damage, but which proved quite successful in use. In most cases, however, such a core would remain too hard under the low heat of the molten aluminium.

Gating. — Gating is another feature requiring careful attention. Unlike some of the other non-ferrous alloys, it is a mistake to make the gates too large. The practice usual with iron serves for most aluminium work, the essentials being to get a steady, but not too forceful, stream into the mould. This will allow all points to be properly filled; but if the pouring is too rapid there appears to be difficulty with intricate moulds in getting the metal well into all parts. A little experience soon teaches the importance of the rate of pouring.

To facilitate the escape of the air and gases from small moulds a vent wire at the point farthest from the gate is sometimes useful, though not generally necessary. With large work, where heavy sections occur, risers or feeding heads are necessary to take care of the shrinkage. As soon as possible after pouring, the castings should be removed from the mould so that the final shrinkage may proceed unimpeded by the mould; and in order to do this the risers and gates may be chilled by introducing pieces of scrap metal.

Melting. — One of the most important points to observe in melting the metal is to avoid overheating. The ordinary brass-melting furnace and crucible are quite suitable for melting the aluminium alloys Some aluminium founders find that the most economical procedure is to employ an iron pan, the top of which completely fills a furnace fired by oil or gas. Such a furnace is said to allow better control over the oxidation of the metal, which often proves so troublesome. Where it has been customary to melt some of the high-melting brasses there is danger of raising the metal to too high a temperature. The crucible, charged with pieces as uniform in size as possible, should be placed on a good fire, and sufficient coke to last the heat filled round it. Since the heat required to get the metal to the condition for pouring is comparatively little, the fire does not require refuelling during the melt; in fact, the metal can be melted by placing the crucible on a good hot fire without packing it round with fuel.

Having attained a dull-red heat, the metal may be poured, though in the event of overheating, pieces of scrap, gates, &c., may be added to cool it. But excessive oxidation is incurred by overheating, to the detriment of the metal. Common salt may be used as a flux, this being thrown on to the metal as it is removed from the furnace. Chloride of zinc is also useful for the zinc-aluminium, a small piece being added and the metal thoroughly stirred.

If the foregoing precautions are taken the aluminium alloys are not difficult to cast; but it is necessary to remember that they vary considerably in constitution. It is not proposed at the moment to enter into the question of the mixing of different alloys; it is sufficient to state that regard should be paid to the nature of the constituents, or the practice that gives success with one alloy may prove very unsatisfactory with a different one.—"Foundry Trade Journal."

TESTS FOR ROLLING MILL POWER REQUIREMENTS.

BY B. N. WESTCOTT.

THE power required in the mechanical reduction of steel has been the subject of considerable investigation in recent years. To secure data bearing on this subject, a great number of tests have been made in rolling mills under actual commercial conditions, and as a result a large amount of valuable information has been secured. There are, of course, many different kinds of rolling mills, depending upon the character of the product rolled. Fig. 1 gives a brief summary of a few of them. The arrangements of the stands, dimensions of the steel rolled, &c., for the various mills should not be considered as fixed for any one type of mill, as different companies use various modifications of the arrangements shown; but the tabulation will enable a good general idea to be formed of the various classes of rolling mills.

Representative classes of Rolling Mills, showing sequence of operations							
Rail Mill	Cogging or Blooming Mill	Billet Mill	Rod Mill	Plate Mill	Merchant Mill	Sheet Bar Mill	Sheet Mill
Ingot Cast 19" x 19" x 46"	Ingot Cast 19" x 19" x 46"	Blooms received direct from blooming mill without reheating	Billets 4" x 4" x 72"	Slabs. Various dimensions Approx. 20" x 20" x 4"	Billets 4" x 4" x 72"	Billets 6½" x 6½" x 40	Bars 8" x 30" x ½"
Reheated in Soaking Pits	Reheated in Soaking Pits	Continuous Mill 2 high stands	Billets heated in furnaces	Reheated in furnace	Reheated in furnace	Received hot from Steam Hammer or Billet Mill	Reheated in furnace
1 Blooming Stand	Blooming Stand 2 high reversing or 3 high mill Screw down rolls	Flying Shears	Continuous Mill 2 high stands	2 high reversing or 3 high mill. "Universal" Mill has side rolls for finishing edges of plate. Shear Plate Mill has no side rolls and leaves edges unfinished.	Continuous Mill 2 high stands	6 Roughing 4 Finishing Passes 2 high stands	Roughing Finishing Both are 2 high stands with screw down rolls
Bloom Shears	Bloom Shears		2 high finishing stands	Plates ¼" to 2" thick	2 high finishing stands	Sheet Bars 8" wide, ½" to 1" thick, 20' to 50' long	Sheets from .05" to .01" thick Rolled in packs of 2, 4, 6 or 8 sheets
3 to 6 Roughing Passes	Blooms 9" x 9" Sq.		Rods reeled or put on cooling beds	Straightening Rolls	Angles or other small structural shapes	Shears	Shears
7 to 10 Intermediate Passes			Shears	Shears	Cold straightening rolls		Cold Rolls for finishing
11 to 15 Finishing Passes			Finished Bars, Rounds from ⅜" to 1½" Diam. and small flats.		Shears		
Hot Shears							
Cambering Rolls							
Cooling Beds							
Gagging Hammers							
Drill Presses							
Finished Rails							
Dimensions given are approximate							

FIG. 1.—BRIEF SUMMARY OF DIFFERENT ROLLING MILLS, SHOWING THE VARIOUS SUCCESSIVE OPERATIONS.

With regard to testing, rolling mills may be divided into two classes, steam-driven and electric-driven. The same information is sought in testing either type of mill, but the methods of test are somewhat different. In both cases we wish to determine the power that is required to roll a piece of steel of a given sectional area and length, to a smaller section of increased length, in a definite time. As several passes are usually required to effect any considerable reduction, the total horse-power seconds represent the energy required for this work. If there is no flywheel effect in the system, the power developed by the prime mover while the steel is in the rolls is the actual power required to turn them. This condition is approximately realised when the steel requires 8 secs. to 10 secs. to go through the rolls, so that even though there be a flywheel connected, its energy is entirely given up before the pass is completed and the total torque required to turn the rolls must be furnished by the prime mover.

When, however, there is considerable flywheel effect present and the passes are of short duration, the power developed by the prime mover while the steel is actually in the rolls may be only a small fraction of the total power required, the remainder of the power being supplied by the flywheel. With steam-engine drive the proportion of the total power that is furnished by the flywheel is determined by the speed regulation of the governor, as there is a tendency toward a large drop in speed as the load comes on the throwing load on the flywheel; while with electric-motor drive the amount of power supplied by the flywheel is determined by the regulation of the motor, in other words, its tendency to drop in speed as it is loaded up.

In any case, the total horse-power seconds furnished by the prime mover will not be materially altered, because when a flywheel is used, power will be required for acceleration after the steel has gone through the mill. However, in many instances we desire to determine the actual torque required to turn the rolls while the steel is passing through them. If the total horse-power seconds necessary for a given pass be divided by the time in seconds during which the steel is actually in the rolls, the power required to turn the rolls will be determined. A rough check on this figure can be made by determining the horse-power seconds given up by the flywheel in slowing down.

If N_1 = revolutions per minute at start of pass

N_2 = revolutions per minute at end of pass

I = moment of inertia of flywheel.

$$\text{Horse-power seconds} = \frac{I \times (2\pi)^2 \, (N_1^2 - N_2^2)}{2 \times 3600 \times 550}$$

$$= 0{\cdot}00000997 \times I \, (N_1^2 - N_2^2)$$

For the various classes of mills, changes in detail arrangements for testing must be made, and these will be taken up under the headings of steam and electrically-driven mills. In steam-driven mills, one of the first essentials is to secure a good record of the horse-power developed by the driving engine while the steel is being rolled, and the best way to do this is to use a continuous drum steam-engine indicator. This differs from the ordinary steam-engine indicator in that the paper on which the indicator card is made is a long continuous strip, which is reeled inside the drum and feeds around the drum ¼ in. at each stroke of the engine. Fig. 2 shows the general lay-out used in testing steam-driven mills, and a description of the methods and apparatus used will now be given.

A recording instrument for speed, time, and general information regarding work in the mill is used, which consists of pens, actuated by magnets, that mark on a strip of

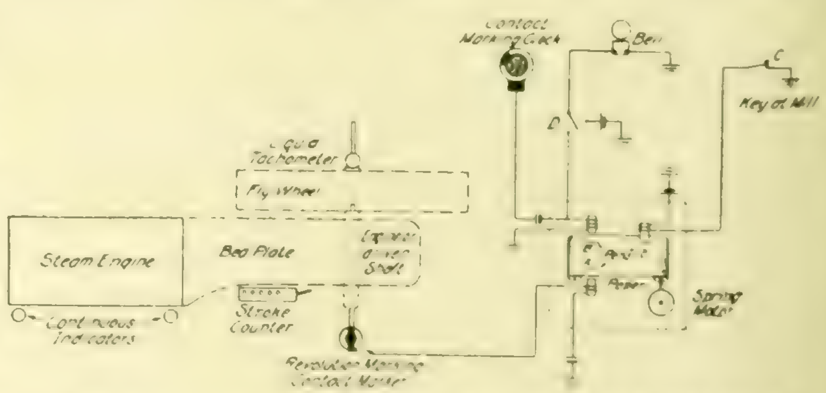


FIG. 2.—GENERAL LAY-OUT FOR TESTING STEAM-ENGINE DRIVEN MILLS.

paper which is moved at a uniform rate beneath them by a spring motor. In most cases three pens are used, A, B, and C, Fig. 2; A is actuated by a contact maker, which is driven from the engine shaft or other convenient place so as to complete the circuit of magnet A several times for each revolution of the engine, the number of contacts per revolution depending on whether the engine is high or low speed. Pen B is controlled by a contact-making clock, which is regulated to close the circuit of B once in every five seconds, or at shorter

intervals if preferred. In addition to actuating B, the contact-making clock also closes the circuit of an electric bell, or in some cases that of an electrically-operated whistle. The third pen C is controlled by a manually-operated key located at the rolls. In addition, a liquid tachometer, consisting of

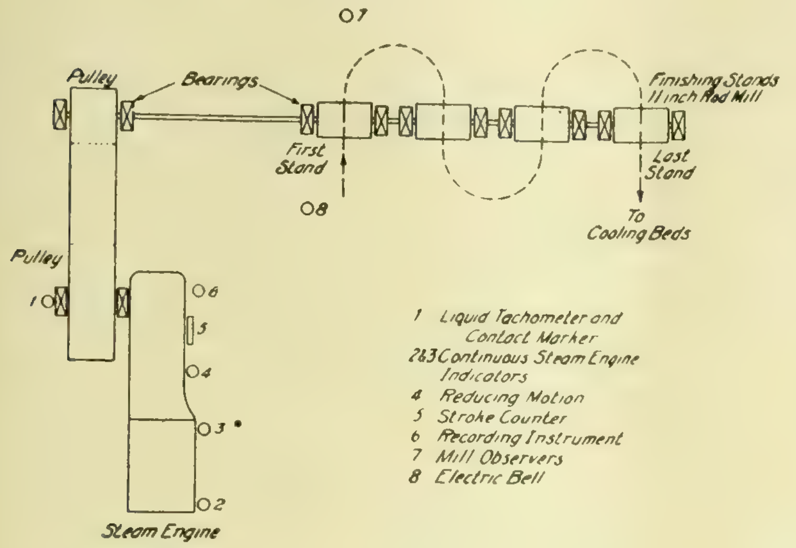


FIG. 3.—ARRANGEMENT OF FOUR FINISHING STANDS OF AN 11IN. ROD MILL.

a small centrifugal pump, which raises a column of coloured alcohol to a height depending on the speed at which the pump is driven, is used to indicate speed variations of the engine. A stroke counter is connected to the engine to record strokes and furnish a check on the graphic instrument.

The equipment described will enable an accurate record to be determined of the power that is furnished the mill, but the work the mill is performing must be noted by other means. In mills where the engine drives one set of rolls, and where the rolls are screwed down between passes and the ingot is reduced in the one stand by passing back and forth, the reduction data is secured as follows: The weight of the ingot being known, and also the weight of a cubic inch of steel being rolled, the volume of the ingot is calculated and is made to serve as a check on the reduction measurements. Before the first pass the length of the ingot is measured with a hooked iron rod. The length is taken after each pass, and in addition measurements of the width and thickness are made with calipers. The three measurements at each pass should check with the original volume.

Where the engine drives more than one stand it will be necessary to have measurements of the steel taken at each stand. In many mills to be found in commercial operation, steel may be in two or more stands at one time, all of the stands being driven by one engine. In such cases, if tests are being made simply to determine the power required by the mill as a whole, it will only be necessary to note what stands are occupied at any particular time, and have observers at each stand to make the reduction measurements. However,

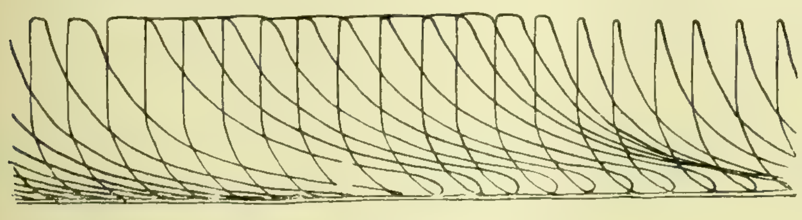


FIG. 4.

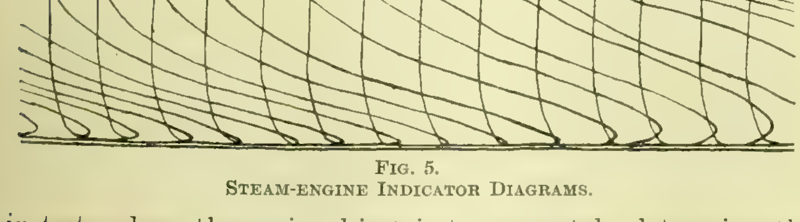


FIG. 5.
STEAM-ENGINE INDICATOR DIAGRAMS.

in tests where the main object is to accurately determine the power required to reduce the size of a definite weight of steel by a given amount in a certain time, it is well to arrange to have only one stand occupied at one time. Most tests on steam-driven mills are made with the first object in view, that is, to determine the total power required by the mill with an aim to supplying a satisfactory motor to replace the engine. The data on the steel which is being rolled is recorded merely to serve as a means of definitely determining the duty which the mill is performing. In most cases where a mill is made up of several stands driven by a number of different engines, it is best to test one engine at a time, in order to avoid impeding the output of the mill and also to reduce the number of men and instruments required for the tests. The methods used are best outlined by a description of the actual details of a rolling-mill test.

Fig. 3 shows the lay-out of the four finishing stands of an 11in. rod mill. In rolling the smaller sizes of steel, the rod is passing through all four stands at once, while in some of the larger sizes perhaps only two of the stands will be occupied by the same rod at the same time. At 1 is located the liquid tachometer and the contact-maker, both of which are attached to one end of the engine shaft; 2 and 3 are the continuous indicators, one for each end of the engine; 4 is the reducing motion of the indicators, in this case consisting of an inclined plane fastened to the crosshead, on which rests a steel roller supported from one arm of a bell crank lever. As the crosshead moves back and forth, the roller moves up and down on the inclined plane, this vertical motion being converted into horizontal motion by the bell crank lever and transmitted to the indicator. A stroke counter, 5, is actuated from the reducing motion, and the reducing motion, and the recording instrument previously described, shown in Fig. 2, is located at 6; 7 is an observer stationed at the mill and having in his hand the key C, Fig. 2, while 8 is an electric bell.

When the man in charge of the test has seen that the observers are in their places and that steel such as desired is

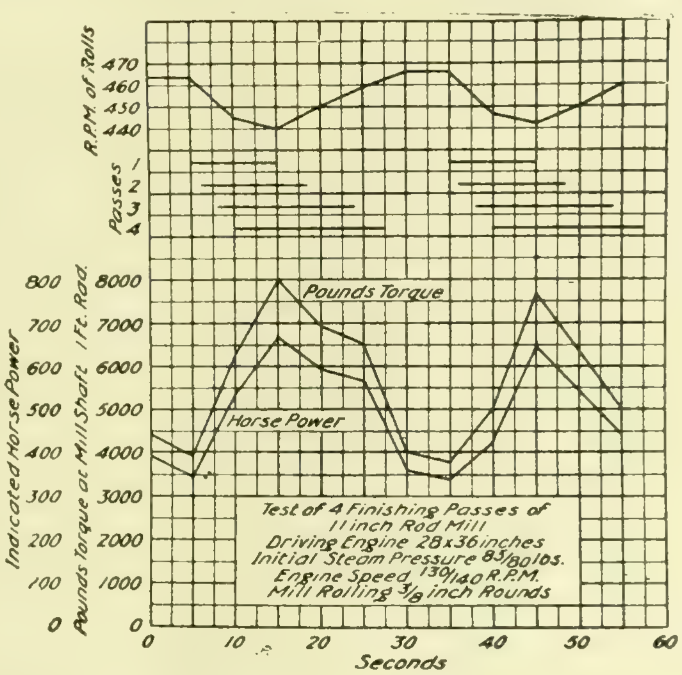


FIG. 6.—CURVES FROM DATA SECURED IN TESTS OF AN 11IN. ROD MILL.

coming through the mill, he rings the bell with a predetermined signal to warn the observers to get ready. He then throws switch D, Fig. 2, on the contact controlled by the clock, and the observers proceed as follows: The man at 1, Fig. 3, reads the liquid tachometer every time the bell rings, that is, every five seconds. The men at the continuous indicators, 2 and 3, have their indicators in working order, the reducing motion connected, and, in fact, everything but the continuous feed operating. When the bell is first rung by the time clock, the feeds on both indicators are started simultaneously, and from then on the indicators automatically record the torque developed by the engine. The stroke counter is read and a record made by a man at 5 every time the bell rings. The recording instrument at 6 has been making a chart of engine strokes against five-second intervals, and from these strokes records of the speed of the engine at any instant may also be scaled off. In addition, the observer at 7 has been signalling by his key the instant at which steel enters each pass, and this has been recorded on the chart and is an accurate record of the location of the steel in the mill against time in seconds from the start of the test. The graphic speed record, the tachometer readings, and the stroke counter serve to check one another, and from them sufficient data may be obtained for calculating the flywheel torque developed, in case the flywheel effect is sufficiently great and the character of the load is such as to make it worth considering.

In a mill of this type, the rolls are set by trial at first, and when once the correct setting and reduction for each pass have been obtained, the rolls are not changed while the size of steel that is rolled remains the same. Because of this fact, it is comparatively easy to get the reduction of the steel per pass. Before the first pass a sample is sheared from the rod and likewise after each of the passes, and from these samples the reduction may be determined.

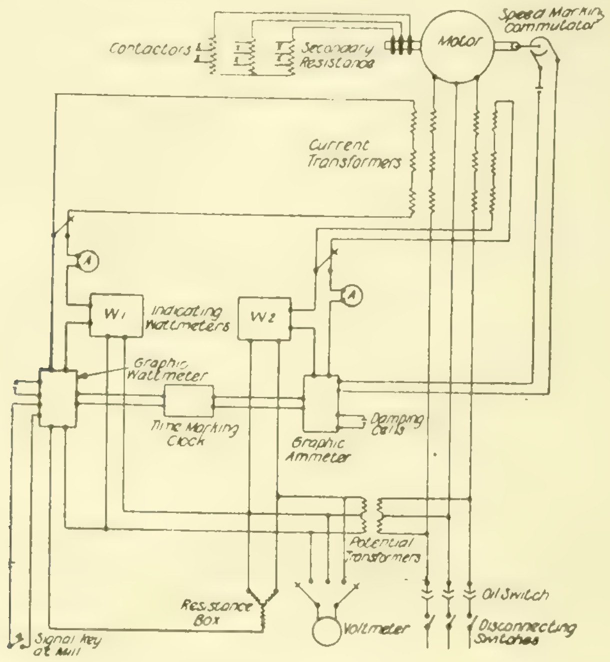


FIG. 7.—WIRING DIAGRAM FOR TESTING ELECTRICALLY-DRIVEN SHEET-BAR MILL.

The temperature of the steel affects to a great extent the power required for rolling. It is, therefore, the usual practice to make temperature measurements of the steel by means of a pyrometer. The best pyrometer for this purpose is some form of the spectrum or colour type, where the colour of the steel is compared with another colour, such as an incandescent lamp filament, and the temperature determined from experimental data and tabulations. Another scheme is to focus the rays of light from the steel on a thermal couple, which is connected to a galvanometer calibrated to read temperature.

Figs. 4 and 5 show portions of continuous indicator cards from steel mill tests. Fig. 4 was taken from a 44 by 60 simple Corliss engine driving 12 stands of a continuous rod mill. The instant at which the steel enters the rolls is distinctly shown by the point where the engine begins to take increased steam. For about 12 strokes the engine does useful work and then drops back to friction load. Fig. 5 shows cards taken from a 28 by 36 simple slide valve engine driving the four finishing stands of an 11in. rod mill. The cards show what a large proportion of the total power developed by the engine was used in overcoming friction and other losses. This engine ran at 130 revs. to 140 revs. per minute, and was belted to the mill shaft so that the latter ran at 440 revs. to 470 revs. per minute.

In Fig. 6 are plotted curves from data secured in one of the tests of the 11in. rod mill mentioned. The top curve is the roll speed in revolutions per minute, and below it is a graphical representation of the passes occurring in the mill at any instant. For instance, the rod entered pass 1 at five seconds, and the last end passed out from stand 1 ten seconds later; the head end in the meanwhile having entered stand 2 at six seconds, stand 3 at eight seconds, and so on. During the period from 10 to 15 seconds, all the stands were occupied. The next curve shows the pounds torque at 1ft. radius that was developed by the engine at the mill shaft, and beneath the torque is a curve of horse power determined by combining the torque and speed curves. By a consideration of all of these curves the proper size of motor to replace the engine may be determined.

In testing electrically driven mills, the conditions are much more favourable for a close determination of the power required to reduce steel than in steam driven mills, because of the great accuracy of electric meters as compared with the steam-engine indicator. The information obtained from testing motor-driven mills is of extreme value in estimating the size of motors required in new mills or in mills at present driven by engines, where a certain tonnage for the mill is given, together with information as to the dimensions of steel rolled, number of passes, roll speeds, &c. The rolling motor may be designed for either direct or alternating current, the majority installed to-day being of the latter type. We will, therefore, outline first the methods used in working with alternating-current apparatus.

Fig. 7 shows the wiring used in testing an electrically-driven sheet bar mill. This mill is 2-high, with rolls from 16in. to 20in. diam., and is driven by an induction motor of

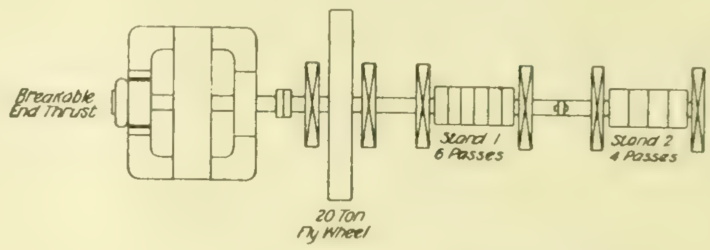


FIG. 8.—PLAN OF 20IN. BAR MILL.

1,000 h.p., 83·3 revs. per minute synchronous speed, operating from 2,200-volt, 3-phase, 25-cycle mains. The power required to drive the mill is recorded by a graphic wattmeter, which may be of the single-phase type, but calibrated to record 3-phase power. To check the recording wattmeter, single-phase indicating wattmeters are used, together with indicating ammeters; potential transformers stepping the 2,200-volt supply down to 110 volts, and current transformers of suitable ratio being used for the current coils of the wattmeters and the ammeters. Each of the graphic meters is provided with two pens in addition to the main pens for recording power and current. On the graphic wattmeter one pen is connected to the time-marking clock and spaces off equal time intervals, while the other pen is controlled by key located at the mill. In the graphic ammeter one pen is likewise connected to the time-marking clock, and the other in circuit with the speed-marking commutator, which is connected to one end of the motor shaft. A voltmeter is wired in circuit, so that voltage between any two lines can be read; and in addition to the above equipment, a liquid tachometer is used to indicate the motor speed.

The motor is started up with all resistance in the secondary, and as it comes up to speed, the contractors close and short-circuit portions of the resistance, bringing the motor nearer to synchronous speed. Sufficient resistance remains permanently in the secondary circuit to cause a considerable drop in speed from no load to full load, thus allowing the 20-ton flywheel to take some of the peak power demands. The steel is rolled as follows: A billet about 5ft. long and 6in. square is

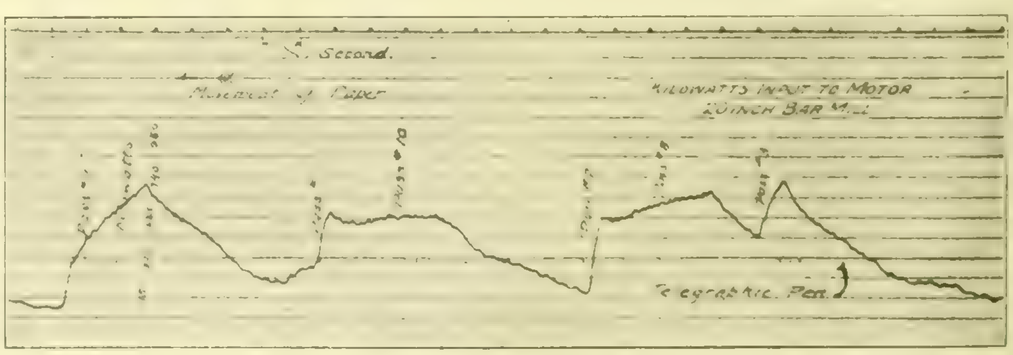


FIG. 9.—GRAPHIC WATTMETER RECORD.

brought to the first pass on stand No. 1 and sent through the rolls. It is caught on the other side, returned over the top of the rolls, and sent through the second pass. This procedure is kept up until the last pass, when the billet has been reduced to a sheet bar about ½in. thick and 40ft. long.

When the mill is in regular commercial operation, as many as three billets may be in the stands at once, but in most of the tests that were made it was decided to have only one billet in the mill at a time. With this understanding the mill was tested as follows: Just before the billet entered the first pass, the spring motors on the graphic meters were started, the

short-circuiting switches on the secondaries of the current transformers opened, and the time-marker clock started. At each pass from then on, these instruments recorded kilowatts and amperes input to the motor, speed and time, and the man at the mill signalled just what passes were occupied at any instant. As the billet went through each pass, the speed dropped, and a man at the liquid tachometer noted the high and low speeds of the motor. In addition to these records, readings of voltage were taken, while two men took measurements of the billet at each pass, using calipers for width and

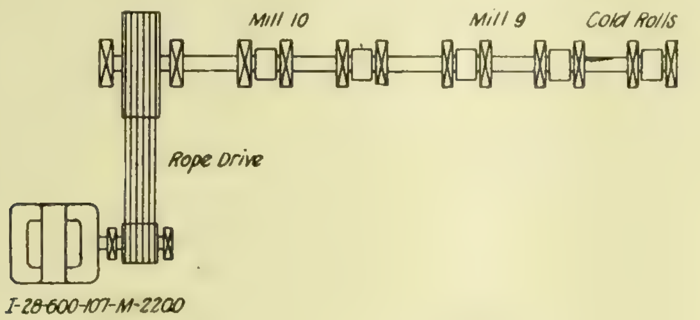


FIG. 10.—PLAN OF 30IN. FOUR-STAND SHEET MILL.

thickness and a hooked iron rod for length. The recording instruments were checked with the graphic meters, by taking simultaneous readings during a long pass when the input to the motor was steady for a sufficient length of time to permit of good readings being secured.

In working up the data obtained, the characteristic curves of the induction motor were calculated. For any given pass the graphic records showed the kilowatts input to the motor, the time of the pass and the drop in speed. The size of the flywheel was known, and, therefore, the value of all the factors for substitution in the formula.

$$T = T_1 - \frac{T_1 - T_0}{e^t_A}$$

Where $A = \left(\frac{308\ T}{WNS}\right)$

T = Motor torque at any time
T_1 = Total torque of the load
T_0 = Initial torque of the motor at zero time
e = Base hyperbolic log = 2·718
t = Motor torque at slip S
W = Flywheel effect in pounds at 1ft. radius
S = Slip at torque t
N = Synchronous speed in revolutions per minute.

When the total torque required in reducing the steel has been determined, curves of torque at each pass may be plotted against time, and from these, curves of horse-power-hours per ton against per cent. elongation can be laid out. The latter curves are extremely useful in estimating the power requirements of future mills.

With direct-current motor-driven mills, the testing apparatus and methods are very similar to those used for induction motor-driven mills with the exception that no potential or current transformers need be employed. The recording meters are similar in appearance to the alternating current meters.

Figs. 8 and 9 relate to the test of a 20in. bar mill. Fig. 8 is a plan view of the mill, and Fig. 9 is a graphic wattmeter record from a test made while the mill was in commercial operation. The first peak on the record was caused by steel entering pass No. 7. This pass required about three seconds, and the manner in which the flywheel took the peak load, causing the input to the motor to increase comparatively slowly and likewise decrease slowly, is clearly shown. The next peak was caused by steel in pass No. 1, and then a bar which had been waiting was sent through the mill for its last, or tenth pass, and so on as noted in the curve. At the top of the sheet the time is marked off in seconds, and below may be seen the record of the telegraphic pen. The speed-marker record is on the graphic ammeter chart, which is not shown.

Figs. 10 and 11 relate to a test of a 30in. 4-stand sheet mill. Fig. 10 shows the lay-out of the stands, motor drive, &c., and Fig. 11 is a portion of a graphic wattmeter record made while mills Nos. 9 and 10 were in commercial operation. The speed marker is shown at the top of the record, and time intervals below. The telegraphic pen in this case was on the graphic ammeter record. The first peak was made exceptionally heavy by reason of the fact that a pack of steel sheets in mill No. 10 pulled the speed of the mill down, and before the motor had time to accelerate another pack was sent into mill No. 9, the result being that the motor had a dead drag of about 800 h.p. to pull through. The difference in character of the load on the motor when the flywheel is able to supply part of the torque is well shown by the next peak, produced by sheets in mill No. 10.

This article will serve to give a general idea of the methods used in testing rolling mills. It will be noted that the general scheme of testing either steam or electrically-driven mills is the same, and may be summed up as follows: (1) To secure a continuous record of the power required to drive the mill; (2) to secure a continuous record of events taking place in the mill; (3) to definitely and positively connect records of (1) and (2).

As a final word, it might be well to note that all apparatus and equipment that is used should be as simple and reliable as possible, in order that the tests may run smoothly.—" General Electric Review."

MARINE OIL ENGINES.

AT the annual meeting of the British Corporation for the Survey and Registry of Shipping, held in Glasgow on the 21st ult., Mr. Francis Henderson, chairman of the society, said the Sub-Committee on Internal-combustion Engines had personally, and through specialists on the staff, kept themselves in closest touch with all the latest inventions and improvements in this department, and had issued provisional rules for construction which embodied in a tentative fashion existing knowledge, but which were in practice used

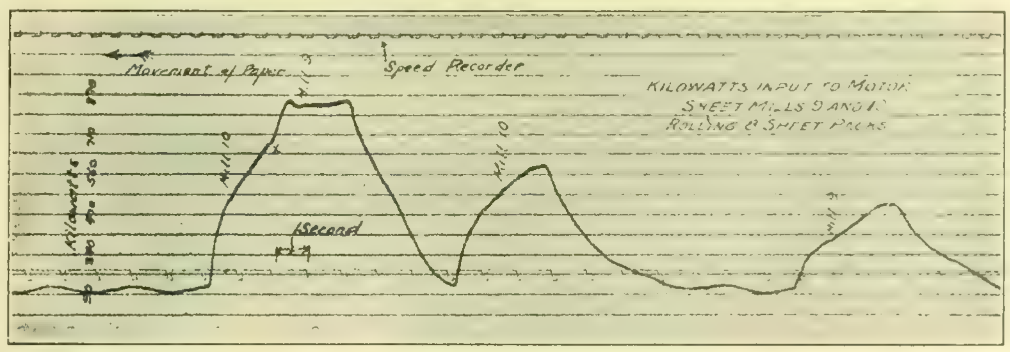


FIG. 11.—WATTMETER RECORD OF POWER SUPPLIED TO TWO MILLS.

only as a basis for interchange of views with designers rather than as regulations, because they felt that they were still a long way from the last word on this subject. Reference had already been made to the successful voyage of the "Toiler" across the Atlantic and to the fact that a sister vessel of somewhat larger power was under construction. Success had also attended the auxiliary motor ship "Sound of Jura" and two whalers with oil engines, and they were waiting with great interest the results of the trials of the 7,000-ton oil-driven ship "Jutlandia," built by Messrs. Barclay, Curle, & Co., and the 3,200-ton cargo ship, by Messrs. Richardsons, Westgarth, & Co., all of which vessels were being built to the classification of the registry. Even more, from an educative point of view, might, however, come from the development of the fleet of coasters with oil motors, which was being built under their survey for Mr. John M. Paton, of Glasgow, because the lessons of experience were most easily applied during the growth from small things to great.

The British Electrical and Allied Manufacturers' Association.—A meeting of the Council of this association was held at the offices, 36, Kingsway, London, W.C., on the 15th ult. The Secretary reported the completion of the work of the Committee appointed to suggest amendments of the Model General Conditions, and was directed to present its report, after printing, to the Institution of Electrical Engineers. The Secretary further reported that the Committee appointed to revise the Standards for Electrical Machinery (Report No. 36) had made considerable progress with this work.

FAILURE OF A BAKER'S STEAM OVEN.

For the purpose of baking, steam-heated ovens are now extensively used in place of the old-fashioned direct-heated ovens. These appliances consist of two or three horizontal layers of tubes, about 7ft. or 8ft. long by $1\frac{3}{16}$in. external diameter and $\frac{3}{8}$in. bore nearly filled with water and welded up at both ends. The tubes are set at a slight inclination, and one end is allowed to project into a brickwork chamber at the bottom of which the fire is placed. The other part of the tube projects into the several compartments of the oven. The general arrangement is shown in the accompanying sketch, taken from the Board of Trade Report No. 2,079, which records two explosions from tubes in the same oven, one on the 1st and the other on the 17th of September last, at a bakery at Warrington. The tubes theoretically are of enormous strength, and the two in question—as well as the others in the oven—had been tested by the makers to a pressure of 10,000lbs. on the inch before they were used, but being hermetically sealed, and nearly filled with water, it

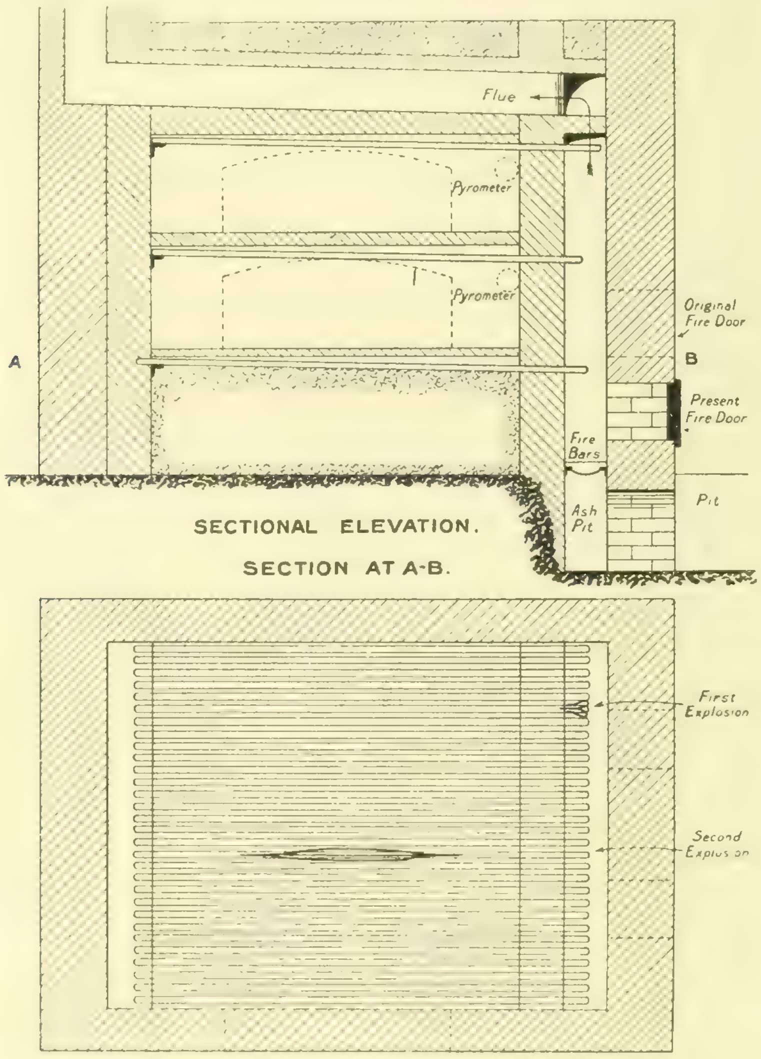


Fig. 1.—Views of Steam Oven, showing Position of Tubes which Failed.

will be evident that when exposed to the action of heat they are subject to enormous steam pressure. It is difficult to say exactly how much, but some idea may be formed from the fact that in the oven chambers heated by the tubes the temperature is often over 500° Fah., and when the tubes burst, although the quantity of water in them is small, the explosive effects are at times very violent. The danger of this occurrence usually rises from overheating through the maintenance of too large and too fierce a fire in the furnace. It is necessary, therefore, if failures are to be avoided, that the temperatures of the ovens as measured by the pyrometers supplied should not exceed makers' instructions. In the case under notice the oven contained two compartments, heated by three tiers of tubes, and the attendant appears to have been misled as to the temperature in the lower tier owing to the pyrometer in the lower oven being out of order, and to the temperature being inferred from the reading of the pyrometer in the top oven. The explosions were violent, as the photo views of the burst tubes show, and from past failures it would appear that care is required in the working of this class of apparatus if failures are to be avoided.

TERRESTRIAL MAGNETISM.

At the annual general meeting of the Physical Society of London, recently held, Prof. A. Schuster, Ph.D., D.Sc., LL.D., F.R.S., delivered his presidential address on "A Critical Examination of the Possible Causes of Terrestrial Magnetism." In forming any theory of the cause of terrestrial magnetism the first question was, he said, whether we

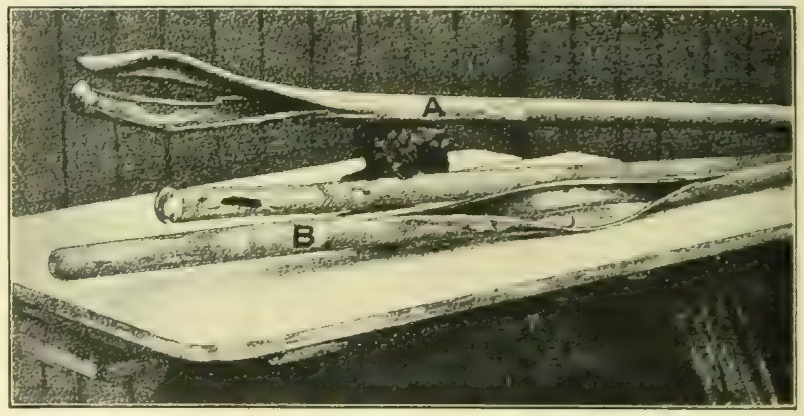


Fig. 2. Ruptured Tubes from Steam Oven

were to consider the near coincidence of the geographical with the magnetic axis as accidental or significant. The secular variation argued for the second alternative, and scientific opinion had always favoured the view that there was a definite reason for the close approach of the magnetic to the geographical pole. The view that iron was responsible for the observed magnetic field had, he stated, generally been put aside, because iron lost its magnetisation at temperatures lower than those which all were agreed must hold at moderate depths below the surface. But the objection raised on this ground disregarded the possibility that the critical temperature of iron might be raised by pressure. It might be shown that if that temperature depended on molecular distance, and the ratio of compressibility to thermal dilatation was assumed to be independent of pressure, the rate of increase of temperature with the depth was less than the rate of increase of the critical temperature, so that iron would retain its magnetic properties. Experiments on the effects of pressure on the critical temperature of iron had been in progress during the last four years, but had not hitherto led to a decisive result. For the present we must, therefore, keep our minds open to the possibility that the iron contained in the earth was magnetisable.

Prof. Schuster next examined the alternative opinion that electric currents circulating inside the earth were the cause of electric currents. Though this view seemed to be favoured by scientific opinion, it had to overcome formidable difficulties before it could be accepted. Were the electric currents permanent, or were they only survivals of a former state of things which was dying out? If permanent, we must account for the electromotive forces, and we knew of no such forces which could act in the manner required. If the electric currents were survivals, their intensity when the earth crust first formed must have been at least 10^{12} times as strong as it was now, and the difficulty of accounting for their original production would be correspondingly increased. In the opinion of the author, the difficulties which stood in the way of basing terrestrial magnetism on electric currents inside the earth were insurmountable.

The question whether the rotation of the earth might be responsible for its magnetic field was next examined by the author, and different possibilities were considered. If the rotation of a sphere independently of the chemical nature of the substance were to produce a magnetic field, it was shown by the theory of dimensions that the field at the surface of the sphere would be proportional to the angular velocity and independent of its size. The effect of rotating bodies set into rotation in our laboratories would give, therefore, magnetic forces equal to those of the earth with one rotation per day, and with angular velocities of the order of one per second the effects would be so large that they could not have escaped detection. A second supposition, that a neutral molecule in its motion behaved as if it carried a charge, led to the result that if terrestrial magnetism be due to such a cause the effects

to be expected in any laboratory experiment that could be proposed were far too small to be detected. But the theory was finally negatived by the additional conditions which must be imposed to destroy the effects of translation independently of rotation. A distinction must here be made between possible magnetic effects of a rotatory body on a magnet which was at rest and on one the supports of which were fixed to the rotating body. Returning to the effects of rotation, the author considered the possibility that rotation instead of directly determining magnetic intensity, determined magnetic force which might or might not cause magnetisation according to the nature of the body. This view, he considered, deserved attention, because there was some theoretical foundation for it, inasmuch as molecules might be considered to behave in a manner analogous to that of a gyrostatic compass. The theory would also explain in a natural manner the secular variation by a processional motion of a magnetic molecule. On the other hand, the theory would have to explain why the iron inside the earth became—by rotation—more strongly magnetised than the iron in our laboratories. There was, of course, always the possibility of some substance being subject to the effects of rotation in a much higher degree than iron. Such questions could only be settled by experiments which were now in progress. Other theories of the secular variation were considered.

In conclusion, the question was raised whether the negative electron was subject to gravitation, and if so, whether in comparing the weight of a negative electron with that of the unit positive charge, we must consider the proportionality between gravitation and mass to hold. In Lorentz' theory of gravitation this was abandoned. It was pointed out how fundamental questions had a bearing on the problem of terrestrial magnetism.

BOOK REVIEWS.

Liquid Fuel and its Apparatus. By Wm. H. Booth, F.G.S., Member American Society of Civil Engineers, &c. 8¾in. by 6in., 308 pages. London: Constable & Co., Ltd. Price 8s. 6d. net.

The subject of liquid fuel has latterly come very much to the front, not so much in connection with steam generation on land, except in a few favoured places where it can be easily and cheaply obtained and adequate supplies are available, as for use in internal-combustion engines and metallurgical furnaces. In the Navy, however, it has been extensively adopted for boilers, and promises to be more so, owing to its great heating value and convenience for meeting forced conditions. It is easier in some ways to store and also to control than coal, while its use also permits of a continuity of service, unbroken by the fire-cleaning intervals inevitable even with the best of solid fuel. For such advantages, the Navy, which is not fettered by commercial considerations, is, of course, willing to pay a good price, but oil fuel at its cheapest is so many times the price of coal in this country that it has no chance of superseding the latter for ordinary boilers, except, perhaps, in such contingencies as a coal strike, such as we are now experiencing, and which makes the publication of this work opportune. The scientific aspects of the subject have often formed the subject of papers before societies, and a few years ago the United States Liquid Fuel Board instituted the most exhaustive investigation respecting it that has been made. These various sources have been largely drawn upon by the author and welded into his general discussion of the various aspects of the subject, which make it a convenient work of reference respecting oil-burning practice whether on land or at sea and for all classes of boilers whether stationary, locomotive, or marine. The author has had a wide boiler experience of all kinds and in many directions is capable of discussing matters at first hand and with full knowledge of the limitations which actual practice imposes on general theories. It is a book we have every pleasure in commending.

* * *

Railway Signal Engineering. By Leonard P. Lewis, of the Caledonian Railway, Lecturer at the Glasgow and West of Scotland Technical College. 8¾in. by 6in., 358 pages. London: Constable & Co., Ltd. Price 8s. net.

With the development of railways and their complicated crossings, congested traffic, and imperative demands for safety, the problems of signalling have created a special field of engineering. Its literature is not extensive, and the present work should appeal to a wide class of readers and students. Its author's aims are to provide an outline of the general principles of mechanical signalling, including both hand and power operated, and to illustrate these by descriptions and discussions of actual practice. His experience has afforded him exceptional opportunities of studying the questions involved and his treatment is very satisfactory. Their clear understanding requires copious illustration, and the author has not spared himself. They are both numerous and well done and materially enhance the value of the text which, apart from its laborious accessories, deserves a word of praise for its clearness and arrangement.

* * *

Elementary Graphic Statics. By W. J. Crawford, D.Sc., Lecturer in Mechanical Engineering at the Belfast Technical Institute. 8in. by 5¼in., 131 pages. London: Chas. Griffin & Co., Ltd. Price 2s. 6d. net.

Elementary graphic statics scarcely permits of a great display of originality, and there are already many excellent text books. The chief merits of this one are that it is cheap, clearly written, and contains some good practical examples worked out in detail with a sympathetic knowledge of the difficulties liable to beset the student when he tackles problems of this kind for the first time.

* * *

Tables of Physical and Chemical Constants and Some Mathematical Functions. By G. W. C. Kaye, D.Sc., and T. H. Laby, B.A. 10in. by 6¾in., 153 pages. London: Longmans, Green, & Co. Price 4s. 6d. net.

This is a most admirable collection of data, a type of book that involves an enormous amount of work in the collection and arranging of the matter and checking of the proofs, and which at a casual glance does not show much for it. The labour can only be properly appreciated by those who have attempted similar work. It entails not only the consulting and checking of numerous authorities, but also an expense which is seldom reaped from sales, though we hope this may prove an exception to the rule. The value of the work finally, of course, turns largely on its authoritative character, for it requires unceasing vigilance to prevent errors creeping in. Judging from the excellent arrangement of the tables, a great deal of pains and care have been expended. The matter covers the principal constants required in dealing with almost any calculation likely to arise in connection with general physics, heat, sound, light, electricity, magnetism, radioactivity, chemistry, in addition to five figure tables of logarithms, reciprocal sines, cosines, tangents, &c., usually found in such books of reference. Finally, a word of praise is deserved for the excellent setting of the tables and matter, with its judicious use of heavy type for headings, &c.

Marine Oil Engines.—Lord Inverclyde, speaking at the annual dinner of the Scottish staff of Lloyd's Register held in Glasgow a few days ago, said the past year had been one of great activity for the society. The "boom" in shipbuilding had resulted in an enormous tonnage being submitted for classification. For each of several weeks close on 80,000 tons gross of new work had been approved, and between December 5th and February 6th 563,000 tons had been approved. A great advance had been made recently in the application of internal-combustion engines to vessels of considerable size. Their chief engineer had recently attended the trials of the "Selandia," of about 5,000 tons, which had been built at Copenhagen under the society's supervision. The "Selandia" was the largest vessel in which Diesel engines had yet been fitted. She had done 13 knots with 7,400 tons deadweight, although she had had to force her way through loose ice, and he had just heard from the secretary of the society in London that the trials had been in every way satisfactory. The mechanical difficulties in the construction of internal-combustion engines appeared to have been practically overcome. There still remained, however, the important question whether it would be possible to obtain a constant and well-distributed supply of oil for merchant vessels which had to go all over the world. The adoption of internal-combustion engines in ordinary cargo steamers would depend to a large extent on the satisfactory settlement of the question of supply.

SOME CONSIDERATIONS ON THE CHOICE OF AUXILIARY PLANT FOR POWER STATIONS.*

BY A. H. FINCH, M.A.

(Concluded from page 272.)

(*b*) **Auxiliaries as Labour-saving Devices.**—We now come to another class, or subdivision, of auxiliaries; those, that is, which are in reality only substitutes for labour. It is here that a temptation towards multiplication is so often evident. Certain of them, however, are so obviously superior to the intermittent or collectively large amount of labour which they displace, that there is usually no question as to the advisability of adopting them: such are, water service pumps and coal handling machinery, cranes, and bilge pumps. In the case of cranes, it is the ability to concentrate the requisite power into a small space that is valuable; with coal handling machinery it is advantageous in any event to use some form of mechanical lifting appliance, and the question of applicability of the power settles at once the method of driving. No such argument applies to mechanical stokers. Here the question is between an expensive appliance, capable, however, of giving smokeless combustion and better efficiency due to absence of frequently opened doors, and more even distribution of fuel, and a cheap arrangement involving a larger amount of labour and producing poor combustion at times. No comparison in an exact sense is possible, for the reason that the conditions prevailing in any given station, such as load factor or number of shifts worked, will radically influence the figures.

The following illustration is intended to apply to a boiler house running on a load factor of about 60 per cent. with three equal shifts, capacity 8,000 kw. The capital costs are taken to be:—

For mechanical stokers, shafting, motors and wiring, and dumping gear	£3,460
For firebars and furnace fronts adapted to hand-firing	320

Capital charges taken at 15 per cent. Maintenance charges on mechanical stoker gear, at 10 per cent., and on hand-firing apparatus, due to wastage of firebars, at 80 per cent.:—

Mechanical firing—	£
Capital charges	519
Maintenance	346
Power, say 16 kw. for 4,600 hours per annum at ·25d.	77
Labour, three shifts at 125s. per week per shift	975
	£1,917

Hand-firing—	£
Capital charges	48
Maintenance	256
Labour, three shifts at 245s. per week per shift	1,910
	£2,214

In this instance there is apparently a balance of £300 in favour of mechanical stokers, making out a fairly obvious case. If, however, no night shift (in the ordinary sense) is worked, the necessary night attendance, if any, being in both cases the same, the mechanical arrangement is reduced to £1,592, and the hand-firing to £1,577, and in such a case a more careful enquiry into the actual figures for maintenance, cost of power, &c., obtained in practice might point to adopting hand-firing in spite of the better combustion obtained with the alternative method. Or again, if we consider the case of an installation where native labour is available, the account for a 3-shift load might stand as under:—

Mechanical stoker—	£
Capital charges as before	519
Maintenance as before	346
Power as before	77
Labour, three shifts at £104 per shift per annum, being composed of twice the number of men assumed in the previous example, but at something like one sixth the rate	312
	£1,254

Hand-firing—	£
Capital charges	48
Maintenance	256
Labour, three shifts at £200 per shift per annum	600
	£904

showing a substantial advantage in hand-firing. Clearly then the labour conditions, and the nature of the load, are weighty factors in settling such a point. In fairness to the stoker method, it must be pointed out that better combustion generally results from its use, and inferior coals can be successfully burned. On the other hand, the method of hand-firing offers greater flexibility, and enables a wider variety of coals (as regards their components) to be used. Hence it is that no exact comparison is possible without full details in every case considered; while a further factor is the limitation imposed by the length of grates where very large hand-fired boilers are involved. In such cases the necessary grate area can only be obtained by increasing the width of boiler, which may lead to structural difficulties and an abnormal amount of floor space.

Another item in which the labour question is a prominent feature is ash handling. Owing to the nature of the material, all mechanical apparatus, except of the simplest character, is a source of excessive maintenance costs. On the other hand, the conditions under which ashes have to be handled make it difficult to obtain labour at a reasonable rate. Where tunnels are used they are often unbearably hot, or, being situated below everything else, and liable to choked drains, they readily become flooded. Large quantities of dust are produced in the process of handling, and if quenching or spraying is resorted to, this results in the formation of active corrosive agents.

Systems have been developed in which air or water is the conveying agent, and these have the advantage over any mechanical system in that the handling involved is a minimum, and no moving machinery is required except a pump, which can be placed out of reach of damage from the dust, and a breaker or crusher. With this arrangement there is necessarily considerable wear on the tubes or channels which convey the ashes; but such parts are cheaply replaced. The drawback of the system, from the point of view we are now considering, is that it introduces two auxiliaries, viz., the crusher and pump, but the former can be a very robust piece of apparatus. The channels for conveyance of ashes can be brought close up to each boiler, and by using suitable means for introducing them into the crusher or channels dust can be effectually confined.

Where the conditions of manual operation are so unfavourable, there is a strong case for mechanical handling, but the choice of apparatus should fall on that which can be made of the stoutest construction, a consideration which would operate against conveyers, elevators, or hoists of the usual description.

The case of large valves operated by motors or compressed air is settled more by the question of time than of cost in the ordinary sense. The valves commonly so operated are main exhaust valves between turbines and their condensers, or large circulating water valves. Speed in closing the former becomes valuable in such a case as that of a condenser suddenly choked with floating matter from a river. By closing the valve quickly enough the condenser may be protected from damage due to overheating. Likewise large water valves may require to be operated in certain designs where the flow of water through a condenser is reversed for cleaning purposes, an operation which might require to be carried out with the utmost dispatch. Either electricity or compressed air may be adopted, the latter depending on the extent of other uses to which air can be put. But steam is unsuitable, for, readiness in operation being essential, the engine would have to be kept always warmed up, involving waste and leakage.

The working of switches is a question wherein ease of manipulation from a distance is the paramount consideration. To bring the control of a large number of switches into any convenient compass can, it is true, be accomplished in the same way as with railway signals and points, by a system of levers and rods; but this system is being replaced on important signal installations by electricity, either alone or in com-

* Paper read before the North-East Coast Institution of Engineers and Shipbuilders.

bination with compressed air. In a power station where electrical manipulation is unaccompanied by exposure of apparatus to the rough conditions of a railway track, it is obviously indicated in preference to a purely manual process for control of a large number of switches, failure of the current being a remote contingency owing to the invariable practice of employing a battery.

There remains for consideration a class of casual services whereon motors are often employed, such as water softeners, weigh bridges, air compressors, and boiler cleaning pumps. The general principle applicable to such cases is that the extent of use should settle the method of driving. To take the cases cited: the softener may be used continuously, and so require regular attendance, or intermittently, being idle for weeks. In the former case power operation is justified, in the latter, not; unless, owing to great size, manual labour cannot be advantageously employed. Weigh bridges of a type in which a motor is necessary to move counterweights or raise the table only justify themselves by frequency of use. Air compressors, universally used for cleaning electrical apparatus, are a necessity in a large power station, but a luxury in a small sub-station where bellows will do the work; and boiler cleaning pumps (for use with water-tube boilers) become necessary where the frequency of use is such that a boiler feed pump cannot be spared for the purpose, or where salt water is used for cleaning and the risk of getting it into boilers cannot be run.

Certain auxiliaries are to be found associated with the purely electrical portion of a station, which do not exactly fall into either of the two arbitrary divisions that have been discussed. Such are fans for ventilating electrical apparatus, whether rotating or stationary. The measure of the value of these is, in general, the degree to which they increase the capacity of a given weight of copper or iron in electrical apparatus. With rotating plant the alternative is ventilation by what really amounts to a fan on the rotating portion of the generator itself; and as the rotation of this portion in most designs is necessarily accompanied by some fan action, it would appear a logical extension of the principle to make the rotor do the whole work of ventilation, the slight additional power requiring no increase in the shaft or bearings. Clearly then, an auxiliary fan is not justified in this case, unless the conditions are such (for instance) that air has to be brought to the generator from a distance in an enclosed duct, the friction of which, unless it be unduly bulky, might result in an insufficient supply; or where air filters are necessary; or, in similar circumstances, when the resistance to be overcome is greater than can be dealt with by a rotor fan whose speed and diameter are fixed by those of the generator.

With non-rotary apparatus, such as transformers, the method of direct ventilation by air finds an alternative in cooling by oil or water. Oil is of necessity the immediate cooling agent of the metal. It is practicable to cool the oil either by water pipes within the transformer case, or by passing it through an external cooler, wherein water is circulated. Where a supply of water exists under sufficient head, a water pump is not necessary, but an oil pump is introduced with the method of external cooling. This is against the method; its advantage lies in more effective cooling and a reduction in the risk of leakage of water into the oil, which can be accomplished by giving the oil within the cooler a higher pressure than the water. Any system of water cooling has the advantage over the usual methods of fan cooling that the heat abstracted is not liberated within buildings; more important perhaps in tropical climates than in these latitudes.

Exciters almost claim a place by themselves, particularly since so much attention has always been devoted to the subject. As between the independently driven machine and one directly coupled to the shaft of the alternator it is intended to excite, the arguments may be grouped thus:—

Against the direct coupled exciter—

(1) Small size and inefficiency.
(2) In turbine stations, addition to length of whole unit which may require a wider engine-house.
(3) Cumulative effect on busbar pressure of a fall in speed.
(4) Inability to be used for station lighting, &c.

Against the independent exciter—

(1) Cost of separate engine or motor (usually the former) to drive it.
(2) Cost of running the same, including maintenance and ultimate coal consumption.
(3) Duplication.

Given sufficiently good voltage regulation, the method of direct-coupled exciter, even if accompanied by motor generators for battery charging or station lighting, produces a simpler total combination, and one more easily kept in an efficient state of repair.

Methods of Driving Auxiliaries.—Having now indicated the bearing of certain general considerations on the simplification of auxiliary plant, we may discuss the best means of providing the necessary power. Three systems are in vogue, viz., electricity, steam, and (for certain limited services) compressed air. The last is the least efficient, but has the merit (where a reservoir is provided) of being to some extent independent of failure of the main supply.* For an infrequent service, such as valve operation, economy ceases to be of importance, and the use of air may be justified by cheapness of the actual engine and piping employed in comparison with an electric motor and wiring. On the other hand, an independent source of power, viz., air compressor, is necessary, whereas auxiliary current at most requires only a transformer.

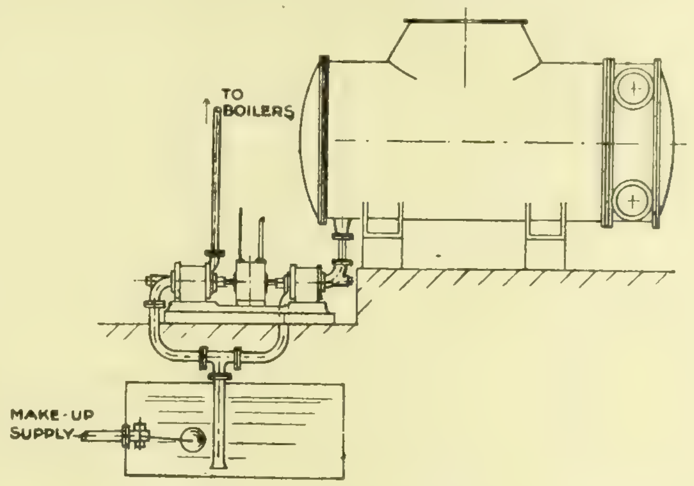


FIG. 2.—CLOSED CYCLE SYSTEM OF BOILER FEEDING. ARRANGEMENT PROPOSED BY MR. FULLAGAR.

On general grounds, since a power station must employ steam and generate electricity, it would seem preferable to use one of those agencies rather than air, which requires additional apparatus and only introduces an indirectness in the application of power.

As between steam and electricity, the principle suggested is that steam should only be used where it introduces a simplification, not so much in respect of economy as by offering a simpler combination of apparatus. This is said with particular reference to the use of exhaust steam for feed heating. Where the exhaust cannot be so used, either wastefulness is introduced by exhausting to atmosphere, or complication ensues from the addition of an auxiliary condenser, and possibly an oil separator, to the total of auxiliary plant.

Let us examine the case of a direct-acting feed pump working without lubrication. It consumes anything between 65lbs. and 100lbs. steam per water horse-power per hour, say 75lbs.; whatever the pressure at release, in round numbers, the exhaust carries away 1,200 B.T.U. (reckoned from 0° Fah.) per pound. To fix the ideas, consider a 1,000 kw. turbine, using 18,000lbs. steam per hour. With boiler pressure 175lbs. per square inch, the water horse-power is 3·58, and the pump steam per hour = $3{\cdot}58 \times 75 = 268$lbs. Therefore the heat available for feed heating is $268 \times 1{,}200$, or say 320,000 B.T.U.

If the initial temperature of the feed be 90° Fah. (28in. vacuum corresponds to 101° Fah.) each pound contains 90 B.T.U. reckoned from zero, and the whole feed contains $18{,}000 \times 90$, or 1,620,000 B.T.U.

The final temperature therefore becomes—

$$\frac{1{,}620{,}000 + 320{,}000}{18{,}268} \text{ or } 106^\circ \text{ Fah.}$$

In this case, an expenditure of $\frac{268}{6{\cdot}5}$, say 41lbs. of coal per hour, pumps the necessary feed, and heads it by 16° Fah.

* Employed for this reason in actuating the brakes on some forms of electrical winding gear for collieries.

To effect a comparison, we may consider pumping the same quantity of water electrically, and heating the feed by live steam; assumed at 175lbs. per square inch: Water horse-power = 3·58; efficiency of pump and motor, 60 per cent. Then power required by motor, in kilowatts $= 3{\cdot}58 \times \frac{1}{6} \times {\cdot}746 = 4{\cdot}5$ kw., which, at 3lbs. per kilowatt-hour, would result in a consumption of 13·5lbs. coal per hour. Quantity of steam to heat the feed $16° = 256$lbs., requiring $\frac{256}{6{\cdot}5}$ or 39·4 lbs. of coal. Total coal by this method, 44lbs., which is therefore inferior as regards both steam economy and power to vary speed within wide limits.

Thus, apart from the question of capital cost, which is almost certainly in favour of the steam pump, a clear case can be shown for steam. But such superiority might vanish if, owing to the introduction of lubricant, an oil separator were rendered necessary, or the exhaust were wasted.

Small reciprocating engines are inferior to electric motors in respect of upkeep, coal consumption, and stand-by losses when not in use but kept ready for use, but small turbines are not necessarily so.

Reference was made at an earlier stage to a set consisting of a small turbine driving the condensing auxiliaries; and it was shown that certain advantages accrued to such a use of steam if the exhaust could be profitably employed. We thus arrive at an argument of the following order: In modern high-vacuum plants the air pump discharge is so much reduced in temperature that if introduced into an economiser without further heating it would cause sweating of the pipes. Consequently feed heating is a necessity. Steam feed pumps and turbine-driven condensing auxiliaries can be shown to have a thermal superiority over similar electrically-driven services if the exhaust be used to heat the feed, and are compact and easily maintained. To the extent, then, that the exhaust can be usefully absorbed for this purpose, steam driving is clearly indicated for such services. But if the use of steam involves either waste of the heat of exhaust or the introduction of additional appliances it ceases to have any recommendation as against electricity, with a possible exception in cases where speed variation within wide limits is required. It has been argued that steam offers a protection against failure of the auxiliaries in company with the main generators when a complete electrical breakdown occurs. In the system just described, the auxiliaries most essential to the restarting of the plant, viz., those connected with the condensers, would be steam driven.

To the advantage of steam it is to be added that it detracts nothing from the capacity of electrical generating and transforming plant, and little more from that of boilers than does an electric service. Electric power, on the other hand, while it detracts from capacity of alternators, &c., has the following broad advantages: (1) Small attention required while running. (2) Relative ease of installation at any distance. (3) Ease of control from any desirable point.

The latter quality is particularly useful in the case of motors which drive stoker gear or fans; or for an object like a coal conveyer which extends over a great length and may have to be stopped from anywhere in case of accident.

Means of Providing Power.—Where steam is employed it can usually be taken from the main range. Cases sometimes arise, where the main supply is superheated, but saturated steam is required for, say, a feed pump; in such cases provision can be made by drawing the saturated steam supply from two or three boilers which are not likely to be shut down all at the same time. As regards electricity, it is only proposed here to consider the two systems of supply which are most usual, viz., 3 phase and continuous current.

The distinctive advantages of 3 phase current (absence of brushes or commutator, and solid and cheap construction) and its disadvantages (invariable speed) are well known. A 3 phase supply for auxiliary circuits may be provided by three different methods: (1) by separate transformers connected with each generating unit; (2) by transformers from the busbars; and (3) by separate auxiliary generating sets

(1) The first named, generally known as the complete unit system, wherein all the auxiliaries connected with any main generator or driven from a transformer attached to that generator, possesses advantages in the matter of reliability, but is obviously costly. In isolated stations and with electrically-driven condensing auxiliaries it is justified if not pushed to excess, as is liable to become the case where the boiler-house is concerned. Without an altogether disproportionate amount of spare boiler plant, each boiler-house or group of boilers must be considered the common property of the engine-house. Consequently a unit system must be interconnected in some way, which leads to expense and begins to vitiate the principle of unity. But apart from this the argument against the alternative of driving from busbars, which is valid in the case of the turbine auxiliaries, is not necessarily applicable to the boilers. For a busbar failure, or a failure of one of the station transformers, does not vitally affect the supply of steam, if feed pumps are steam driven, and natural draught can be substituted for artificial; the grates (if mechanical) can be operated by hand for long enough to enable the busbars to be made alive again, or the reserve transformer switched in. Coal or ash handling plant, or the crane, cannot be allocated to any one turbine. It thus becomes necessary to have in any case a connection from the station busbars to the unit transformers.

Apparatus which is inalienable from its own generator is usually confined to air pumps, and in some cases circulating pumps and ventilator fans. Where the circulating and air pumps are steam turbine driven, and the alternator supplies its own draught, the principal arguments for the unit system are absent.

(2) A supply from the main busbars through transformers has an advantage over either of the other methods in the matter of initial cost. The transformers detract, of course, as much capacity from the main alternators as the unit method, and have to be in duplicate. Otherwise this system is exceedingly simple and obvious.

(3) The recommendations of the independent method are protection from electrical breakdown of the main system, and increased saleable capacity in the main alternators. The cost is necessarily much greater than that of the busbar method, and space has to be found for at least two auxiliary steam-driven generators with their equipment.

A supply of continuous current from a 3-phase station can be furnished (1) by motor generators, with or without a battery; (2) by independent generators.

The advantage of continuous current is its particular applicability to variable speed services, cranes, and locomotives. With the addition of a battery, auxiliaries are quite independent of the state of the main busbars. After these things are granted, its disadvantages soon become apparent in the upkeep of commutators and brushes, increased initial cost, and perpetual loss in conversion by motor generator or storage in the battery. This, of course, would not apply in a direct-current station.

In some cases where alternating current is generated the device has been adopted of having some auxiliaries driven by alternating, and others by direct current, furnished by a motor generator in normal operation and by a battery if the supply fails. Thus some at least of the auxiliaries, and the station lighting, can always be kept going. But the introduction of two electrical systems is objectionable. The use of air for motive purposes about a power station is so small that its provision need hardly be discussed.

Conclusion.—We may now summarise the conclusions indicated by the foregoing remarks. Starting from the assumption that a large station is to generate 3-phase high-tension current, certain services must be arranged for, some driven by steam, others by electric power. Preference is to be given to 3 phase current which can be provided for either by independent generators, by transformers from the busbars, or by transformers from each generating unit. Being necessarily in duplicate and steam driven, independent generators are a costly means for obtaining the power. It has been shown that turbine-driven air and circulating pumps, with the possible addition of feed pumps on the same shaft, besides fulfilling a useful and economical function in heating the feed, render unnecessary a subdivision of auxiliary services into unit groups. Therefore it is submitted that such pumps, with other electric auxiliaries supplied by transformers connected only to the station busbars, combine simplicity with a sufficient measure of reliability. The transformers must, of course, be in duplicate.

But where for any reason, such as small size of units, with consequent wasteful consumption on auxiliary power, or exces-

sive power rendered necessary by exigencies of the pumping system, steam cannot be economically adopted (having reference to the heating of the feed water), a grouping of motors into units, in which either one or two generators may participate, with electrically-driven condensing auxiliaries, is to be recommended on the score of the immunity which it furnishes from simultaneous breakdown of all auxiliary services.

The following services may with advantage be electrically operated: Mechanical stokers, if fitted; fans, if fitted (variable-speed motors are desirable here, if efficient at low speeds); water service pumps of all sorts, except those very rarely used, where steam ejectors can be employed; economiser scrapers; coal and ash handling plant; cranes.

TABLE I.—*Aggregate of Auxiliary Power Installed at Various Stations.*

Station.	Total Main Generating Plant. Kw.	Auxiliary Power Installed. H.P.	Motor Generators or Auxiliary Steam Sets.	Auxiliary Power H.P. per 1,000 Kw. of Main Plant	Remarks.
Lots Road, Chelsea	48,000 3 ph.	2,223	4-135 kw. Steam	46·5	The four steam sets supply excitation and some D.C. motors.
Carville	35,000 3 ph.	3,411	2-25 kw. 1-100 kw. M.G.'s	97·5	
*Greenwich (L.C.C.)	34,000 3 ph.	2,064	2-150 kw. Steam	61	
Glasgow—Port Dundas	22,400 3 ph.	1,850	2-40 kw. M.G.'s	80	
Dunston	19,000 3 ph.	1,184	1-9 kw. 2-50 kw. 1-200 kw. M.G.'s	62	
Glasgow—St. Andrew's Cross	16,400 3 ph.	1,725	2-40 kw. M.G.'s	105	Fan draught cooling towers.
Brighton	10,200 3 ph.	912	2-220 kw. Steam 2-300 kw. M.G.'s	90	Motor generators and steam sets used also for external load.
Hamburg Ov'rhead	7,900 3 ph.	590	—	74·5	Condensing auxiliaries and feed pumps turbine driven.
Märkisches (Berlin)	7,200 3 ph.	508	—	70	
Stepney	6,000 D.C.	580	(D.C. Station)	96	
Newcastle and District Co.	5,450 D.C. and 1 ph.	473	(D.C. Station)	87	
Cambridge	1,880 1 ph.	117	1-45 kw. M.G.	62	Single-phase generators. Motor generator for external load.
Alnwick	140 D.C.	15	—	107	Non-condensing.
Morpeth	60 D.C.	12·5	—	210	

* Figures for Greenwich are, as regards 85 per cent., taken from a paper read by Mr. Rider before the Inst.E.E. in 1909.

The following should, where possible, be steam driven: Feed pumps, and combined air and circulating pumps for the condensers.

Exciters should preferably be directly attached to the shafts of their generators. Ventilation of alternators to be effected by fans on the rotors. Switches to be electrically operated.

Large valves where speed of operation is essential may be operated either electrically, or, if the station is on a large enough scale to warrant a supply of compressed air always available for cleaning electrical apparatus and driving pneumatic tools, by air.

Circumstances, of course, make it impossible that any one scheme should be the best. Exigencies of pumping or of cooling arrangements may introduce quite abnormal features into a design. What is permissible in a station which is one of a system may involve grave risk in an isolated station; or again, an abundant provision of steam from an external source may indicate that agency for auxiliary work. In a certain station in Yorkshire the ashes are handled by ponies, because the company happen to have a grass field with no other use for it. And there is the same scope for variety everywhere. What has been aimed at is to advocate those arrangements which make for simplification, whatever the external circumstances may be, and to show how they may be compatible with the reliability demanded of the supply of a public commodity.

We may conclude by a brief reference to the tables which are appended to the paper, and this opportunity is taken of acknowledging the kindness of the engineers associated with the various stations in furnishing information. Motor generators and auxiliary direct-current sets are shown in a separate column, as their inclusion among auxiliaries proper would be misleading. Steam feed pumps are estimated.

A great divergence is exhibited in the degree to which auxiliary power is actually employed. Local peculiarities account for some of this divergence. For instance, in the case of Greenwich power is wasted due to the leakage of circulating water in connection with the straining appliances rendered necessary with Thames water and electrically-driven feed pumps bulk largely in the total. At Carville, the station being set back some distance from the river in order to obtain suitable foundations, the power required for pumping water is considerable; on the other hand, practically none is needed for coal handling owing to an advantageous use of the natural levels of the ground. Of the two Glasgow stations, one (St. Andrew's Cross) employs fan draught cooling towers, the other a canal. Hence the high figure in the case of the former.

TABLE II.—*Analysis of Power used for Various Purposes.*
All figures H.P. per 1,000 k.w. of Main Plant.

Station.	Feed Pumps	Stoker and Economiser.	Fans.	Condensing Auxiliaries.	Coal and Ash.	General Services.	Total.
Lots Road, Chelsea ...	5	5	—	19	7	11	47
Carville	12	4	33	41	3	5	98
Greenwich	12	3·5	—	34	7	4·5	61
Glasgow—Port Dundas	11	3	21	37	5	3	80
Dunston	10	2·5	14	26	3	7	62·5
Glasgow—St. Andrew's Cross..	9	3	8	78	5	2	105
Brighton	12	3·5	45	24	2·75	2·75	90
Hamburg Overhead...	32	3	—	25	9	5	74
Märkisches (Berlin) ...	22	1·5	12·5	25	7	2	70
Stepney	11	3·5	12	49	6·5	14	96
Newcastle & District..	8	3·5	22	48	1	4·5	87
Cambridge	21	1	1	33·5	—	5·5	62
Alnwick	107	—	—	—	—	—	107
Morpeth	110	—	—	100	—	—	210

At Stepney circulating pumps and fans account for much of the power. The latter also contribute a large proportion in the case of Brighton and Carville. In fact it is almost correct to say that they constitute the principal difference between the high figures and the low figures, except at Dunston, where fan power is moderate and not duplicated.

Cambridge is of interest because it exhibits another factor of the auxiliary question. Being started as a single-phase station in days when single-phase motors were unsatisfactory, the bulk of the power is furnished by steam, 12 h.p. only being electrical; the air and circulating pumps are for the same reason driven by gearing from the main turbines.

The installation of induced-draught apparatus accounts for a large proportion of the power at the Newcastle and District Company's station. As a matter of every-day practice induced draught is not used there, but the fan motors are

included because a classification has to be made on a uniform basis for comparison. The rated power of motors installed, which is the figure stated, is roughly a measure of the capital spent on auxiliaries. The daily energy used, which would be more indicative of the annual cost, might have been selected, but such a figure would be difficult (in some cases impossible) to arrive at, and the former figure perhaps brings out in a more striking fashion the importance of the whole question from the capital point of view.

INDUSTRIAL AND TRADE NOTES.

The Automatic Standard Screw Company, Ltd. We are informed that this business has for family reasons been converted into a private limited company, but that the conduct and management will remain in the same hands as heretofore.

Electric Control Gear Applied to Woodworking Machinery.— From the Adams Manufacturing Company, Ltd., of Bedford, we have received an illustrated pamphlet describing examples of control gear for the electrical power equipment of woodworking factories. It is devoted to the problems met with in this class of machinery, and should prove of service to those engaged in the design or equipment of this class of work.

Electric Steel.—Messrs. Vickers, Ltd., of Sheffield, have decided to erect an eight-ton Heroult furnace. This furnace, which will be the largest so far constructed in England, is being built after the experience of over a year's continuous operation with a 2½-ton furnace of the same type. It is of the three-electrode type, and is interesting as being the first to use three-phase current in this country, although several are in operation abroad.

Shipbuilding Deal. — The London and Glasgow Engineering and Iron Shipbuilding Company, Ltd., have issued a circular to the shareholders, which states that they have recently approached Messrs. Harland & Wolff, Ltd., and have concluded an agreement with that company under which they agree to purchase the whole of the shares of the London and Glasgow Company.

Clyde Shipbuilding.—The Clyde shipbuilding output during February, totalling 49,500 tons, spread over 20 vessels, has only once before been exceeded in the second month of the year, viz., in 1901, when 60,000 tons were recorded. For the year to date the 86,000 tons launched constitutes an easy record. The new work booked during the month has fallen considerably below that recently recorded, the fears of labour troubles in the coal trade and elsewhere having deterred shipowners.

Railwaymen Object to Eyesight Test.—An ultimatum for presentation to the directors of the North Eastern Railway Company has been prepared on the question of the eyesight test by the members of the Amalgamated Society of Railway Servants on that system. The matter has frequently been before the Conciliation Board at the instance of the men, who say they want a more practical test. Many workmen, having failed to pass the test, have been reduced or offered inferior positions, and the feeling against it has become very acute. The ultimatum is of a drastic character, and the men threaten to precipitate a general strike if the present test is not abolished and more satisfactory methods substituted.

North British Locomotive Co.—The report for 1911 shows that the company made £36,300 more profit in 1911 than in 1910, but the balance brought forward having been much reduced, it has been necessary to take £40,000 from the reserve in order to pay 5 per cent. again upon the ordinary shares. The directors state that the relatively small demand for locomotives during the year prevented the company's works being employed to their best advantage, and this, combined with the continued low level of prices, accounts for the result shown in the balance sheet not being more satisfactory. In 1909 a dividend of 8 per cent. was paid, for each of two years before that 10 per cent., and for 1906 12 per cent. The reserve is now £360,000.

Accidents in Factories and Workshops.—A Parliamentary paper has just been issued containing statistics of cases of industrial poisoning and accidents occurring in premises under the Factory and Workshops Acts during the year 1911. The tables, it is explained, are published in advance of the annual report of the Chief Inspector of Factories, and are subject to correction. The increase in the number of accidents corresponding with increased volume of manufacture which was observed in 1910 continued last year, during which period the Board of Trade returns showed further improvement in trade. The total number of cases of industrial poisoning in 1911 was 755, as against 573 in the preceding year. Fatal accidents to the number of 1,182 occurred in various industries last year, as against a total of 1,080 in 1910. There was a total of 118,735 non-fatal accidents notified in 1911, compared with 129,174 in the preceding year.

Trade Union Law (Amending) Bill.—This Bill, the text of which has just been issued, is presented by Mr. Johnson, supported by a number of well known labour leaders. It is sought to enact that a trade union shall have power, and shall be deemed always to have had power, whether acting by itself or in conjunction with any other trade union, association, body, or person, to apply its funds, or any portion thereof, for or towards or in connection with (a) the purpose of procuring, or assisting to procure, the return of members of Parliament, or of any public or local authority, or of any other public body; or (b) the purpose of providing, or partly providing, for the maintenance and other expenses of such members; or (c) both such purposes, and to do such other acts as may, in the opinion of the trade union, be desirable in order to promote the interests of workmen.

British Coal Output in 1911.—An advance report has been issued by the Home Office giving the tables (subject to correction) relating to the output of coal and other minerals and the number of persons employed at mines worked under the Coal and Metalliferous Mines Regulations Acts during the year 1911. It shows that the output of coal in 1911 was 271,878,924 tons, as compared with 264,417,588 in the previous year. The number of persons employed at coal mines was 1,067,213, an increase of 17,806. The increase in the output of coal was at the rate of 2·82 per cent., and the increase in the number of persons employed at the mines at the rate of 1·70 per cent. Including fireclay, ironstone, limestone, &c., the total output of minerals in 1911 amounted to 285,943,032 tons, as against 278,609,949 tons in the preceding year. The total number of persons employed was 1,067,213, as compared with 1,049,407 in 1910.

Electrically-driven Grinding Machinery.—B. R. Rowland & Co., Reddish, Manchester, send us a descriptive illustrated catalogue of their various specialities connected with the electric driving of grinding machinery. The comparatively high speed at which such machinery runs suits direct electrical driving very well, particularly in the case of wheels from 10in. to 30in. diam. With larger wheels than this the size of the motor necessary becomes excessive, owing to the low speed at which it runs, so that independent motors and belt drives then become desirable. Most of the machines illustrated are portable, and can be put down on any level surface, which is of advantage during constructional work in shipbuilding, bridge building, &c. Modern grinding machinery is particularly suitable for the application of ball-bearings, and the firm are now extensively making use of these, both for belt-driven and motor-driven machines. The use of variable speed motors provides an excellent means of keeping the peripheral speed of the wheel at its correct value for the maximum efficiency.

German Machine Tool Trade.—In a recent address Prof. G. Schlesinger, of Charlottenburg, discussed the position occupied by German machine toolmakers in the markets of the world. The imports of tools from England into Germany consist largely of very heavy machines, whereas American imports are almost entirely small and medium-sized machines, in which the cost of labour constitutes the principal expense of manufacture. As a result the importation of American machine tools into Germany lessens the opportunities for employment of the German worker to a much greater extent than the imports from any other country. The exports of German machine tools, according to statistics for the past ten years, increased from 11,000 tons in 1900 to 58,000 tons in 1908, while the imports averaged 5,500 tons during the same period. The German exports of machine tools to England are greater than the imports from that country, but the German exports to the United States are small. It was suggested that the makers of German machine tools should do all in their power to reduce the cost of their product and improve the quality, so as to be able to compete in the American market.

Safety Appliances for Mine Cages.—Replying to a question in the House of Commons recently respecting the employment of safety appliances for mine cages, Mr. McKenna said that the subject had been recently investigated by the expert committee which was appointed by the Royal Commission on Mines to enquire into the means of preventing shaft accidents, with the result that they were satisfied that under the conditions obtaining in this country none of the existing types of safety catch could be regarded as reliable. The Royal Commission, after hearing a large number of witnesses, and in view of the Committee's opinion, unanimously reported that they were unable to recommend that the use of safety catches should be requested by law. The subject was debated on the Report stage of the Coal Mines Bill of last session, and a proposal made to make the use of safety appliances compulsory, but this was not adopted. There was nothing more which could usefully be done by the Department at the present time, but the Act of last session contained a number of new provisions intended to guard against the risk of a cage falling down the shaft.

The "Manning" of Machines in Engineering Works.—At a central joint conference of the Engineering Employers' Federation and representatives of the Amalgamated Society of Engineers, the Steam Engine Makers' Society, and the United Machine Workers' Association, held in York, the question of the systematic displacing of skilled workers by handymen was under discussion, and it is understood that a serious deadlock ensued. The contention of the men is that engineering employers in all parts of the country are "manning" machines with labourers on every possible occasion. In this way employers are finding it possible to reduce average wages in machine shops from about 36s. per week to about 26s. The employers contend that Section 7 of the National Agreement gives them the right to select and train any operatives they desire to work machines. The men reply that this is so only when no members of the union are available.

Scottish Iron Combine.—We understand that the negotiations which have been in progress for many months with a view to the amalgamation of the principal malleable iron firms in Scotland have been brought to a successful conclusion. A company will be formed, of the title of the Scottish Iron and Steel Company, with a capital of about £1,000,000 in preference and ordinary shares, to acquire as from January 1st last the undertaking of the following 13 firms, which operate 15 works, having a combined output of about 250,000 tons per annum: Archibald Baird & Son; Downs & Jardine; Thomas Ellis; the Glencairn Iron and Steel Company; C. F. Maclaren & Co.; Hugh Martin & Sons; A. & T. Miller; John Shearer, Coatbridge; William Tudhope & Son; the Victoria Iron and Steel Company; the Waverley Iron and Steel Company; Wyle & Co.; and the Woodside Steel and Iron Company. Some half-dozen other firms engaged in the manufacture of malleable iron remain outside of the combine, as it has been impossible to include them owing to the fact that the production of bars, &c., forms only a branch of their business.

Launch of a Self-trimming Collier.—At the shipyard of Messrs. W. Doxford & Sons, Ltd., Pallion, on Thursday of last week, the "Herman Sauber," a specially-designed self trimming collier, with mechanical discharge, was launched. The vessel is 315ft. long by 43½ft. broad and 23ft. deep, and carries 3,750 tons on 18ft. draught. She has been fitted with triple-expansion engines and boilers by Messrs. Doxford, and has been designed for a speed of 10 knots. There are nine hatches, 33ft. wide and 16ft. fore and aft, leaving a minimum of deck space and allowing of the whole of the cargo being teemed and self-trimmed. The chief point in the vessel's design is the discharging gear, and the construction is such that the cargo can be discharged at the rate of 800 tons per hour, or allowing for barge changing, at 600 tons per hour, and the whole cargo can be finished in six hours, employing only six men. The economy in labour and time is seen by a comparison with the record for similar work by the most modern colliers with derricks and winches, which is about 300 tons per hour with 112 men. The steamer has been built to the order of Messrs. Sauber Bros., of Hamburg, and will run in their Hamburg trade.

Swedish Iron Industry.—A recent report by H.M. Consul at Stockholm contains some particulars of the Swedish iron industry in 1911. It stated that in the last quarter of the year 96 blast furnaces, 212 hearths, 18 Bessemer and 52 open-hearth furnaces were in operation. The production in the year was as follows, the figures for 1910 being added for purposes of comparison:—

	1910	1911.
	Tons.	Tons.
Pig iron	604,300	633,800
Blooms	150,500	146,700
Bessemer steel ingots	97,900	93,800
Open-hearth steel ingots	370,700	364,400

It was stated at a meeting of the Swedish Ironmasters' Association, held at the end of January, that the results for the year 1911 were less satisfactory than those for 1910, except as regards the exportation of pig iron. Production was hampered by lack of water in some districts. The output and exportation of pig iron very much exceeded those in any previous year; the exports of this product have doubled in less than 10 years. Prices during 1911 were steady; production and consumption kept, on the whole, about level.

Circuit Breakers for Continuous Current.—Messrs. Dick, Kerr, and Co., Ltd., Abchurch Yard, Cannon Street, London, E.C., send us a descriptive catalogue and price list of their circuit breakers for continuous current, the chief feature of which is the blow out wherein provision is made for the protection of the solenoid. The coil is placed in a casing of copper or other non-magnetic material and can thus be brought directly into the sweep of the arc. The external magnetic field created round the shield of non-magnetic metal attracts the arc to the shield and divides it in two, one arc going from the contact piece to the shield and the other from the shield to the finger. These two arcs travel rapidly in opposite directions on the copper shield and finally become united again in the air but around the coil and shield; the arc at this stage has become attenuated to such an extent as to rupture, and may in fact be ruptured long before it has actually encircled the blow out device. This circuit breaker has been in use for several years, and its success and popularity is evidenced by the large number of repeat orders obtained from power users. The same firm also send us a pamphlet giving an illustrated and interesting description of the scheme of electric traction carried out by them some years ago on the Liverpool-Southport line of the L. & Y. Railway.

Beyer, Peacock, & Co.—Sir Vincent Caillard, presiding at the annual general meeting of shareholders of Beyer, Peacock, & Co. at Westminster on Friday last, said the past year was one of great difficulty by reason of the widespread labour unrest which obtained during pretty well the whole period. Their own establishment did not escape, their workshops being closed during virtually the whole of August in consequence of a strike of a section of workmen. English demands for locomotives were of course always small, but he thought economies might be effected on all English railways by putting their work out to tender, as did most railway companies in other countries. As to the foreign market, it had been almost monotonous in its depression. Taking it as a whole, he could not see that 1911 showed any real improvement over 1910, which was the worst trade year they had known since 1902. After pointing out that they were keeping up the efficiency of the works and that they had written down the discarded electrical machinery to less than its value, the Chairman said he believed the shareholders would agree with the directors' decision to apply a proportion of the reserves to secure a distribution of 5 per cent. With regard to the prospects, no one could possibly foresee what might be the duration of the calamitous coal strike which had now begun. Further, their expenses were bound to go up owing to such measures as the Old Age Pensions and Insurance Acts. At the same time if trade revived they could hold their own. They had also the possibility, he would almost say probability, of a branch of prosperity all their own in the Garrett locomotive, the type of articulated locomotive to which he alluded last year, and of which they had the sole rights. He believed it was destined to supersede most existing types of articulated engines.

Flux for Welding Aluminium.—To obtain good results in welding aluminium by the oxy-acetylene blowpipe, it is necessary to use a flux on the portions to be welded. A flux for this purpose, which is claimed to give good results, has been patented by the Aktien Gesellschaft für Autogene Schweissung, of Zurich, Switzerland, comprising potassium chloride 60 parts, cryolite 6 parts, calcium chloride 30 parts. The quantities may, if desired, be varied, those given being for ordinary work. The best results are obtained by melting the whole together and then pulverising before using on the aluminium. This will give a homogeneous mass of the flux which will melt more evenly. By the use of this flux the metal is protected from oxidation when melted by the blowpipe flame, while it also serves to dissolve the oxide formed on the surface of the molten metal.

Electro-technical Laboratory at Manchester University.—On Friday last the new extensions to the physical and electro-technical laboratories of the University were opened by Dr. Arthur Schuster, F.R.S. The main buildings of these laboratories were opened by Lord Rayleigh on June 24th, 1900, but the increasing number of students and greater amount of research work, especially in connection with radio-active substances, which requires a certain amount of isolation, had made increased accommodation necessary. The extension consists of two wings on the north and west sides of the dynamo-house. The ground floor, together with the existing dynamo-house, is devoted solely to electro-technical work, the electro-chemical work being carried on in its old quarters. The first floor of the west wing includes a large lecture-room and auxiliary accommodation, whilst the corresponding floor of the north wing at present accommodates a number of small research rooms, intended mainly for Prof. Rutherford's searchers in the field of radio-activity. The equipment of the electrical engineering department, under Dr. Beattie, has ensured every need of the student being considered and, within the limitations of space and finance, met.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1910.

Change speed gearing. Tardy, Fisher, & Tardy and Thurdin, Ltd. 24974.

Compressed gas motors. Julius Pintsch Akt. Ges. 26192.

Apparatus for heating and filtering boiler feed water. Morison. 26482.

End plates of cylindrical boilers. Annie Allsopp. 28701.

1911.

Low pressure steam heating systems. Wierz. 3252.

Apparatus for blowing off boiler mud and slime. Fonó. 3513.

Starting apparatus for internal combustion engines. Hodgson. 3538.

Cementation and annealing furnaces. Graddon & Blumenau. 3628.

Internal combustion engines. Wolseley Tool and Motor car Company, Ltd., Remington, and Rowledge. 3892.

Apparatus for heating buildings. Lees, Lees, and Lees. 3923.

Engine valve mechanism. Trefois. 4092.

Carburetters for internal combustion engines. Owers. 4246.

Smoke preventer and fuel economiser. Storey Smoke Consumer and Fuel Economiser Company. 4415.

Rotary pumps. Lean. 5487.

Apparatus for generating gas from liquid fuel. Dumontier. 5989.

Steam engines. McNeil, McNeil, and McNeil. 6018.

Sand-blasting machines. Kenyon. 7411.

Regulating means for steam engines. Karlin. 8419.

Sand moulding machines. Soc. Anonyme des Etablissements Ph. Bonvillain and E. Ronceray. 8817

Valve gear of internal combustion and steam engines. Johnston and Womersley. 8859.

Two stroke cycle internal combustion engines. Sangster. 8878.

Process and apparatus for coating objects with fluid metal. Ostermann. 9034.

Variable speed mechanism. Richards. 9221.

Variable speed gearing. Wise. 9882.

Pipe couplings. Albert. 10120.

Method of producing hollow or tubular ingots. Bury's & Co. and Brown. 10201.

Explosion pumps. Siemens Schuckertwerke Ges. 11450.

Bearing for shafts. Robertson. 11583.

Smokeless combustion of fuel in the furnaces of steam boilers. Papa Federoff & Scortecelletti. 13201.

Valve gear for steam engines. Stumpf. 14928.

Furnaces. Wilton. 15459.

Lathes. Benson and W. A. S. Benson & Co. 15665.

Chain or travelling grates. Wood. 15737.

Governing mechanism for elastic fluid turbines. Vereinigte Dampfturbinen Ges. 17781.

Propulsion of boats and ships. Oppenheimer. 17911.

Brakes for railway vehicles. Van Waeyenbergh. 18318.

Variable speed gearings. Wetherell. 18460.

Automatic car-couplers. Willison. 18461.

Two stroke cycle internal combustion engines. Wells. 18803.

Micrometer gauges. Smith. 19040.

Ships' derricks. Clare. 19549.

Chucking mechanism. Robertson. 19575.

Journal bearings. Perkins. 19733.

Processes of making castings for steam turbine wheels. Hopson and Rearick. 20557.

Precipitating coal dust in mines. Cremer. 21083.

Adjustable joint or coupling for transmission gearing. Burnand. 21765.

Locking devices for nuts. Prince. 22913.

Combustion chambers for gas turbines. Blaisdell. 22928.

Fluid pressure brake apparatus. Soc. Anon. Westinghouse 23514.

Appartus for feeding or suppying liquid fuel to internal combustion motors. Soc. Jules Gronville, H. Arquembourg, et Cie 23681.

Jacks operated by compressed air. Barbey. 23831.

Fluid pressure braking apparatus. Turner. 26157.

Couplings for shafts. Clark and Deasy Motor car Manufacturing Company. 28147

ELECTRICAL, 1911.

Electrical heating apparatus. Berry. 1071

Electric controllers for lifts. Easton Lift Company and Huggett 3258

Underground electric cable troughing. Thomas. 3446.

Electric incandescent lamps. Royer. 3541.

Holders for electric lamps. Cottam. 5594.

Spark generator for wireless telegraphy. Walker. 7582.

Storage battery plates. Lake. 8821.

Electrically insulated fish joints for railway rails. W. R. Sykes Interlocking Signal Company and Sykes. 11711.

Automatic starting devices for electric motors. Haddan. 12587.

Metallic armouring for insulated electric cables. Howard. 13750.

Electric incandescent lamp. Schaller. 16195.

Speed regulation of dynamos. Pieper. 17675.

Apparatus for shaping filaments for electric lamps. Suman. 19047.

Single phase commutator motors. British Thomson Houston Company. 20829.

Sparking plugs for internal combustion engines. Robert Bosch. 20899.

Common battery telephone systems. Aktiebolaget L. M. Erriesson and Co. 23823.

Cables for electric current distributing systems. Merz & Hunter. 26857.

Telephonic transmitters. Marchant. 29195.

METAL QUOTATIONS.

TUESDAY, MARCH 5TH.

Aluminium ingot	65/- per cwt.
„ wire, according to sizes, &c. ......from	102/- „
„ sheets „ „ ...... „	120/- „
Antimony .... £27/-/- to	£27/10/- per ton
Brass, rolled	7¾d. per lb.
„ tubes (brazed)	9⅞d. „
„ „ (solid drawn)	8d. „
„ „ wire	7¾d. „
Copper, Standard	£64/17/6 per ton.
Iron, Cleveland	49/9 „
„ Scotch	55/7½ „
Lead, English	£16/2/6 „
„ Foreign (soft)	£15/16/3 „
Mica (in original cases), small	6d. to 2/ per lb.
„ „ „ medium	2/6 to 4/- „
„ „ „ large	4/6 to 8/6 „
Quicksilver	£8/7/6 per bottle.
Silver	26¼d. per oz.
Spelter	£26/10/ per ton.
Tin, block	£196/5/- „
Tin plates	13/7½ „
Zinc sheets (Silesian)	£29/10/- „
„ (Stettin; Vieille Montagne)	£30/-/- „

The Institute of Metals.—The autumn meeting of the Institute of Metals will take place in London in the last week of September. The next ordinary meeting will be held on May 10th, when Sir J. A. Ewing, K.C.B., F.R.S., will lecture on "The Inner Structure of Simple Metals." The corrosion investigation recently taken up by the Institute of Metals is being actively pushed forward. The experimental condensing plant has been working continuously since January 1st, and valuable data are being accumulated. The Corrosion Committee desire also to learn the experiences of others respecting the corrosion of brass condenser tubes, and to enable information to be readily obtained the committee have prepared an enquiry form, and it is desired that a copy of this form should be in the hands of every person interested in corrosion, and that the document shou'd be answered as fully as possible. Copies may be obtained from the Institute, Caxton House, Westminster, S.W.

New British Naval Airship.—The Admiralty propose to give the order to Vickers, Ltd., for the construction of another naval airship, which will be of improved design to No. 1, which was wrecked at Barrow some months ago as she was being hauled out of the airshed in Cavendish Dock. The designs of the new dirigible have been adopted on the experience the Admiralty and Vickers, Ltd., had in the building of the first dirigible. The first ship was built of dularium, a patent metal produced at Birmingham by Vickers, Ltd., and the second airship will also be built of this metal, which is as light as aluminium and as strong as steel.

The Mechanical Engineer

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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

Curious Explosion of a Devulcaniser.

The official Board of Trade Report (No. 2,068) on an explosion arising in a very curious way from the failure of a steam-jacketed vessel used as a devulcaniser,* has just been issued. The circumstances under which the failure occurred are interesting and instructive to those who use vessels of this kind, and as they could hardly have been foreseen by the engineers who designed the vessel, it may be well to recount them for the benefit of others. The vessel consisted of a cylinder about 18ft. 6in. in length, with a diameter of 5ft. 6in. at the centre, tapering to about 5ft. at the extremities, which were fitted with dished ends resting on two trunnions. Surrounding this cylinder was an outer steam jacket, about 6ft. 2in. diam. The general construction of the apparatus, which was used for digesting refuse rubber articles, such as motor tyres, &c., with heated caustic soda, in order to dissolve the canvas or other organic materials and recover the old rubber, will be readily seen from the illustration on page 315. The charge of material was placed in the internal vessel and heated by the steam which was admitted to the external jacket. This steam was supplied from boilers working at a pressure of 160lbs. on the inch, and hence the pressure of any water vapour in the internal vessel could not exceed that corresponding to the steam pressure in the jacket, and as this had been tested hydraulically to 300lbs. on the inch before the vessel was put to work there would appear to have been no possibility of explosion, and the forcing out of one of the dished ends, therefore, at the working pressure of 160lbs. appeared at first sight inexplicable, especially as no defects could be found either in materials or workmanship. In fact, before the accident any engineer examining the structure would have been inclined to consider failure from excessive pressure as practically impossible. The puzzle was how came it about that the dished end plate of the internal cylinder was forced out, as calculation showed it clearly must have been, by excessive pressure? Like most mysteries in connection with boiler

* For account of Formal Inquiry see our issue for Dec. 13th, page 745.

failures, it disappeared under searching investigation, and the explanation, when discovered, proved to be as simple as it was extraordinary. The object of the apparatus, as we have stated, was to digest old rubber articles, and it appears that under the action of caustic soda and heat such material swells considerably, and further, that the attendants had overcharged the vessel, with the result that when steam was turned into the jacket the heat produced not only a vapour pressure corresponding to the temperature of the jacket steam, but a hydrostatic pressure due to the swelling of the contents. This was so great that one of the dished ends sheared the double row of circumferential rivets uniting it to the cylinder, with the result that the scalding caustic contents escaped and caused the death of one man and serious injury to another. The engineers at the enquiry all agreed that the pressure of 160lbs. was quite inadequate to cause the end plate to fail in the way it did, and that a hydrostatic pressure developed in the manner described was the sole cause of the disaster. This, as we have stated, occurred in a way that could hardly have been foreseen, and the Board of Trade Commissioners under the circumstances held that neither the owners nor their engineers responsible for the working of the vessel were to blame. The question that gave rise to a good deal of discussion at the enquiry was what kind of safety apparatus could be devised which would render a repetition of such an occurrence impossible; and, having regard to the nature of the contents, it was easier to put the question than to answer it. An inspection of the design will show that it would not be easy to attach a safety valve of a size that would be any use, since it could only be applied to the end of the trunnion shaft with a stuffing-box connection, and that the passage to the valve would be very liable to become choked, which would destroy its automatic character. The material, it will be seen, was placed in the internal vessel through a manhole in the outer cylinder, and the best safeguard would appear to be to so arrange matters that the manhole could never be used when in its top position: in other words, the material could only be put through the manhole when it was a little on one side, so that the vessel could never be quite filled. Of course, the personal element still comes into play, and with stupid men and inefficient supervision mistakes are always liable, though the publication of the facts relating to this failure will, it is to be trusted, prevent a recurrence. The difficulty of dealing with such an apparatus by means of an ordinary safety valve was evident to the Commissioners, for while urging the desirability of some automatic safety appliance they declined to make any definite recommendation as to what form such a safety appliance should take.

Miners' Hours and Output.

AT the time of the agitation for the Miners' Eight Hours Act the argument that, apart from its disadvantages and inconveniences to miners in many cases—which experience has only too truly confirmed—it would lead to diminished output and hence increase in price, was met by the assertion that the shorter hours would permit of greater intensity of work, and that this, coupled with greater efficiency of management, would prevent any diminution of output. Unfortunately official statistics have not supported this sanguine contention. The figures available show that the average production of miners in the United Kingdom has been declining for some time, and in view of the present troubles and demands on the part of miners the figures are interesting and instructive. In 1907 the individual production from the coal mines was about 294 tons per person, a quantity which has fallen year by year until in 1911 it was only 259 tons per person. It is true that during this period the total production has been increased, but this has been the result of the greater number of miners employed, the increase for the past year being nearly 18,000. It is needless to say that the diminished production per individual would increase the cost per ton if wages remained stationary, but as we know wages have also been greatly increased during recent years. There appears very little probability of coal ever falling again to the prices that ruled some years ago, and it manifestly cannot continue advancing as it has done without jeopardising other industries. If wages are not to be sacrificed, then the only remedy is increased output, which must be effected either by greater individual effort, the wider adoption of mechanical appliances, or more efficient organisation.

Dangers of Gas Lighting on Trains.

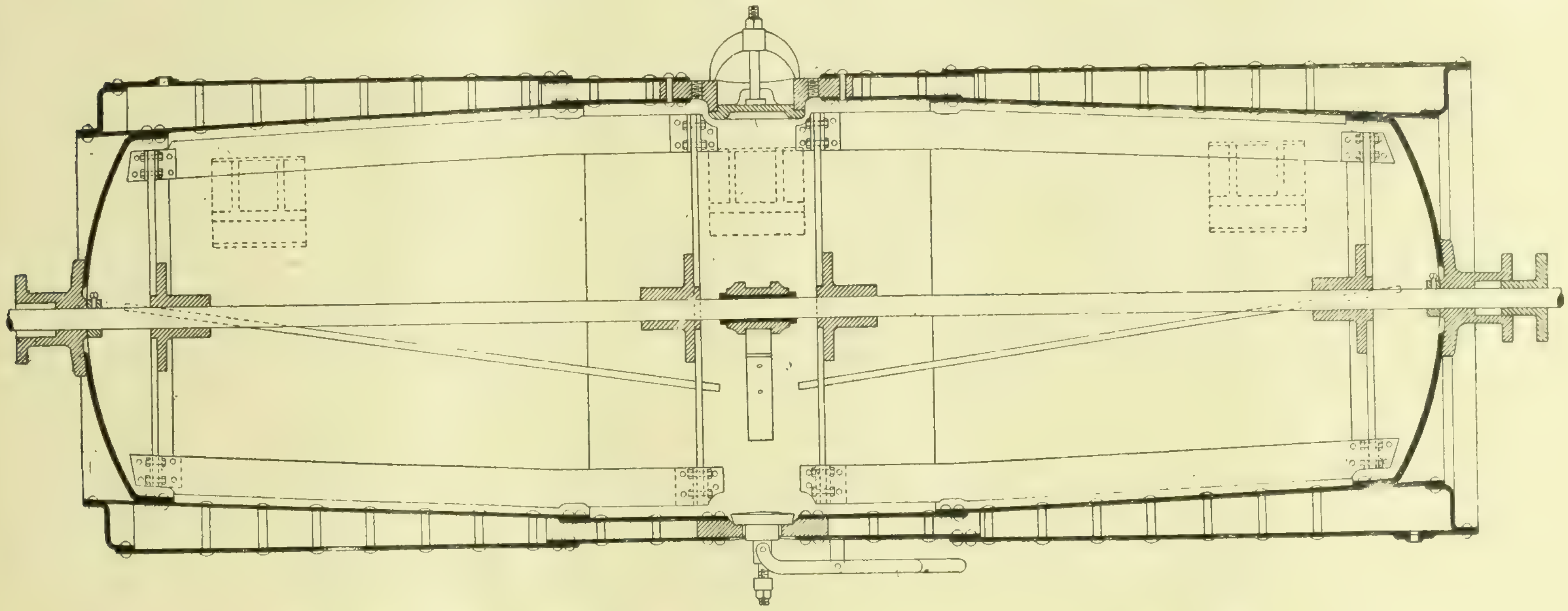
OUR readers will be able to recall the awful railway disaster which occurred at Hawes Junction, the horrors of which were intensified by the burning of the wreckage through the ignition of the lighting gas escaping from the damaged storage cylinders. Another railway accident just reported on by Major Pringle illustrates again how the consequences of a collision may be aggravated in this way. In this case a train from Walsall to Birmingham was stopped by a signal, when a following train ran into it. Although no one was killed, 21 passengers were injured, and, as in the Hawes case, two gas cylinders carried under the floor of a carriage were perforated and set on fire. Fortunately, in this instance a number of men from an adjoining goods yard were quickly on the spot, and as water was available and there was no wind to fan the flames, the fire was extinguished before it got any serious hold, but the case contained the latent elements of serious disaster, and, as Major Pringle remarks, clearly points to the desirability of either abandoning the use of gas for lighting purposes on trains or of making such structural alterations and additions as will lessen the liability of fire.

Railway Electrification.—The London and South-western Railway have decided to electrify a portion of their suburban lines. The company have decided on the overhead system of electrification, which has proved so successful on the Victoria-Crystal Palace branch of the London, Brighton, and South Coast Railway, and the work will be proceeded with almost immediately.

Application of the Microscope to the Examination of Metals.—A paper on this subject was read by Prof. A. Campion at a recent meeting of the Glasgow Microscopical Society. He spoke of the great advance which had been made in this branch of metallurgy in recent years, and stated that by the use of the microscope many things hitherto looked upon as mysteries had been explained clearly. For determining the constitution of metals, the cause and cure of its "diseases," and the mode of growth of its crystals, the microscope was now held to be one of the principal agents in metallurgical research. Prof. Campion exhibited a large number of photomicrographic lantern slides to demonstrate the constitution of various metals and to show the numerous structures and inclusions which give rise to defects in the metal, dividing these into three main groups—viz., chemical, mechanical, and thermal. Of the first class numerous slides were shown of fractures caused by the presence of sulphide of iron, sulphide of manganese, and silicate of iron. As examples of mechanical defects slides showing fractures caused by the inclusion of scale, by the segregation of carbide of iron, and by quenching were shown, while the effects of heating and cooling on various metals were illustrated and explained. Diagrams of the solidification of metals were also explained by Prof. Campion.

THE OIL-ENGINED LINER "SELANDIA."

THE performance of the liner "Selandia," fitted with Diesel engines, will be looked forward to with interest by marine engineers. The vessel, which has been built and engined by Messrs. Burmeister & Wain, of Copenhagen, for the East Asiatic Company, has a length of 370ft., a beam of 53ft., and a gross tonnage of 4,964 tons, and is the largest vessel that has so far been equipped with oil engines. The main engines consist of two sets of 4-cycle Diesel motors, each with eight cylinders 20·8in. by 28·7in., giving together 2,500 i.h.p. at 140 revs. per minute. The cam shaft, which actuates the valves, is driven at half the engine speed through a small spur wheel on the crank shaft, which gears into a larger wheel mounted on an intermediate shaft. This latter, by means of cranks and connecting rods, drives a second shaft placed higher up, which in turn by gearing works the cam shaft. For each cylinder there are two sets of four cams, and according as one or other of these sets is in contact with the valve rods the direction of the motion is ahead or astern. Reversing from full speed ahead to full speed astern can be accomplished in less than 20 seconds. Compressed air, at a pressure of 300lbs. per square inch, is used for starting the engines. The oil is forced into the cylinders at a pressure of about 900lbs. per square inch by a pair of pumps placed above the starting lever, each pump serving four cylinders. Should the speed of the engine become excessive, the oil is cut off from the cylinders by means of an Aspinall governor. There are two 3-stage compressors for furnishing the necessary compressed air. These are driven by two auxiliary Diesel engines, having four cylinders and developing 250 h.p. at 230 revs. per minute. The compressors deliver the air at a pressure of 300lbs. per square inch, which is stored in four large cylindrical tanks. For injecting the fuel air is taken from these and raised to 900lbs. pressure by compressors driven from the crank shafts of the main engines. For emergency purposes an independently-driven Reavell compressor is provided. The two auxiliary Diesel engines, in addition to driving the air compressors, each work a dynamo for lighting and auxiliary purposes. The "Jutlandia," a sister ship to the "Selandia," is nearing completion at the Clyde yard of Messrs. Barclay, Curle, & Co., whilst a third is under construction by Messrs. Burmeister & Wain.



CURIOUS EXPLOSION OF A DEVULCANISER.—LONGITUDINAL SECTION OF DEVULCANISER. (See page 313).

INSTITUTION OF NAVAL ARCHITECTS.

MEETINGS of this Institution will be held in the Hall of the Royal Society of Arts, John Street, Adelphi (by kind permission of the Council), on Wednesday, March 27th, and the following two days. On the Wednesday morning, the President will deliver his inaugural address, after which the Institution gold medals and premiums will be presented. The following papers will then be read and discussed: (1) "Some Military Principles which bear on Warship Design," by Admiral Sir Reginald Custance; (2) "On Turning Circles," by Prof. W. Hovgaard; (3) "The Law of Comparison for Surface Friction and Eddy-making Resistances in Fluids," by T. E. Stanton; (4) "Description of the William Froude National Tank (Part II.)," by G. S. Baker. In the evening the annual dinner will be held. On Thursday the following papers are down for reading and discussion: (5) "Results of Trials of the Diesel-Engined Sea-going Vessel 'Selandia,'" by W. I. Knudson; (6) "Gas Power for Ship Propulsion," by A. C. Holzapfel; (7) "The Effect of Bilge Keels on the Rolling of Lightships," by George Idle and G. S. Baker; (8) "Results of Calculations Regarding the Effect of an Internal Free Fluid upon the Initial Stability and the Stability at large angles in Ships of various forms," by A. Cannon; (9) "On the Solignac-Grille Boiler and its Application in French Channel Steamers," by G. Hart; (10) "Results of Experiments on Water-tube Boilers, with Special References to Superheating," by Harold E. Yarrow. On Friday, the following papers will be read and discussed: (11) "Geared Turbine Channel Steamers 'Normannia' and 'Hantonia,'" by Prof. J. H. Biles; (12) "Performance on Service of the Channel Steamer 'Newhaven,'" by P. Sigaudy; (13) "On the Measurement and Automatic Recording of Dead Reckoning," by F. R. S. Bircham; (14) "Description of a Tide Indicator," by Commander G. J. Baugh; (15) "The Arrangement of Boat Installations on Modern Ships," by A. Welin; (16) "Torsional Vibrations of Elastic Shafts of any Cross Section and Mass Distribution and their Application to the Vibration of Ships," by Dr. L. Gumbel; (17) "Load Extension Diagrams obtained Photographically with an Automatic Self-contained Optical Load-extension Indicator," by Prof. W. E. Dalby.

Some Features of the West African Government Railways.—In the course of a paper on this subject, read by Mr. F. Shelford, B.Sc., M.Inst.C.E., before the Institution of Civil Engineers, the author gave a brief history of railway construction in the West African Colonies of Sierra Leone, Gold Coast, Southern Nigeria, and Northern Nigeria, and dealt in detail with the methods of surveying and the difficulties met with in the clearing of forests. The method of constructing earthworks was also dealt with, and the forms of pipes and culverts found most suitable for these tropical railways were referred to. Particulars of about forty of the more important bridges were given in tabular form, with general remarks upon the methods of erection employed. The types of structures adopted for terminal and wayside stations, workshops, engine-sheds, coal stores, carriage sheds, wagon-repair shops, stores, bungalows, quarters, water tanks, &c., were mentioned, and the permanent way and system of signalling described. Details were given of the various classes of locomotives supplied to each railway, with their principal dimensions. The rolling stock for both passengers and goods, and its equipment, was also noticed briefly. The paper concluded with particulars of the costs of construction and the results of working in the case of each colony.

THE BALANCING OF LOCOMOTIVES.—IV.

BY JAS. DUNLOP.

Minimum Weight Balancing.

Arithmetical calculations, whether performed in the usual manner or by means of the proportional scale, give exact results, but they have the disadvantage that it is only by means of a long series of trial and error calculations the resultant weights for varying proportions of inside to outside

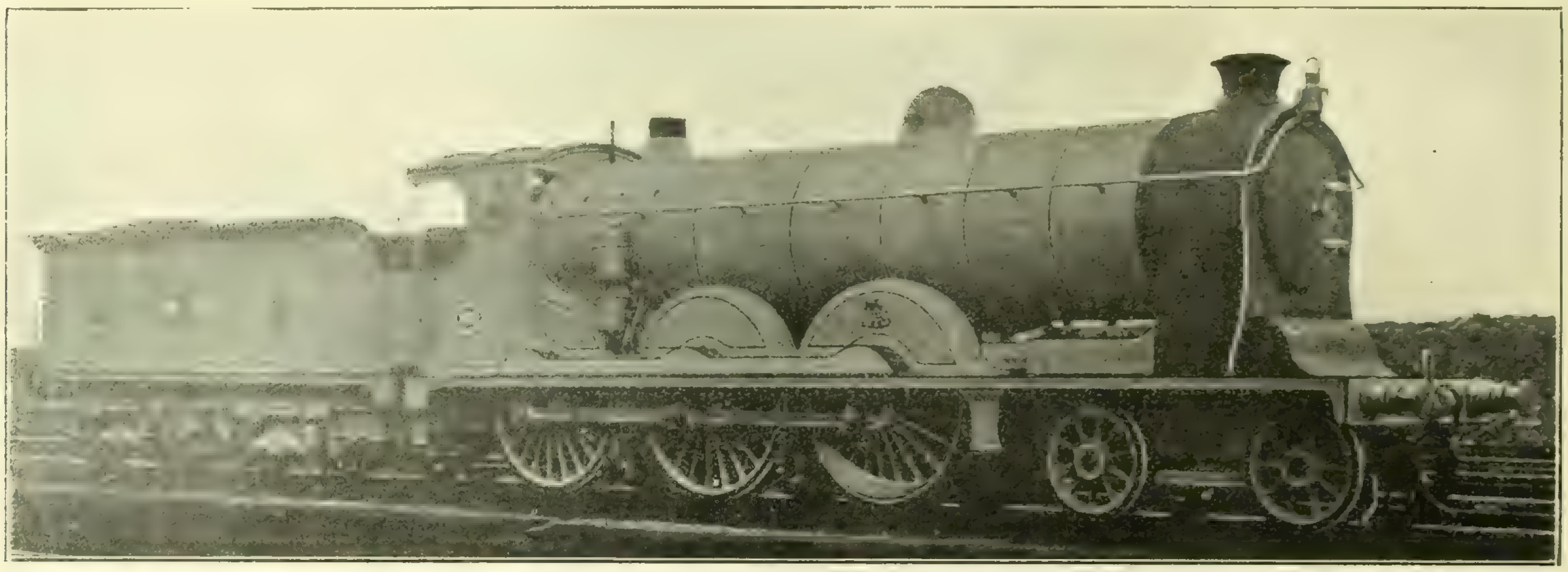


Fig. 33. Caledonian Railway. Inside 2-Cylinder Locomotive. Heaviest of its Type.

parts can be ascertained for an inside cylinder-coupled driver engine. When the wheel loads of such an engine are in the neighbourhood of the maximum permissible over a given road it becomes a serious question whether any reduction can be made in the amount of balance weight used without sacrificing anything in the quality of the balance effected. By the usual arithmetical rules of balancing there is only one answer to such a question and it is a distinct negative. Fortunately, however, graphical methods are capable of demonstrating clearly the means by which it is possible to effect a considerable reduction in the amount of balance weight used on all inside cylinder-coupled driver engines without sacrificing anything in the quality of the balance and without affecting the running qualities of the engines in any way. Fig. 33 illustrates an engine running on the Caledonian Railway which is probably the heaviest engine of this type running in this country. From the illustration it will be recognised, by noting the balance weight position, that the leading coupled wheels are the driving wheels and that the balance weights are of considerable magnitude. Assuming, as is no doubt the case, that a reduction of the weight in the wheels of this engine is a desideratum, it is necessary to examine the cross-section drawing of the engine. This is illustrated in Fig. 34 and in the same manner as already described in the case of Fig. 26 has the balance weights for the inside and outside parts shown by C F, C G and C E, C H respectively. On each side of the engine these weights are combined in one, viz., E F and G H, the combination being that for equal weights of inside and outside parts, and the coupling cranks set as usual at 180° apart from the inside cranks on either side. From the relative positions of C G and C H it will be understood that the shortest line that can be drawn between them (in any proportion) is one at right angles to C H through G, viz., G J as shown. That is to say, the least amount of balance weight it is possible to use without affecting the balance of the engine is G J, but that is only possible if the weight of the outside parts are reduced by the amount K D ascertained by drawing J K at 45°, C D representing, as in all these diagrams, the original weight of the parts. Any further reduction in the weight of the outside parts would require a greater balance weight, as will be plainly evident by assuming them reduced to zero, C G then being the amount of the balance weight. There is, however, a very simple means of making the balance weight considerably less than G J even, without a reduction in the weight of the outside parts at all.

If the coupling cranks in the wheels, instead of being set at 180° apart from the inside cranks on either side and consequently making an angle of 90° between each other, are set at only 60° apart from each other as indicated by the small circles at L and M, then the balancing of the engine may be effected by a minimum of balance weight. That there is no

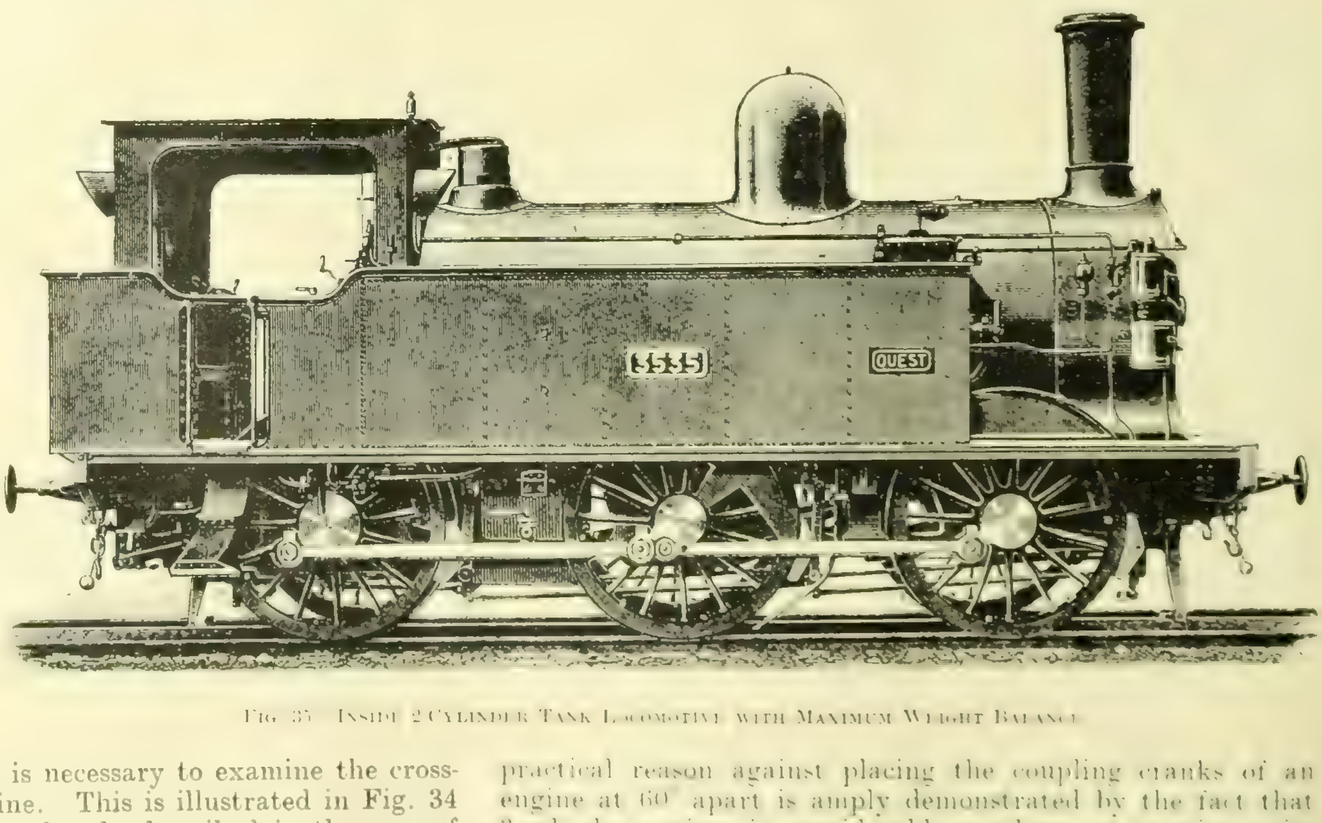


Fig. 35. Inside 2-Cylinder Tank Locomotive with Maximum Weight Balance.

practical reason against placing the coupling cranks of an engine at 60° apart is amply demonstrated by the fact that 3-cylinder engines in considerable numbers are running quite satisfactorily in this country with their coupling cranks set at 120° apart. So far as the effective operation of the coupling rods is concerned there is no difference between 60° and 120° of an angle between the cranks. Consequently a convincing demonstration that, by placing the cranks at 60° apart, a

very considerable reduction in the amount of balance weight necessary for any given engine can be effected, will no doubt be appreciated by many locomotive engineers, although an unfamiliar graphic method happens to be the medium of the demonstration.

Produce the crank line C M through C to O, making C O equal to C D, also along C M set off C P equal to the distance between the coupling rod and balance weight centres. From O and P draw lines O S and P R parallel to C L. Draw C R at an angle of 45°, *i.e.*, parallel to E F, cutting P R in R. Through R draw R S parallel to CO, cutting OS in S. Join C S, then if C O (equal to C D) represents to any scale the weight of the outside parts to be balanced, C S represents to the same scale the amount and the position of the necessary balance weight relative to the position C M of the crank. It will be noticed C S falls almost exactly in line with C G, consequently an amount C T equal to C G has to be subtracted from C S, leaving as the actual amount of the balance weight for equal inside and outside parts the length S T, which it is very evident is much less than G H, this latter being the weight necessary when the cranks are set at 90° apart, as previously mentioned. S T it will also be noticed is much less than G J, which latter is the minimum amount of balance weight it is possible to use when the cranks are set at 90° apart, and it is to be most particularly noted that when the cranks are set at 60° apart no balance weight whatever is necessary when the outside parts are less than the inside parts in weight in the ratio of C T to C S, the position and amount of the outside parts under these circumstances providing exactly for the balance required. When, as in the case of cranks at 90°, the outside parts equal C K, represented by C V, the corresponding balance weight is C W and the resultant weight is G X, which is very much less than G J which was the previous resultant weight for similar conditions. These results should form conclusive proof enough to convince anyone that superfluous weight need not be used in balancing this type of engine.

It may be easily enough perceived that this system of minimum weight balancing depends on the fact that the angle between the balance weights for inside parts is quite independent of the weight of these parts and depends only on the distance between the centres of the cylinders. In standard gauge engines of this type any differences between centres of cylinders or centres of coupling rods are so slight that in most cases the balance weights for inside and outside parts will make no departure from a straight line greater than 2°. In placing this system of balancing before the notice of locomotive engineers the writer is of opinion that their further investigation of it will in many cases prove to be of some considerable value to themselves and their engines.

Maximum Weight Balancing.—Although the practice of placing the coupling cranks at an angle of 180° from the inside cranks on either side of the engine is now probably universal, it was not always so. Fig. 35 illustrates an inside cylinder 6-coupled tank engine on the Western Railway of France in which the position and magnitude of the balance weight in the driving wheels indicates a considerable difference from usual practice. The explanation lies in the fact that the coupling cranks are placed on coincident centres with the inside cranks on either side of the engine. During the time the late Mr. Wm. Stroudley was locomotive superintendent of the London, Brighton, and South Coast Railway the whole of the engines on that line had their coupling cranks set in that way, the object in doing so being to reduce the pressures between axleboxes and hornblocks and in that way reduce the wear on these parts. The influence this practice had on the amount of balance weight necessary to balance the inside and outside parts may be seen in Fig. 36, which illustrates the cross-section drawing of a passenger engine on the Western Railway of France. As in previous diagrams, the balance weights for the inside and outside parts are shown by C F, C G and C E, C H respectively, but E F and G H are not the resultant balance weights in this case. These latter are found by constructing with C E and C F, also with C G and C H, the parallelograms C E J F and C G K H. Then, if C D represents to any scale equal weights of inside and outside parts, C J and C K represent to the same scale the amounts and the positions of the necessary combined balance weights. Differences in the weights of inside and outside parts alter the amounts and the angles of the resultant weights, but in each case the procedure is the same as above. A time-saving hint is that C J and C K bisect E F and G H, while at the same time E F and G H bisect C J and C K. This saves the construction of the parallelograms by those conversant with the method.

Another type of inside cylinder engine in which the balance weights necessary are unusually heavy is illustrated in Fig. 37, which shows an engine with separate coupling cranks outside the engine frames. This type of engine was originally designed for the Great Western Railway in the days when that railway was of 7ft. gauge and the practice then established to a great extent influenced the design of the

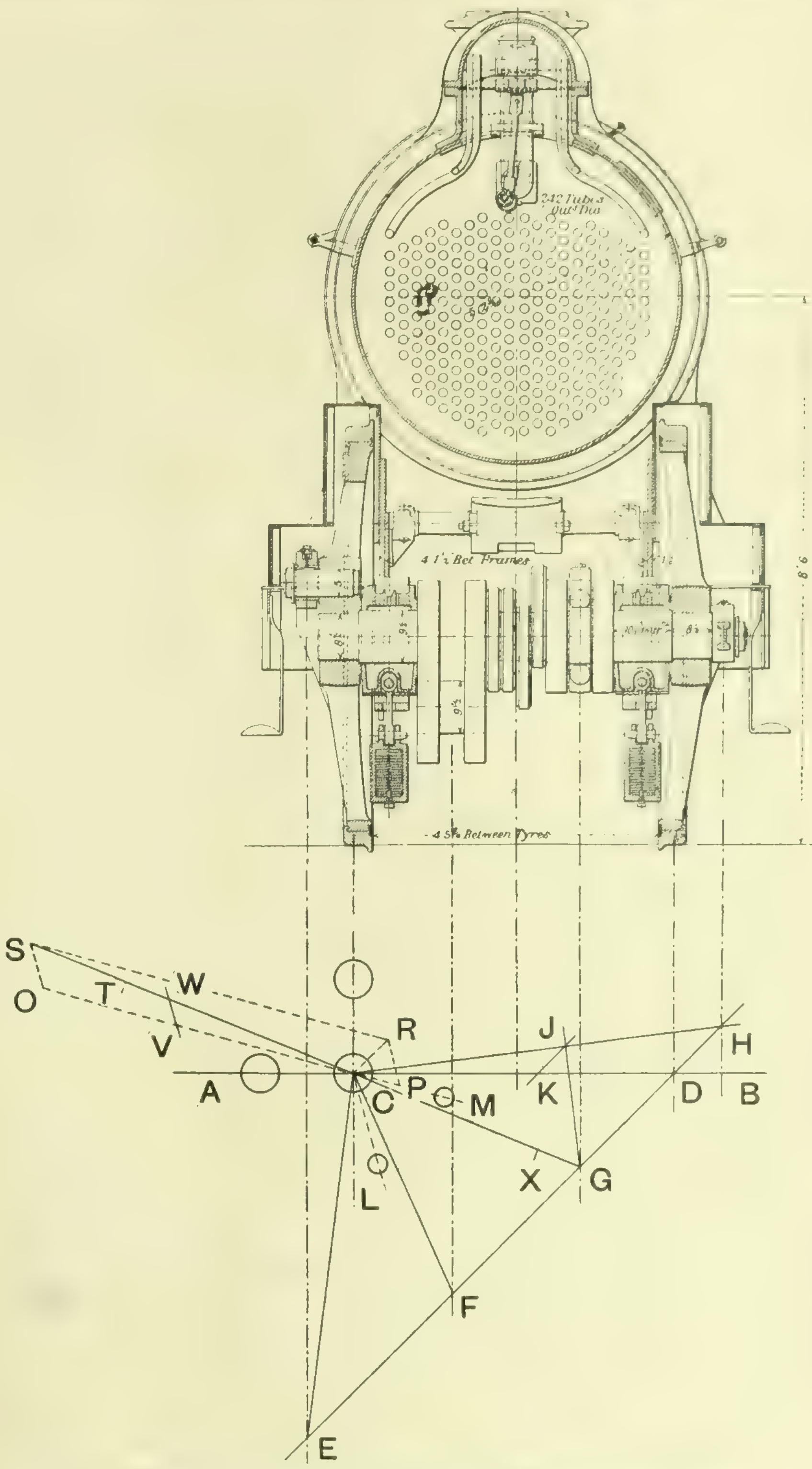


Fig. 34.—Balancing Diagram showing Ordinary and Minimum Weight Methods of Balancing.

engines used in the early days of its conversion to standard gauge. The balance weights are formed of cast-iron blocks placed between the spokes of the wheels and secured by wrought-iron plates on either side, the rivets through these plates passing through the blocks. This construction enabled trial and error methods of balancing to be conducted on each engine and is a practice probably in use at the present time.

The extent to which the separate outside cranks increased the amount of balance weight necessary compared with cranks in the wheels is illustrated by the cross-section drawing of the engine given in Fig. 38. The relation between W, the distance between the centres of gravity of the balance weights in the wheels, and the various primary and secondary weights compared with the corresponding weights in Fig. 31 will show

at a glance the reasons for the increase in the amount of balance weight. At the same time, it will be noticed the cranks require a secondary balance weight to maintain transverse balance, while cranks in the wheels require a primary weight only. The increase in weight chiefly concerns the coupled wheels, the driving-wheel weights being actually less

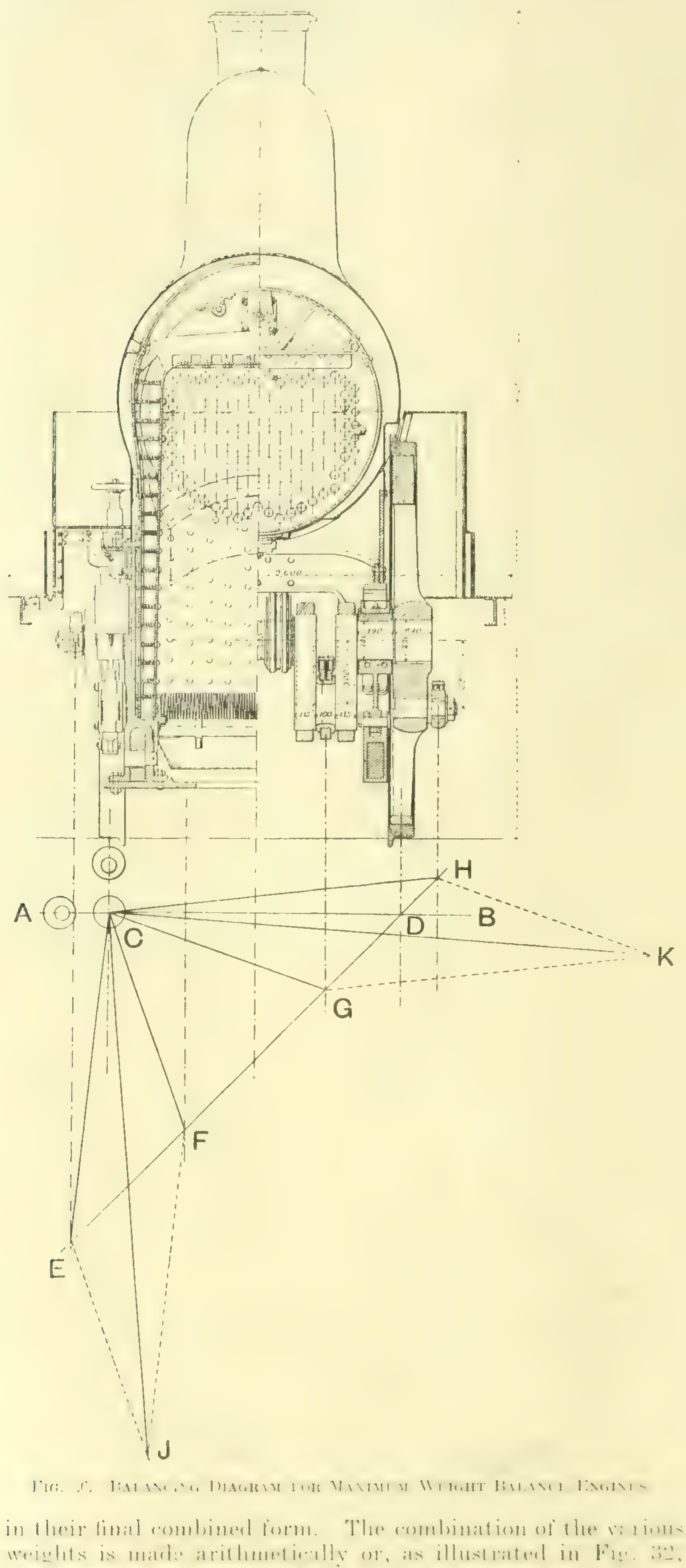


FIG. 37. BALANCING DIAGRAM FOR MAXIMUM WEIGHT BALANCE ENGINES

in their final combined form. The combination of the various weights is made arithmetically or, as illustrated in Fig. 32, according to the designer's particular preference.

To most locomotive engineers in this country the engine illustrated in Fig. 39 will, no doubt, appear crude and primative in its design and construction, and, beyond noting that the power is transmitted to the driving wheels of each bogie by bevel gears and longitudinal shafts with universal couplings, they would probably make no further investigation into the peculiarities of the engine. Were they to do so they would probably be surprised to find that this is the only type of engine in which reciprocating weights can be perfectly balanced by revolving weights and no "hammer-blow" effects whatever be experienced. As it was stated at the commencement of these articles that a reciprocating weight could only be perfectly balanced by a similar weight moving equal amounts in opposite directions in the same plane, the peculiar property of balance credited to this type of engine requires some little explanation. From the cross-section drawing of the engine illustrated in Fig. 40 it will be seen the cylinders of the engine are placed at an angle of 90° and drive on to one and the same crank pin of the longitudinal shaft that transmits the power to the bogies. From Fig. 1 of these articles it was seen that while a reciprocating weight could only produce a disturbing effect in the direction in which it was guided, the radial effect of a revolving weight could be resolved into two effects acting at right angles to each other. Now in just the same way two reciprocating weights guided at right angles to each other can and do produce a radial effect and this radial effect can at once be balanced by a revolving weight. To show that the peculiar unequal effect of the connecting rod has no influence whatever in preventing this perfect balance of two reciprocating weights by a revolving weight Fig. 41 illustrates two inertia diagrams such as given in Fig. 1 placed at right angles to each other. If along the various crank angle lines the different inertia effects of these two diagrams are plotted as one length it will be found that the various lines end at points coinciding with the circumferences of circles having for their centres the four 45° positions at which the inertia diagrams

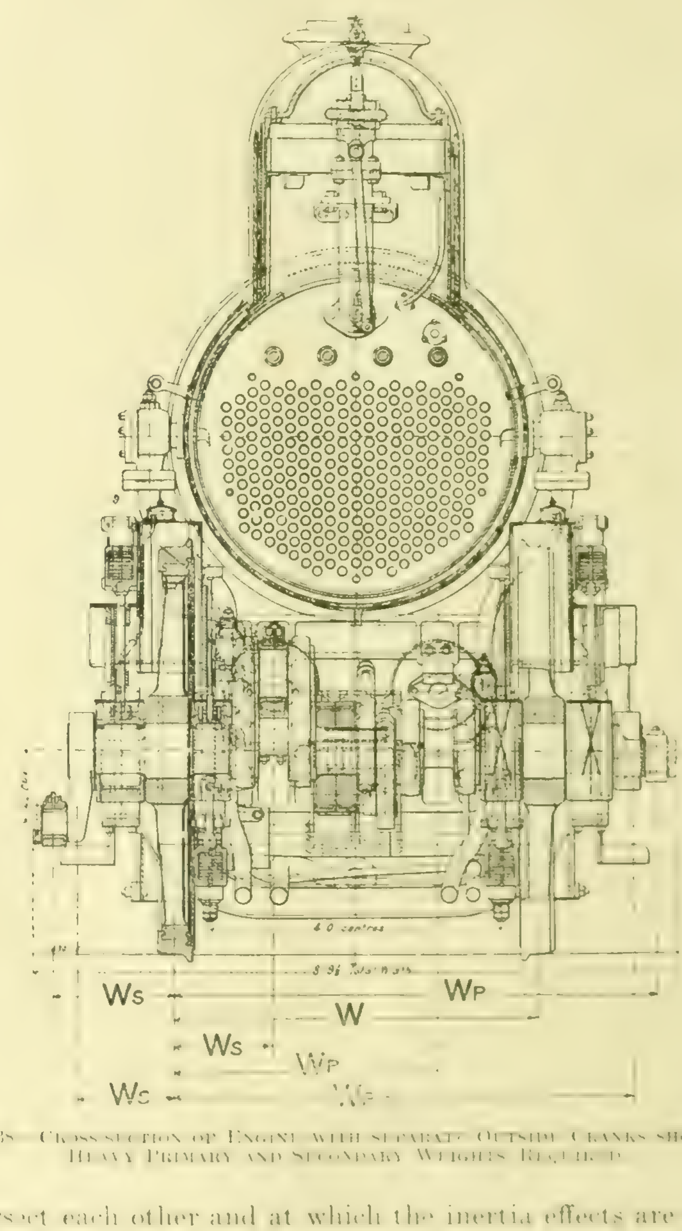


FIG. 38. CROSS-SECTION OF ENGINE WITH SEPARATE OUTSIDE CRANKS SHOWING HEAVY PRIMARY AND SECONDARY WEIGHTS REQUIRED

intersect each other and at which the inertia effects are equal to each other and to the right-angle effects of a revolving weight, as demonstrated by Fig. 1. This coincidence of radial lengths with the circumferences of the polar circles is the only proof required to demonstrate that perfect balance is attained. To prevent swaying couples the cylinders must be placed in one plane and the revolving weight divided into two and placed one opposite each crank web, as shown in Fig. 39. The amount of the weight is represented by the diameter of one of the polar circles and arithmetically is equal to the weight of one set of reciprocating parts multiplied by $\sqrt{2}$.

The conjunction of two inertia diagrams as illustrated in

Fig. 41 makes it convenient to here explain that in an ordinary type of locomotive the horizontal disturbance produced by unbalanced reciprocating parts, when measured at the longitudinal centre plane of the engine, would be exactly that of the polar circles described on A B of Fig. 41, there being no vertical disturbance due to these parts. Unbalanced revolving parts produce both horizontal and vertical disturbances, their amount in each direction being the weight of parts on one side multiplied by $\sqrt{2}$. This disturbance at the longitudinal centre plane of the engine is sometimes termed the "galloping effect," but is not to be understood as an entirely separate effect, being dependent on and entirely set up by the disturbances taking place at the motion planes on either side of the engine.

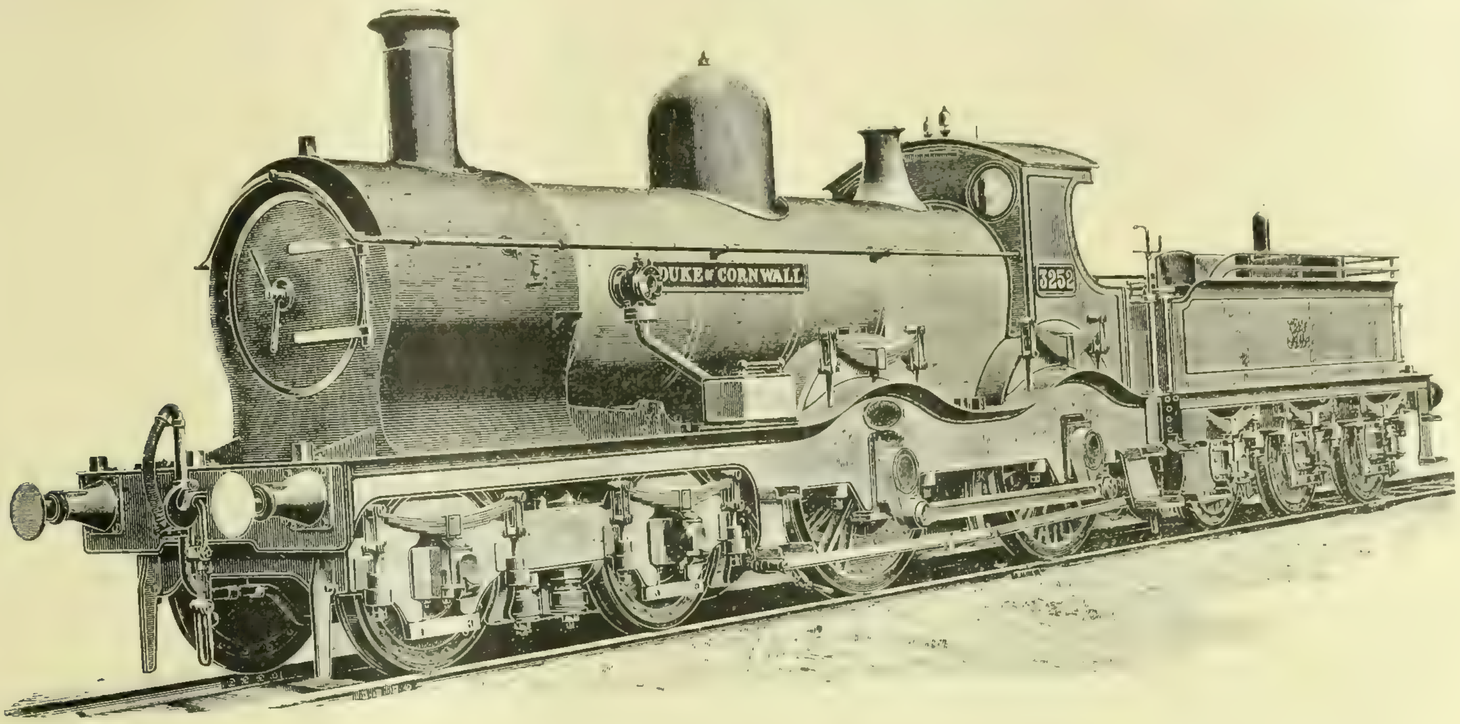


FIG. 37.—INSIDE 2-CYLINDER LOCOMOTIVE WITH SEPARATE OUTSIDE CRANKS.

It will be appropriate as a natural sequence to illustrate here an engine in which this "galloping effect" is the only disturbing effect that can be counteracted by balance weights in its wheels. This engine is illustrated in Fig. 42 and is remarkable in many respects. In the first place, it has only one line of wheels and two lines of boilers and tenders. It runs on a central elevated rail, two side rails being provided for steadying purposes at a lower elevation. The driving wheels are fixed on short axles with separate outside cranks and it will be easily enough perceived that any balance of swaying couples can only be effected by placing weights on the crank arms opposite the crank pins, the crank centres being regarded as the distance between the centres of gravity of the balance weights as is actually the case. Whatever necessary balance is left unprovided for can only be effected in a partial degree by placing weights in the wheels at an angle of 135° from each crank, the amount of these weights being equal to the unbalanced weight of parts on one side multiplied by $\sqrt{2}$. In this engine balance of the revolving weights is of more importance than that of the reciprocating weights from considerations of rocking movements.

This peculiar engine runs on the Listowel and Ballybunion, Latrigue Railway, in Ireland, the wagons and carriages being slung pannier-like on either side of the central rail. The tenders are provided with driving cylinders geared to the wheels to assist in the hauling of the train on inclines. These cylinders are seen in the illustration with their exhaust pipes pointing upwards behind the roof of the cab.

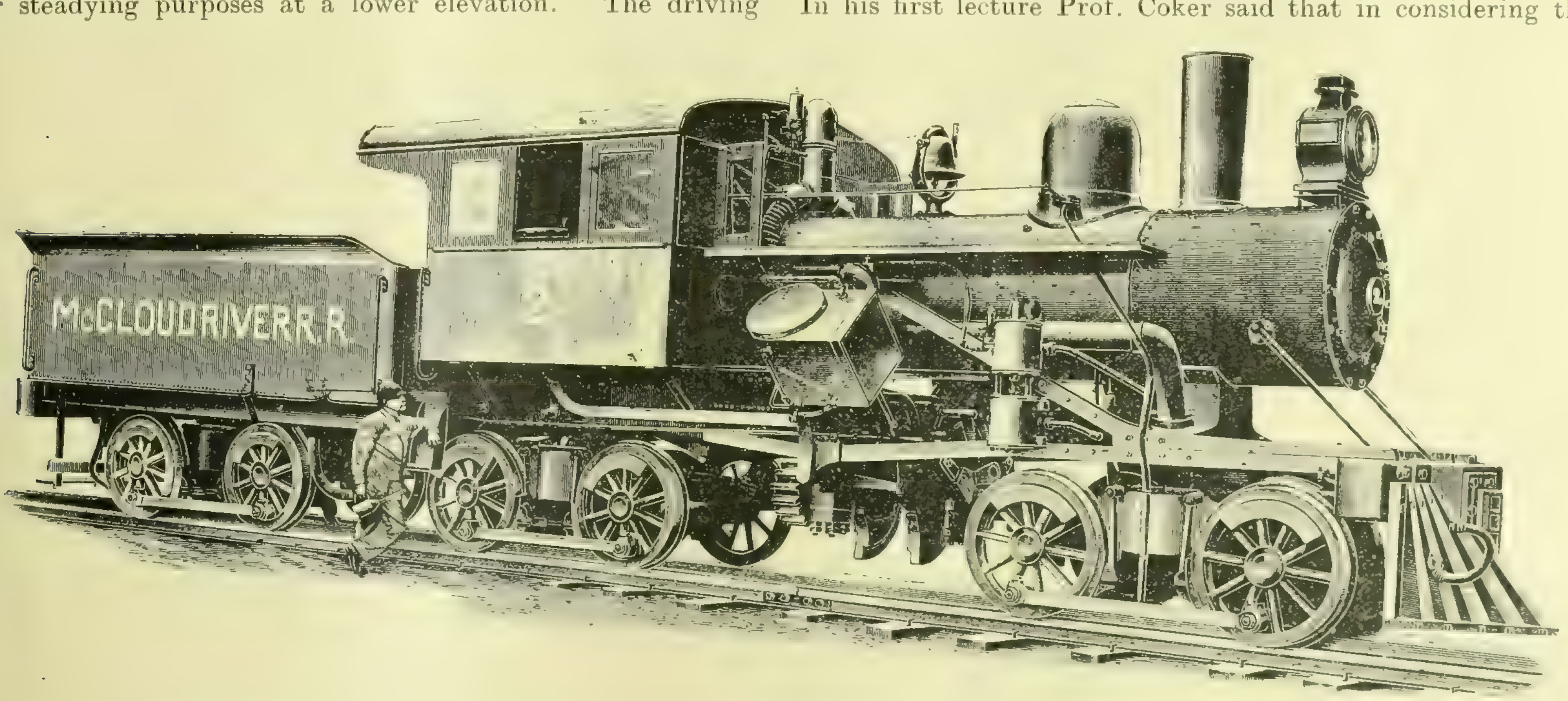


FIG. 39.—LOCOMOTIVE WITH BEVEL GEAR TRANSMISSION. THE ONLY LOCOMOTIVE IN WHICH REVOLVING WEIGHTS PERFECTLY BALANCE RECIPROCATING WEIGHTS.

OPTICAL DETERMINATION OF STRESS.

Two lectures on the "Optical Determination of Stress and Some Applications to Engineering Problems" were recently delivered at the Royal Institution by Prof. E. G. Coker. In his first lecture Prof. Coker said that in considering the means available for the purposes of research and investigation on the strength and properties of materials, it was somewhat remarkable that most of the present experimental knowledge had been obtained by purely mechanical measurements, assuming uniformity of stress and necessarily con-

ducted at the surface, the condition of the interior being usually supposed to be practically identical. The scope of experimental enquiry by mechanical means was thus very much restricted, because in the great majority of cases requiring examination the variation of stress in a short distance was enormous, and the stress at one point on a body

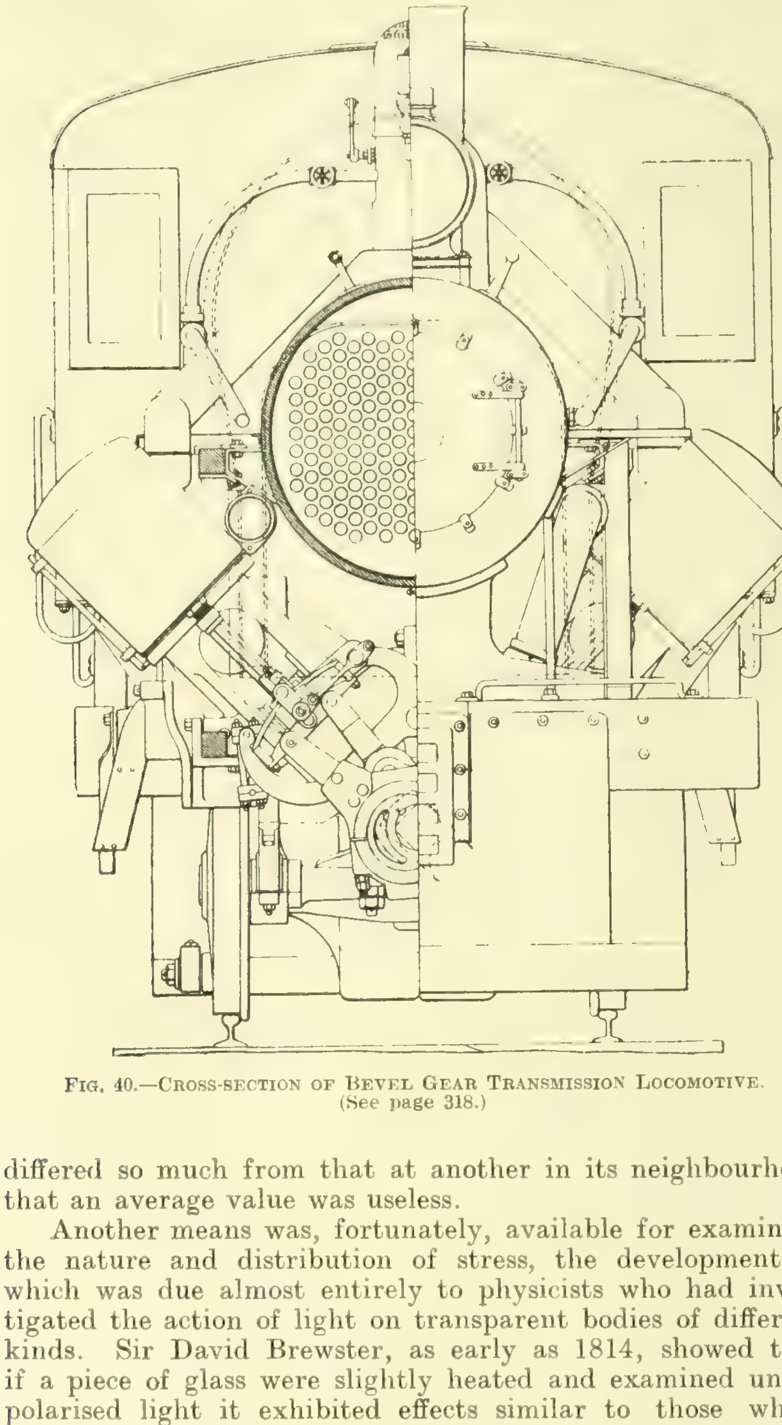


FIG. 40.—CROSS-SECTION OF BEVEL GEAR TRANSMISSION LOCOMOTIVE. (See page 318.)

differed so much from that at another in its neighbourhood that an average value was useless.

Another means was, fortunately, available for examining the nature and distribution of stress, the development of which was due almost entirely to physicists who had investigated the action of light on transparent bodies of different kinds. Sir David Brewster, as early as 1814, showed that if a piece of glass were slightly heated and examined under polarised light it exhibited effects similar to those which occurred in some natural crystals, and he suggested that by similar means valuable information might be obtained concerning the stresses in the arched rings of bridges and like structures. The important advantage offered by an experimental method based on the properties of polarised light was that the colour indications were measures of the stress at different points in a body. If the applied loads of simple tension and compression which produced these colours were measured it would be found that there was a relation between them. The experimental results indicated that the colour effect produced in a plane body under stress was proportional to the algebraical difference between the stresses, and also depended on the thickness of the material; and as the state of stress which occurred in a plane could always be represented at any point by two stresses of definite amount in directions at right angles, the optical appearance enabled the difference of those stresses to be determined.

The internal condition of a beam of transparent material in a state of stress could thus be ascertained by placing it in polarised light, and an important question arose as to how far the determination of stress in transparent materials could be applied to problems relating to the stresses in materials like steel, cast iron, wrought iron, and masonry. If it could be shown that the stress effects arising in such opaque solids were comparable to those produced in transparent materials, then the results found to connect optical behaviour and stress in a transparent body might be applied with a considerable degree of confidence to infer the distribution of stress in engineering structures. A simple way of comparing different bodies was to observe how far the strain effects produced by stress deviated from the ideal condition of a perfectly elastic body. If a rod or bar were subjected to a cycle of stress which gradually increased from zero to a maximum and then decreased to zero again, the strain produced by any given load ought to be the same whether the stress was increasing or decreasing; and if a difference occurred it afforded a measure of the defect from perfect elasticity in the material. Mild steel, wrought iron, and British plate-glass all had the valuable characteristic of being nearly ideally elastic bodies for the range of stress in the experiments of about 9,000lbs. per square inch, whilst cast iron was much less perfect, as was shown by the area between the rising and falling curves which denoted the relation between stress and strain. The area of this loop was in fact a very accurate measure of the defect of the material from ideal elastic conditions, and it was possible with some confidence to predict the distribution of stress in steel and wrought iron from the optical behaviour of good glass, and, with less certainty, that of cast iron.

In his second lecture, Prof. Coker referred to the determination of the lines of principal stress by optical means, taking as an illustration a particular case in which the central lines of a series of dark bands of inclination were shown on a tension member having two fine saw-cuts in it, which diminished its effective cross-section by one-half. Great use might be made of the lines of equal inclination, as the positions of the dark bands appeared to be independent of the physical properties of the material. For many purposes, however, a method which made use of both isoclinic and isochromatic lines was convenient, but it was important to be able to distinguish between black bands which denoted no stress at all and those which showed the positions for which the planes of principal stress coincided with the principal planes of the polarising and analysing apparatus. In a general way it was possible to distinguish between each kind, if the stressed plate of material were turned round in its own plane, and was viewed in a beam of plane polarised light between crossed Nicols. Some bands moved, while others remained stationary, and the former could be identified as

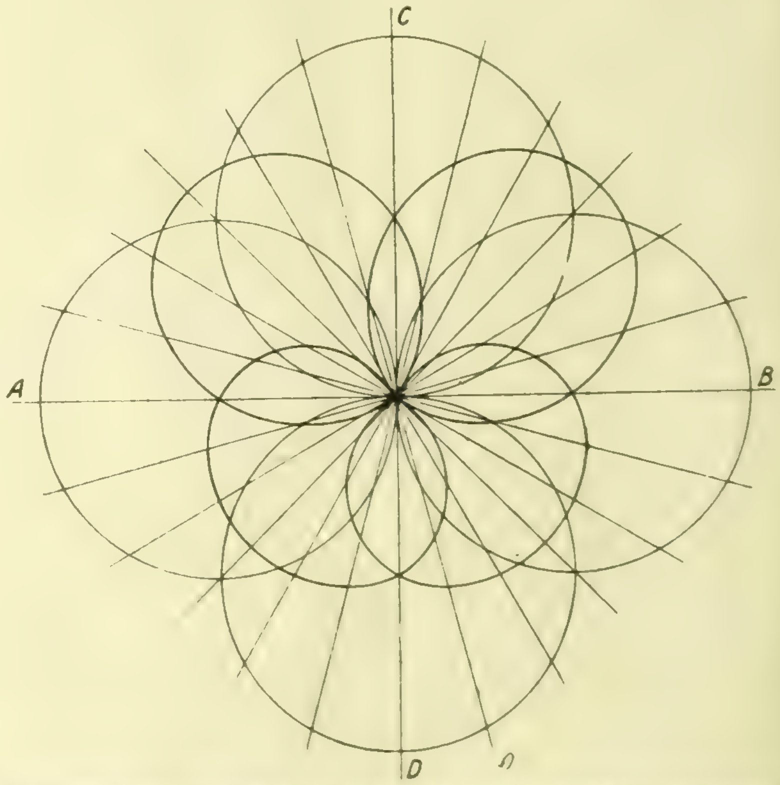


FIG. 41—SHOWING INERTIA EFFECTS OF EQUAL RECIPROCATING WEIGHTS ACTING AT RIGHT ANGLES TO EACH OTHER, AND DEMONSTRATING THAT A REVOLVING WEIGHT PERFECTLY BALANCES THESE EFFECTS. 6 TO 1 RATIO OF CONNECTING RODS TO CRANK AND 15° CRANK ANGLES. (See page 318.)

isoclinic lines and the latter as belonging to the isochromatic group. It was often convenient to show this latter system in their true relation to one another, without disturbance by the dark bands due to the optical system. This might be accomplished by using circularly polarised light. Any

stressed specimen, viewed under such conditions, showed at every point a colour proportional to the difference of the principal stresses, and, since the shear was proportional to this difference, a picture of the shear stress throughout the plate was obtained.

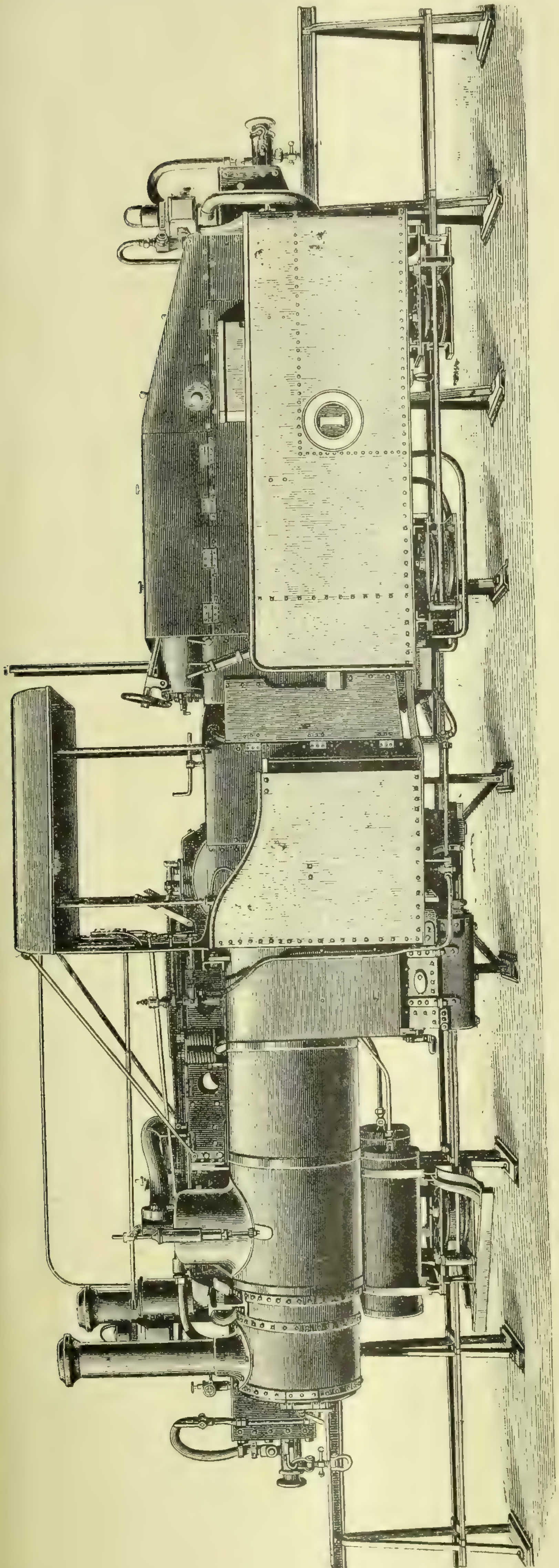


FIG. 42.—LOCOMOTIVE IN WHICH TRANSVERSE OR ROTATIONAL BALANCE CANNOT BE AFFECTED BY WEIGHTS IN ITS WHEELS. (See page 319).

A few cases which arose in practical applications of engineering work due to sudden changes of section were next considered. One of the simplest examples was afforded by a rivet hole. The effect of a simple pull was to cause a complicated stress distribution in the neighbourhood of the hole, due to the crowding together of the lines of stress. It was easy to show experimentally that, if the hole was small compared with the breadth of the plate, the maximum stress rose to about three times its normal value, and theoretical calculation verified the experimental values. In a line of rivet holes the maximum stress at the minimum section could be readily determined. In a riveted joint the distribution was still more complicated, because the stress was carried from plate to plate by the direct pressure of the shanks of the rivets. Another type of discontinuity was afforded by semi-circular holes and rectangular slots in plates and beams. For example, in a tension member with two semi-circular notches in it, away from the discontinuity the lines of principal stress formed a rectangular system, but as they approached the notch they came closer and closer together, and at the waist the nearness together of the lines at the periphery indicated that the greatest stress was reached there. If the notches were small compared with the breadth, the stress rose to twice its normal value. If the notch was rectangular the stress at the re-entrant corners became very great. A similar notch in the form of a square hole in a plate forced the lines of stress to pass through the narrow spaces on each side of the hole, and here, again, the corners of the square showed by the close spacing of these lines, and the colour effects on the specimen, how great was the influence of this kind of discontinuity.

The behaviour of members like springs, hooks, links of chains, and the like, in which the curvature of the member was an important factor in the distribution of stress due to an applied load was referred to. A case which had some resemblance to that of a circular hook section was found in some forms of boiler, in which the flues containing the firegrate and for the circulation of the hot gases of combustion were corrugated in order to increase their strength. The determination of the stress distributions in members like these and in the parts of machines was one of the greatest complexity, and long experience of the behaviour of materials obtained by first-hand acquaintance in some particular branch of this profession, as in, for example, the design and construction of tools or locomotives, could not be replaced by any experiments on models. They could help, however, and indeed mechanical engineers did not require to be convinced on this matter, as the use of models of machines for all kinds of practical purposes was the rule, and not the exception.

The Possible Future of the Internal-combustion Engine.—An interesting paper on this subject was read by Mr. W. P. Durtnall at a recent meeting of the London Association of Foremen Engineers and Draughtsmen. The author first described in detail the early development of the internal-combustion engine from the year 1346. Turning to present-day designs, he thought that the double-acting engine was not so widely used as it deserved to be. For the large engines of the near future Mr. Durtnall considered the trunk type of piston was indefensible without air-cushioning or other similar means of arresting the heavy reciprocating masses, whilst difficulties also arose with such large pistons in connection with lubrication and leakage. He also looked for developments in the constant-pressure engine rather than in the constant-volume type, and that higher efficiences would attend the use of higher compression and expansion nearly to atmospheric pressure. He also remarked that a practically silent engine, without cumbersome exhaust boxes, and utilising either coal or liquid fuel, was about to be constructed in this country for investigation purposes. This engine, to be known as the "Paragon" silent engine (Bowles and Durtnall system) would consume those fuels which at present were difficult to deal with. Finally, he referred to the large field open to internal-combustion engines in the future, instancing marine propulsion, railways and road vehicles.

REVERSING MECHANISM FOR PLANING MACHINES.

THE accompanying illustrations show a construction of reversing mechanism for metal-planing machines, the invention of the High-speed Reconstruction Company, 26, Mark Lane, London, E.C., and R. Stewart. The forward movement, or cutting stroke of the table, is generally one at one-third or one-fourth of the return speed. The reversing mechanism described gives this reverse movement at dissimilar speeds.

The pinion A is connected with the gearing of the planing machine which is used to communicate movement to the table

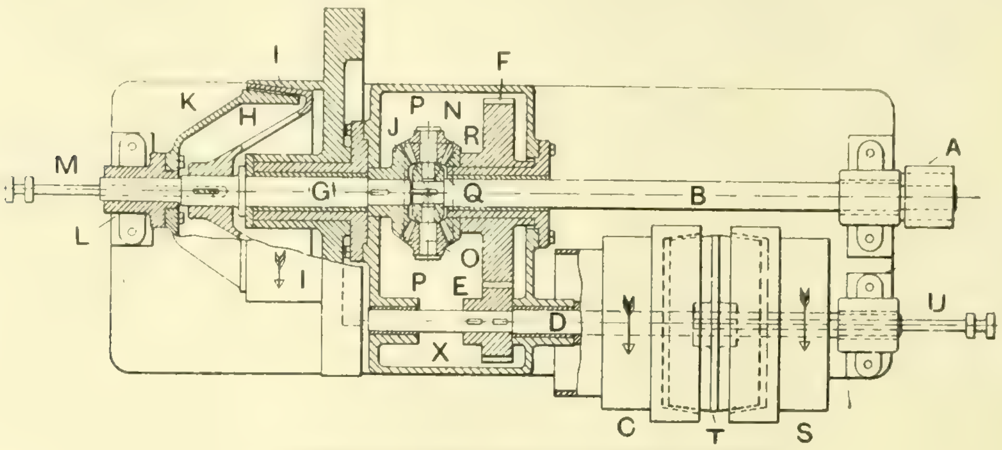


FIG. 1 —REVERSING MECHANISM FOR PLANING MACHINES.

in the usual manner. The shaft B to which the pinion A is fixed is given a rotation in both directions. It is desirable to employ two or three speeds for the forward movement of the table when the tool is cutting, therefore the cone pulley C is used, mounted and revolving loosely on the shaft D which operates the gear F through a pinion E. The cone has a movement constantly in one direction. In some cases the required speeds are obtained by change-speed gearing in the frame X by means of sliding pinions and gears to correspond, and operated by a lever. All the gears that are revolving are placed in the enclosed chamber X, which serves as an oil reservoir to lubricate the gears.

In order to follow out the operation of the reversing of the shaft B, and the pinion A, and thereby the gearing which operates the table of the planing machine, it is assumed for the purpose of explanation that the table is being moved in its forward or slower motion under the tool which is cutting the material. The shaft G and the bevel pinion J are stationary, due to the clutch H being held in contact with the stationary clutch ring K on the bearing L. As the bevel gear J is stationary, it will be understood that the rotation of the bevel gear R will impart movement to the boss Q which carries the bevel pinions N and O, because they will roll around the stationary bevel gear J and consequently give a rotation to the shaft B in the same direction as the gear F is revolving, but the speed of the shaft B will be one-half the speed of the gear F. Just before the table of the planing machine arrives at the limit of its desired forward movement, it operates, by means of the usual tappets on the edge of the table, the rod M to disengage the clutch H from the ring K. Immediately the clutch H is free to turn, all the power which is being transmitted to the table in its forward movement by the cone C, through the gearing E F R P, boss Q, shaft B, and pinion A, is diverted to set the clutch H in motion in an opposite direction to that in which the shaft B is revolving. Therefore the table is arrested in its forward movement at the limit of its stroke by releasing the clutch H and permitting it to revolve freely in the direction that it is to be afterwards driven at an increased speed for the purpose of returning the table at its higher rate of movement. At the time of arresting the movement of the table, the clutch H is set in motion in an opposite direction to the shaft B, but in the same direction that the flywheel I is revolving. Therefore the reversing of the movement of the table is accomplished by imparting the higher speed of the flywheel I to the clutch H. This permits of the use of a heavy flywheel I to give out by inertia the power necessary to set in motion quickly the mass of the table. As the clutch H has already been set in motion and has a considerable speed, the final contact with the clutch surface in the pulley I at its higher speed does not impart a shock to the gearing such as would be the case if the reversing motion operated a stationary clutch. The return movement of the table is obtained through the tappets on the table acting on the rod M to move the clutch H into contact with the flywheel I.

The manner in which the increased speed of the flywheel I accomplishes the return movement of the table through the reverse movement of the shaft B and the pinion A is as follows: The clutch H, shaft G, and the bevel gear J are being rotated at a much increased speed, in an opposite direction to the bevel gear R. The result is, that due to this difference in speed in opposite directions, the bevel pinions N and O cause the boss Q to be revolved in the direction of the bevel gear J as it over-runs the bevel gear R. The number of revolutions of the boss Q and the shaft B will be equal to one-half the difference between the number of revolutions of the bevel gear R and the bevel gear J.

When the table of the planing machine has nearly reached the limit of its rapid return movement, preparatory to being reversed to start on its slower forward movement, the clutch H is withdrawn from the clutch surface in the pulley I, and moved on the shaft G by the rod M until it comes in contact with the stationary clutch ring K, which will at first retard and finally stop the motion of the clutch H, shaft G, and bevel gear J. The action of this stationary clutch ring K to gradually arrest the movement of the clutch H, and thereby the motion of the boss Q with its bevel gears N and O, causes the momentum of the table in its rapid return movement to be overcome without any shock or jar to the mechanism. For this purpose the clutch H, bevel gear J, and pinions N and O, are made as light as possible to give out the minimum inertia. The bevel pinions N and O will again begin to roll on the bevel gear J, but in an opposite direction, thereby imparting the reverse movement to the shaft B and the gear A, operating the planing machine gearing and table, and thus complete the cycle of operations.

It has been found desirable in some cases of planing to accelerate the cutting speed of the table and the work after the tool has entered its cut in the piece being planed, and this

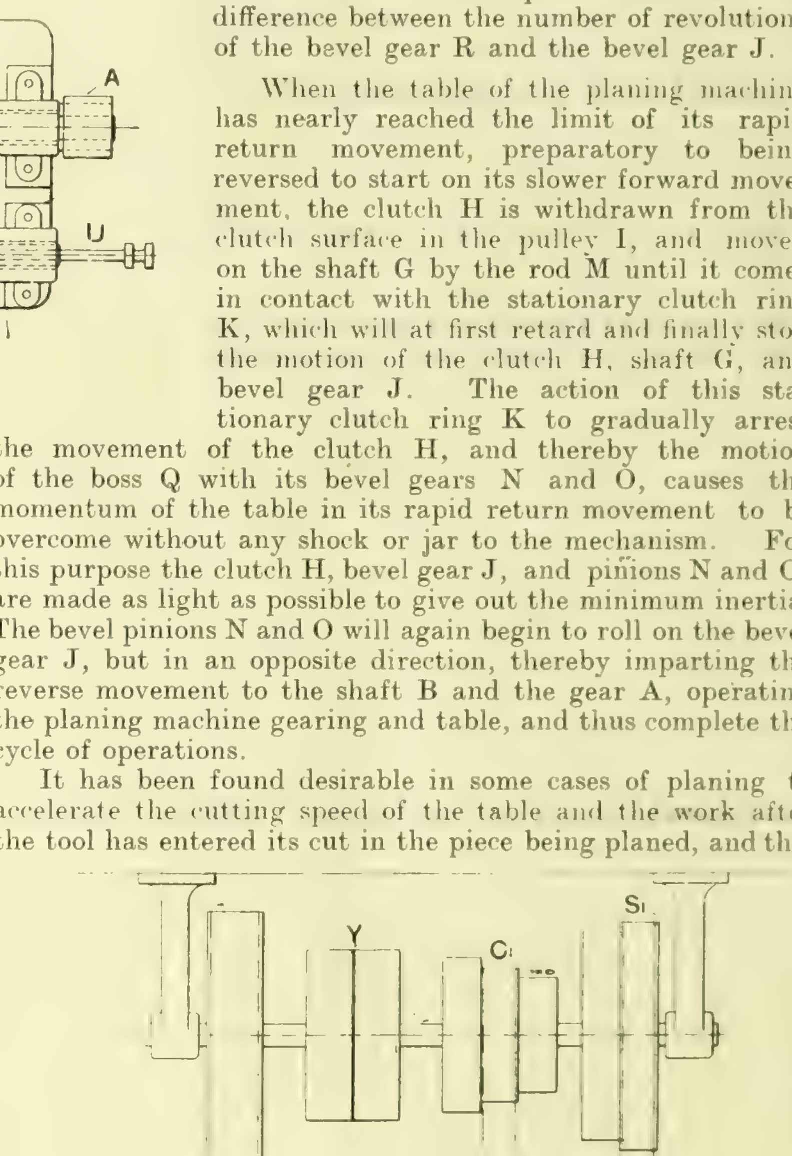


FIG. 2 —REVERSING MECHANISM FOR PLANING MACHINES.

accelerated movement is obtained by the cone pulley S, which runs loosely on the shaft D, and is driven in the same direction as the cone C, also running loosely on the shaft D. Both the cone C and the cone S set the shaft D in motion by a clutch T moved by a rod U. This rod, which operates the movement of the clutch T to connect either of the cones C or S to the shaft D, is acted upon by tappets on the edge of the planing machine table. These tappets are adjusted on the table to suit the length of the piece being planed. To make this accelerating motion clear, we will suppose a long casting,

for example, a lathe bed, is being planed. The table moves, say, at the normal speed of 40ft. per minute, being driven by the belt W on the cone C until the tool has entered a few inches on its cut, when at once the movement is accelerated to 80ft. per minute by the engaging of the clutch T in the pulleys S, which are being driven at the increased speed necessary to give the accelerated movement of the table according to the position of the belt V on the pulleys S. When the tool has nearly completed its cutting course, and before leaving the piece of work, the speed of the table is reduced to 40ft. per minute by the clutch T being returned to the clutch in the cone C. This avoids the breaking of the edges of the piece being planed, particularly when planing cast iron.

The countershaft drives the pulley and flywheel I through the belt Z. The cone C_1 drives the cone C through the belt W, which can be placed on one of the steps of the cone C to give the required speed to the table. The pulleys S_1 drive the cone S by the belt V to give one or other of the desired accelerated speeds to the table of the planing machine. The pulleys Y are the usual fast and loose pulleys for stopping and starting the countershaft. In place of the mechanically-operated clutches, magnetic clutches may be employed.

NON-FREEZING MIXTURES.

THE following data are taken from two recent issues of the "Quarterly" of the National Fire Protective Association:—

The amounts of salt and calcium chloride required to keep water from freezing at different temperatures are tabulated below. The salt should be thoroughly dissolved or the results will not be satisfactory. Calcium chloride is said to be superior to sodium chloride in that it does not corrode steel tanks and barrel hoops. Where calcium chloride is used the wooden barrels should first be well coated inside with asphaltum, or a mixture of crude paraffin and resin, to prevent the shrinking of the staves and subsequent leakage:—

Common Salt (Sodium Chloride).		Commercial. Calcium Chloride.	
Pounds per Gallon.	Freezing Point. Degrees Fahrenheit.	Pounds per Gallon.	Freezing Point. Degrees Fahrenheit.
½	24 above zero	½	29 above zero
1	18 above zero	1	27 above zero
1¼	15 above zero	1½	23 above zero
1½	12 above zero	2	18 above zero
1¾	9 above zero	2½	4 above zero
2	6 above zero	3½	6 above zero
2¼	3 above zero	4	17 above zero
2½	1 above zero	4½	27 above zero
3	3 below zero	5	39 above zero
3½	8 below zero	5½	54 above zero

Glycerine is recommended for use in chemical fire extinguishers. It has no effect upon metals, but has a tendency to disintegrate rubber. It has been stated, however, that the continued use of glycerine in water renders it liable to a decomposition that would develop compounds having a corrosive action on metals. When using glycerine it should be remembered that 1 gall. weighs 10½lbs. The following proportions may be used:—

Glycerine, pounds per gallon.	Temp. solution will withstand.
3½	+ 10° Fah.
5¼	− 10° Fah.

Denatured alcohol has advantages over both glycerine and calcium chloride as a non-freezing element in water solutions, for it has no injurious effect on either metal or rubber. A solution of about 50 per cent. is inflammable; however, it would rarely be necessary to have a solution of over 30 per cent. alcohol.

A 20 per cent. solution freezes at + 10° Fah.
30 ,, ,, ,, − 5° Fah.
40 ,, ,, ,, − 20° Fah.
50 ,, ,, ,, − 35° Fah.

WORM AND SPIRAL GEARING.*

WITH SPECIAL REFERENCE TO MACHINE TOOL DESIGN.

BY W. HAUGHTON.

(*Concluded from page 259.*)

Now a few words upon the conditions necessary to success in worm or spiral wheel drives. Holding a most important place amongst these conditions is the arrangement made for taking the thrust. Many machines still exist where this matter of thrust is ignored; but, generally speaking, some provision is made, if not in both worm and wheel, at least in the worm. In most cases this is all that is necessary, but as the angle of the spiral increases in the wheel it becomes important that some provision should be made for taking the thrust upon the wheel also if the best results are to be obtained. As the angle approaches 45°, so does the thrust upon the worm and wheel become more nearly equal, and it becomes imperative to treat both wheels alike in this respect. In a hollow-face wormwheel it is very important that there should be no side play, especially in the direction of the thrust, as there is a very great tendency, owing to the hollow shape, for the worm to push the wheel over to the side. If this is not attended to, and the work upon the wheel be very heavy, enormous friction is set up, and the wheel will be speedily worn out, to say nothing of the great waste of power.

Among the devices for taking the thrust are the following: Friction washers (sometimes made of best steel hardened and ground, or mild steel case-hardened and ground, sometimes a combination of steel and red fibre) are employed. Washers made of white chilled cast iron are said to have been used with good results. Then we have ball-thrust collars, and also roller-thrust collars. For many purposes the hardened and ground friction washers are perfectly satisfactory, as are also the red fibre washers used in conjunction with steel. Where friction washers are used there should be three, the centre one being loose; of the other two, one should be pegged to the boss of the casting, and the other to the worm. This is not always done. The whole of the washers are left loose, and the friction upon the boss and the worm is relied upon to hold them. But it is better to make the motion definite. In cases where the duty is heavy, the loss in friction with plain surfaces becomes a serious item, and it becomes necessary to employ either ball or roller-thrust collars.

In most cases ball-thrust bearings are at once the cheapest and best method of taking the thrust, and are now generally used. They are in every way satisfactory if the material is all right, but the races should always be hardened and ground. High-quality carbon steel is necessary if both the speed and the pressure be great. In cases where the speed is low and the pressure not excessive, mild steel case-hardened and ground is satisfactory, provided the case-hardening is deep enough. In the instance of the electric worm-driven hoists alluded to in Mr. Libby's article before mentioned, the thrust was taken by ball bearings, the races being made of low-carbon steel case-hardened and ground, and he made a point of the fact that the balls, instead of being used as received from the makers, were tempered by being heated at a temperature of 475°. He said that for this particular they had found this an advantage to the wearing quality of the races, and they got no chipped balls. Ball-thrust bearings are without doubt generally the most satisfactory means of taking the thrust if care be taken to make the size of the balls somewhat proportionate to the pressure. If the balls are too small they are liable to cut their way into the race.

In cases where the work done is very great and the thrust heavy, ball bearings very soon wear out. In such cases it is necessary to substitute a roller bearing. This will stand a much greater thrust, because the bearing is that of a line upon a surface, instead of a point upon a surface, which is theoretically the case with balls. One type of roller bearing has rollers of a taper section, sometimes contained in a notched disc, at other times simply placed in a grooved recess with sides of corresponding taper to the roller. This taper type seems to be the most correct, but is rather expensive to make. Another type has parallel rollers. In this case it is essential to contain rollers within slots, which will keep the centre of

* Abstract of paper read before the Birmingham Association of Mechanical Engineers, February 3rd, 1912.

the rollers radial. Theoretically this type would appear to be wrong, as the outer edge of the roller would revolve at a faster rate than the inner, so that it cannot have a strictly rolling motion, but must slide to a certain extent. This is so, and yet the rollers are quite satisfactory in practice, notwithstanding this theoretical defect, and it must not be forgotten that even ball races which theoretically are free from it in practice become tarred with the same brush. The bearing of a ball race is supposed to be a point upon a surface, and would be so if a material could be found to stand the pressure and wear; but very soon a hollow is worn into the material, and its ball, like its brother the roller, has to do a certain amount of slipping. Makers of ball races now recognise this, and make the race with a hollow radius slightly greater than

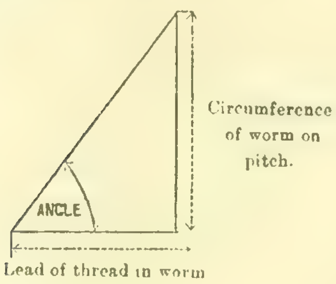


FIG. 1.

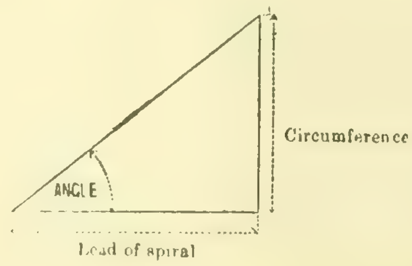


FIG. 2.

that of the ball. The engineer's dream of a pure rolling contact is in this, as in gear teeth, a dream only, without solid foundation in fact. While speaking of the parallel roller thrust, I may mention that a short time ago I met with the difficulty of the ball-thrust races rapidly wearing out under the very great pressure of high-speed drilling. The ball thrust was replaced by a roller thrust, and the result was highly satisfactory, quite overcoming the trouble.

Almost as important as the question of thrust is that of lubrication. Wormwheels should never be allowed to run dry. If the teeth once get really dry and commence to grind, they will grind to powder in a short half-hour, whereas with proper lubrication they might have lasted for years. Whenever possible the worm and wheel should be enclosed in a tight case capable of retaining the lubricant. A worm and wormwheel should be made to wallow in grease. The more slippery and slithery the better—a thin oil is out of place. The thrust also should be well lubricated to get the best efficiency.

The material of which the worm and wheel are made is important. The purpose for which the wheels are to be used, and the speed at which they are to run, have to be considered in selecting a suitable material. For most purposes nothing is more suitable for the wheel than close-grained cast iron, and fairly hard mild steel for the worm. Gun metal is frequently employed in cases where it is quite unnecessary, and is therefore wasteful in expense; cast iron is not only cheaper, but is quite as good for the purpose if properly lubricated. Of course it will soon wear out if allowed to run dry; but so will any material—even gun metal or phosphor bronze cannot do without lubrication. If brass must be used, it should be hard and tough. Phosphor bronze answers to this description, and is therefore much used for the purpose. Soft steel should never be used together for both worm and wheel, owing to their very great tendency to gall. This causes a very great loss in friction, and no amount of oiling will altogether compensate for the disadvantage. If steel must be used for both, then the wheel and the worm should be case-hardened; the harder the surface can be made the better. It is also important that the surface of the teeth should be as smooth as possible. The latest is to case-harden the worm and to grind up the thread, not only with the object of making it smooth, but for the purpose of making the thread true to pitch. The slight distortion which takes place in hardening is thought by some to be so important as to warrant the expense of grinding, involving the necessity of a spiral machine for the purpose.

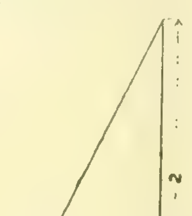


FIG. 3.

Mention of this question of accuracy of pitch recalls the fact that the difference which exists in wormwheels between the normal pitch and the real pitch is often ignored in practice. The normal pitch is that measured at right angles with the thread or teeth, while the real pitch is that measured upon the face of the wheel, and also along the centre line of the worm axis. The pitch in both these cases is alike, so that when the angle is small the difference is a negligible quantity, as it involves only the slight thinning of the teeth; but as the helix angle increases it becomes imperative to take it into account, as with increasing angle the teeth become thinner and thinner until there will be no teeth left. In single-thread worms the angle is usually small, so that it is safe to ignore the difference; but with double-thread worms of small diameter, or triple or quadruple-threaded worms, they should always be worked out as a pair of spiral wheels. While upon the question of angles, I may mention that it is always best to keep the worm as small in diameter as possible consistent with strength. This has a double advantage in that it increases the helix angle, which increases the efficiency, and the circumferential friction is reduced to a minimum.

I may now summarise the various points mentioned as follows:—

1. Wormwheels which have their teeth cut diagonally across the face are quite good enough for many purposes, and are cheap.

2. Wormwheels with spirally-cut teeth, not hobbed, are probably more efficient than wheels with hollow faces, even though these are supposed to be more theoretically correct. There may be less wearing surface, but there is also less friction.

3. Hollow-face wormwheels with hollow teeth are better made with a considerable flat upon each side of the hollow. Some designers think it best to have no hollow upon the top

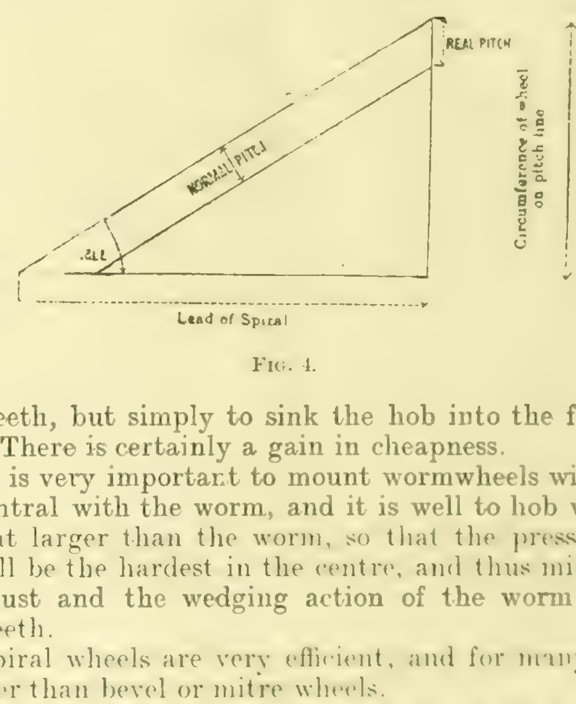


FIG. 4.

of the teeth, but simply to sink the hob into the face of the wheel. There is certainly a gain in cheapness.

4. It is very important to mount wormwheels with hobbed teeth central with the worm, and it is well to hob with a hob somewhat larger than the worm, so that the pressure of the teeth will be the hardest in the centre, and thus minimise the side thrust and the wedging action of the worm upon the wheel teeth.

5. Spiral wheels are very efficient, and for many purposes are better than bevel or mitre wheels.

6. The thrust is a very important matter in wormwheels, ball-thrust being the best where the pressure is not too heavy. For very heavy thrusts rollers should be used instead of balls.

7. Lubrication is of the utmost importance. Whenever possible the worm and wheel should be enclosed in a case capable of retaining the lubricant, and a thick oil like cylinder oil should be used for the teeth.

8. For heavy driving a small spiral angle should not be used. The best angles lie between 18° and 30°, but the efficiency increases with the angle up to 45°.

9. The diameter of wormwheels should be calculated from the real pitch and not the normal pitch

10. The shape of wormwheel teeth is generally found to suit an angle of 29° in the worm-thread, but if the teeth number less than 30 it is usual to make the thread of the worm 40° angle to avoid undercutting the teeth.

Useful Hints and Formulæ for Worm and Spiral Wheels.—To find the angle of teeth in a worm and wheel, make the diagram Fig. 1 to accurate dimensions. This gives the angle of the worm-thread. Subtract this from 90° for angle of wheel teeth. Both these angles will be taken from the axis of the worm and wheel.

Another method to find angle of thread: Divide the circumference of worm on the pitch line by the lead of the spiral; this will give the tangent of the angle. Refer to table of tangents for the angle.

Having the diameter and the angle of a worm or wormwheel, to find lead of spiral. Upon a horizontal line erect a perpendicular line as high as the circumference of the pitch diameter. Mark off the angle with a protractor from the perpendicular line, and extend it until the line crosses the horizontal line. The length of the horizontal line from the perpendicular line to where the angle crosses the horizontal line will be the lead of the spiral (see Fig. 2).

Another method is based on the fact that the lead of the spiral is equal to the circumference of the worm or wheel on the pitch line divided by the tangent of the angle.

For spiral wheels having equal diameters to work at a given ratio it is necessary to know what angles will give the correct pitch to each of the wheels. For example, take a two-to-one ratio. In this case the real pitch in the first-motion wheel must be twice that of the second-motion wheel, as it has only half the number of teeth in the same diameter. To find these angles make the diagram, Fig. 3, to accurate dimensions. This gives the angle of the first-motion wheel taken from the horizontal line and the angle of the second-motion wheel taken from the perpendicular line, both being with wheel axis.

A further method is one in which the larger figure of the ratio divided by the smaller is equal to the tangent of the angle of the first-motion wheel, and vice versâ, the smaller divided by the larger equals the tangent of angle for the second-motion wheel.

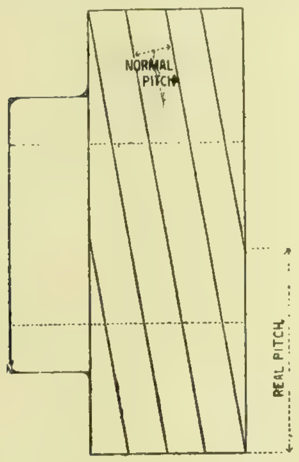


FIG. 5.—DIAGRAM ILLUSTRATING THE GREAT DIFFERENCE THERE MAY BE BETWEEN THE REAL PITCH AND THE NORMAL PITCH.

To find the real pitch of a wormwheel, draw as in Fig. 4 to accurate dimensions. This can only give approximations, but is a good method of checking the methods given in Fig. 5, and is useful in preventing mistakes.

The following formulæ are for wormwheels of circular pitch:—

Real pitch = normal pitch ÷ cosine of angle.

Cosine of angle = normal pitch ÷ real pitch.

Normal pitch = cosine × real pitch.

Tangent of angle = circumference on pitch line ÷ lead of spiral.

Lead of spiral = circumference on pitch line ÷ tangent of angle.

Pitch diameter of wheel = real pitch × number of teeth ÷ 3·1416.

For diametral pitches use the following formulæ:—

Real pitch = normal pitch × cosine of angle.

Cosine of angle = real pitch ÷ normal pitch.

Normal pitch = real pitch ÷ cosine of angle.

Tangent of angle = circumference on pitch line ÷ lead of spiral.

Lead of spiral = circumference on pitch line ÷ tangent of angle.

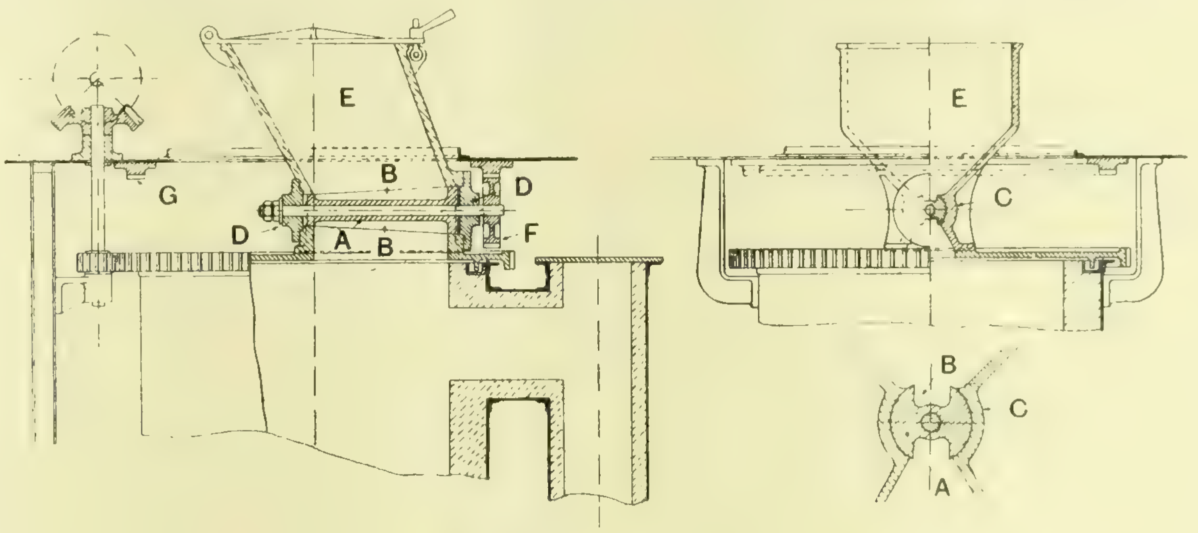
Pitch diameter of wheel = number of teeth divided by the real diametral pitch.

On Monday last the engine cylinder burst at the Acorn Spinning Mill, Lees, Oldham. In consequence of the breakdown over 200 operatives will be thrown out of employment.

CHARGING DEVICE FOR GAS PRODUCERS.

THE fuel-charging device for gas producers shown in the accompanying cuts has recently been patented by F. G. Smith, 37, Ruskin Walk, Herne Hill, London, and J. S. Atkinson. The fuel is delivered into a hopper on the top of the producer, which delivers it through a revolving feeder which has also a motion of rotation round the vertical axis of the producer, and this distributes it over the bed of fuel therein; or the producer may revolve, the feeder remaining stationary, except for the rotation about its own axis. The feeder consists of a conically-shaped body A, with troughs B formed in it and extending throughout its length; the capacity of these troughs increases from the centre of the producer to the periphery, giving an even distribution of fuel over the bed. The feeder A revolves in the casing C, which is open at the top to the hopper E and at the bottom to the producer. The feeder is placed radially just above the top of the producer, and is provided with bearings D at each end. The rotary motion of the feeder A may be given in any suitable way, and for a rotating top producer by a spur wheel F which is keyed to the feeder spindle and gears into a fixed spur ring G.

Either the top of the producer carrying the feeder, or the body of the producer, may be slowly revolved on a vertical axis so that the feeder arrives successively over different sections of the fuel bed. The rotation of the feeder causes the troughs B to be successively opposite the hopper and the producer, being opposite to the hopper when they are being filled with fuel, and opposite to the producer when discharging the fuel on the fuel bed. The sides of the feeder casing C are a sliding fit against the feeder A, thus making an efficient gas trap. More or less sharp edges are given to the troughs B and to the edge of the casing C. Thus large pieces of fuel are cut or broken up, so that they cannot choke up the feeder and arrest its motion. This also ensures fuel of even size being charged into the producer. The apparatus therefore acts as a crusher as well as a feeder and charger. The joint between the top of the producer and the body of the producer is made gas-tight by means of a water or sand seal.



CHARGING DEVICE FOR GAS PRODUCERS.

Mining Institute of Scotland.—A general meeting of the Mining Institute of Scotland was held a few days ago, Mr. McLaren, His Majesty's Inspector of Mines, presiding. For the position of president for the ensuing year Mr. James Hamilton, Glasgow, was nominated. There were nominated a number of members for the offices of vice-president and councillors. Mr. Henry Briggs, Heriot-Watt College, Edinburgh, read a paper on testing for fire-damp and black-damp by means of a safety lamp. The purpose of the paper, he said, was to describe the methods devised by himself of detecting fire-damp and black-damp by aid of a cheap and simple addition to any ordinary safety lamp, and he gave an account of some experiments made in putting the methods to the test. In a discussion which followed an interesting communication was read from Dr. Haldane. He stated that Mr. Briggs' methods were thoroughly sound in principle, and likely to be most useful in detecting black-damp with a safety lamp.

PRIME COSTING AND ESTIMATING.*

BY G. JAMES WELLS, WH.SC., A.M.INST.C.E., M.I.M.E.

The cost of a system is an investment which must be remunerative to justify its existence. It mainly consists of labour, for paper and printing are fortunately very cheap, consequently in devising any system it is very necessary to reduce the clerical work to a minimum. Hence the first step to take must be the determination of the exact information that is required, and the way in which it may best be recorded. The first of these items can only be discussed by those who have had experience in estimating, for it is only in that way one can obtain any notion of the enormous amount of useless labour daily expended in compiling records that will not serve any useful purpose. Even in so simple a matter as recording the weight of parts, errors of transcription lead to most anomalous results.

Errors creep in because prime cost clerks usually do not know how their records are to be used, and, consequently fail to appreciate the sort of information that should be recorded. Further, usually, in most establishments the system is too elaborate, providing too many openings for error without anyone competent to pick them up when they might be rectified.

The aim, therefore, in devising a scheme should be to avoid all unnecessary clerical labour particularly in the shop, and to reduce the items to be dealt with to a minimum, consistent with providing sufficient data for the purposes of the accountant and estimators, also the form to be such that the manager can have placed before him periodically abstracts revealing at once any falling off in efficiency.

In order to deal with the problem intelligently, it is necessary to first settle the general scheme of accounts that must be kept, so that the proper place and due importance of each detail of the whole method can be obtained. Each undertaking exists in consequence of the possession of capital, upon which it expects by reasonable use to earn profits or dividends. In order to earn profits orders must be received and executed. Thus the object of book-keeping is to record systematically all the transactions that occur, so that the position of the undertaking may be readily determined at any time. The starting point for all systems is, therefore, "orders" and "Cash."

The whole scheme is shown in the diagram Fig. 1, in which the sequence of events occur in the order shown, moving downwards towards the bottom. To execute the orders received, wages must be spent, and a certain quantity of raw, partly, or completely manufactured material worked up. The materials come from the storerooms, and like wages have to be paid for with cash. The management and certain charges have to be met in order that there may be a suitable place where the orders can be executed. Thus, there are three main sources of cash expenditure, each of which must be charged against the orders executed in order that their cost may be known accurately.

These several items each find their way *via* the workshop to the prime costing department. At this stage a certain percentage is added to the cost to provide the sum required to pay interest on the capital involved in the undertaking. It is not expected that so far there is much room for difference of opinion, but when the details are examined the best and cheapest way of putting into practice this scheme, it will be seen that there is much room for variation in method.

Prime Costing.

The value of a knowledge of prime cost is attested by the fact that almost every undertaking has such a department organised on a scale depending upon the exact relative value placed upon "prime cost" and the use made of it. The object of the "prime cost office" is to record all the items included in the cost of production of each article manufactured, in such a manner that the estimating department may compare the actual results obtained with those anticipated, and thus learn if (1) the time allowed was sufficient; (2) the amount of material allowed was correct; from which the actual possibilities of the shops can be determined for future use.

The drawing office should also be able to detect if any changes in the design of any standard or stock design has resulted in the anticipated saving in manufacture. The management should be able to learn, by comparing the cost with the prices obtained, which articles pay, and which should be dropped, unless some alteration in design, or method of manufacture, can be devised to reduce costs sufficiently to make it worth while to continue their sale.

Remembering these purposes it is possible to devise a system that will suit any particular class of work, at a minimum of expense, which means that the clerical labour must be reduced as much as possible. There are three principal items to be taken note of in ascertaining the prime cost, viz.: (1) The cost of labour; (2) the cost of material; (3) the true share of establishment expenses that must be borne by each order.

Labour Costs.—The systems most generally followed either make the individual workman record daily the time spent upon each job, or employ a clerk to see each man daily and make the record for him. Sometimes the foreman has to initial each card, to ensure in some measure the reasonableness of the several records before they go to the prime cost office for dissection and entry in the books.

The difficulties are great with each method. The men often regard these cards as a device intended primarily as a trap to discover the quickest workman, and thus elaborate private records are made from time to time to ensure that

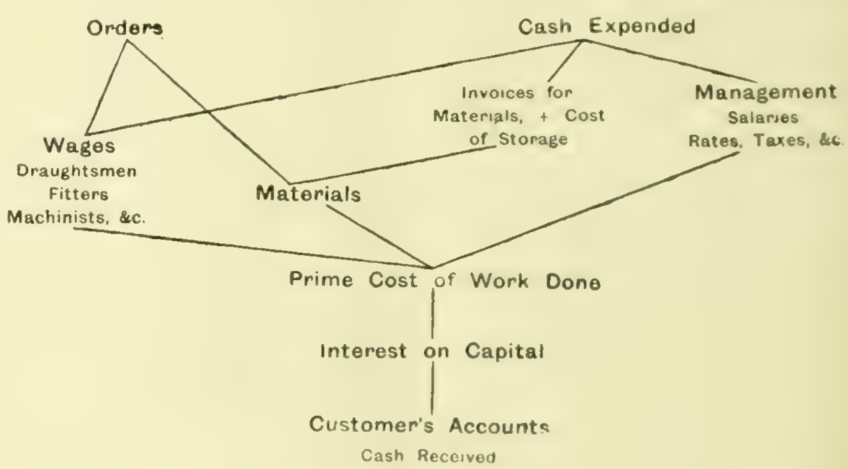


Fig. 1.

there shall be no discrepances if any comparisons are made in the office. To meet this the second method details a clerk to see each man and make the record, but this is no real remedy, for the unfortunate clerk usually does not possess any practical knowledge, and so must put down what he is told. Another difficulty is that men who have a great variety of jobs neglect to record any of them until near the end of the day, and then omit many, charging up their day to one or two unfortunate order numbers that in their judgment are best able to stand it.

The author in dealing with this difficulty has always required the man to record the time occupied, no matter how small, at once to each order number, and leave the lumping-up process to the office to execute upon a plan pre-arranged, so that no injustice is done any particular order number because somebody may consider it well able to stand it. For this purpose cards, Figs. 2 and 3, were printed, and each man on arriving at the time office received card Fig. 2, on which he was required to record his number and machine number; the order number; piece number; and the time he spent upon it; all of which it must be noted are numbers only, no writing of any sort being needed. If overtime was worked this was entered separately, so that the proper extra charges could be made. The workman's number and the machine number enabled the office to enter up his wage rate, and the charges made to cover interest and other charges due to capital cost of the tool. Then by means of a table the value of the time could be entered against each item when the card was ready for the charges to be transferred to the record of each order. For fitters, whose work naturally differed, another card, Fig. 3, was supplied, and these two cards sufficed to satisfy the requirements of machinists, labourers, fitters, pattern makers,

* Abstract of paper read before the Manchester Association of Engineers, March 9th, 1912.

moulders and smiths. On card Fig. 3, charges were made for vice, tools, &c. It should be noted that the overtime was finally put on the backs of the cards, also that the charges added to the workman's time does not form part of the establishment costs proper, but only such as are special to that individual. It should also be noted that the total time, not the value booked up each week by the prime cost department, should equal that posted by the wage clerk, a check upon the accuracy of all concerned. An examination of the forms show that no provision is made for writing, and the reason is quite obvious.

Materials.—The materials used by the workmen are obtained from the stores by means of a foreman's requisition. The stores clerk enters upon it the exact weight issued and cancels it by initialling. At the end of each day all the requisitions are made up in a bundle and sent to the prime cost office. A clerk here enters the rates from the manufacturer's invoices at which the materials are to be charged, plus a charge for handling and storing; also the total values of each item on the requisition, afterwards the items are transferred to the accounts of the several orders to which they belong.

As regards the cost of materials, the author's experience leads him to think that the invoice price of the materials as delivered to the stores in a small works, plus 5 per cent. to cover the costs of handling and storing is about the rate that should be charged in order to make the stores department self-supporting, thus relieving the establishment charge by charging this item to the individual orders concerned.

Establishment Costs.—It is usual to group together under the heading "establishment costs" salaries, gas, water, rents, taxes, office expenses, depreciation and other charges of a non-productive character, and spread them over the year's working, apportioning them between the individual orders executed upon some predetermined method. There are possibly as many ways as shops of apportioning this charge to individual orders, and for each way probably very cogent reasons could be given to show that although in some way or other the apportionment is not just, yet in most instances the results obtained are deemed good enough.

Upon consideration the author adopted the following method of distributing the establishment expenses between the orders in progress. Usually the staff in the office are entitled to a month's notice, so that the total costs do not vary sensibly during any individual month. The rates and taxes vary from year to year, but for the immediate purpose are quite easily estimated. Hence, at the beginning of each month it is easily arranged that the "prime cost" department can be notified that the total cost of the establishment for the ensuing month will be, say £200. Next assume that for the first week in that month the total number of producers are 100, then during that week £50 will be expended to keep the 100 men employed, a charge of 10s. per man per week. Assume that the time worked by the man in that week to be 55 hours, then the establishment charge per hour will be 120 pence ÷ 55, or $2\frac{4}{11}$ pence per hour. At the end of that week, say 35 hours has been booked in all against a certain order number, then the share of the establishment cost that must be paid by that order is $35 \times 2\frac{4}{11} = 82\frac{8}{11}$ pence, say 6s. 11d. The 35 hours is the sum of all time charged to that order number by all the individuals who have contributed anything towards the completion of that particular order.

Suppose now that the foreman engage 20 more men the next week, so that overtime is avoided, then the rate will be reduced, thus the establishment charge would be

$$\frac{50 \times 240}{120 \times 54} = \frac{50}{27} \text{ pence,}$$

a little less than 2d. Thus for 35 hours work the share of the establishment charges would equal $\frac{50}{27} \times 35$ pence, or 5s. 5d.

The changes in the value of this fraction at once indicate certain facts to the observant manager. If the cost increases it shows (1) that the costs of management have increased, if the number of hands and hours worked are unaltered; or (2) if the cost of management is unchanged, then it is clear that they are short of work in the shops, for the product men-hours is less.

This system makes no distinction between the grades of workmen employed, it places them all at the same rate; but this is no real injustice to any concerned, for the boys, pupils, &c., naturally cost more for supervision than the workman, and should be charged *pro rata*, which is actually done by this scheme.

System in Prime Cost Office.—The duties of the prime cost department are now quite plain. Each morning finds two bundles, one containing the time cards, the other the store

Workman's No. *76*					*March 7, 1912.*			
Machine No. .. *20*					Rate per hour .. .. *9d.*			
					Charges .. .. .. *2s. 6d.*			
					Total Rate per hour .. *3s. 3d.*			
Order Nos.	Time	Cost			Order Nos	Time	Cost	
2317—1	*5*		*16*	*3*				

FIG. 2.

Workman's No. *44.*																*March 9, 1912.*
																Rate per hour .. .. *9d.*
																Charges ,, ,, ... *1d.*
																Total Rate per hour .. *10d.*
Order No	Assisting	Cranes	Cleaning	Reamering	Tapping	Fitting	Assembling	Adjusting	Moulding	Coremaking	Pouring	Mixing Metal &c.	Total Time	Cost		
3521—10						*3*							*3*		*2*	*6*
2416—8							*2*						*2*		*1*	*8*
2518—7				*1*	*1*	*2*							*4*		*3*	*4*

FIG. 3.

requisitions; each of these has to be priced and transferred before the day's work is done, for it has to be clearly understood that each day's work must be completed in that day. It cannot be too strongly insisted upon that prime costs to be of use must be true records, and after a lapse of 24 hours it is wonderful how difficult it is for the majority of men to explain or recall what they actually did, thus leading to compromising in details; hence the author strongly insists that each day's work must be completed on the day, and no arrears left to handicap the due performance of the next day's duties.

In order to reduce the clerical work to the smallest limits, the author favours the method of sub-dividing each customer's orders into a group of orders, each individual order being treated as a complete unit in itself. This sub-division should be done upon a uniform plan, so that the work of the estimating and drawing offices is facilitated as much as possible. In tendering for contracts it is often necessary to group together certain units, in order to find the combination that offers the lowest prime cost. The drawing office, in its work of designing, as the result of experience, modifies a certain detail in order to reduce the labour cost, and it wants to see if in the shops the expected gain is realised or not. Processes that are costly in one shop may be in another relatively inexpensive, and these individual characteristics should be clearly shown by the prime cost records.

When the pricing of the time sheets is completed, then the amounts are transferred to the accounts for the respective orders in a book (see diagram Fig. 4) by simply entering up the man's number, the machine number, the number of hours, and the amount. On the opposite page is entered up the

material details. At the end of each week the hours are totalled, and the establishment costs entered up, thus everything is completed as one goes along. The time and material sheets, sorted into their order numbers, are tied together and filed. When the order is completed, then these weekly bundles are tied up together and filed away under their order number in case of need, the prime cost account is then closed, and an abstract is made and entered upon a card and sent to the estimating department, who enter upon it their estimated cost, recording in their files the amounts for reference in the next similar tender they have to make; the card is passed on to the accountant's department, where the customer's invoice is prepared, and the matter closed.

The author claims that the system here outlined is capable of recording the truth, with a minimum expenditure upon clerical labour and consumption of stationery, and where necessary can be elaborated to include smaller details, but on the whole it is submitted that this scheme gives as much information as can usually be made use of satisfactorily, and at the same time gives the data readily for reporting weekly to the manager the total expenditure upon every order in progress, thus enabling him to follow expenditure and income continuously. It is only in this way that a business can be intelligently controlled and dividends earned.

The diagrams and forms show how the various accounts are interlocked with each other, and mutually check each other so that no error or slip can remain long undetected, especially if the weekly balance is carried out, and when once the system is started properly there is no difficulty in obtaining this result without additional appreciable cost.

Order No. *362-12.* Date Issued *26th Oct., 1910.* Date Completed *23th Nov., 1910.*

Workman's No.	Machine No.	Drawings	Patterns	Iron Castings	Brass Castings	Forgings	Smiths	Turners	Planing	Milling	Shaping	Grinding	Drilling	Establishment	Iron	Steel	Brass	Zinc	Phos. Bronze	Lead	White Metal	Timber	Painting Packing	Wages £	Wages s.	Wages d.	Cost of Materials £	Cost of Materials s.	Cost of Materials d.	Totals £	Totals s.	Totals d.
																lbs.	lbs.				lbs.	ft.										
36	42	..	5					..	..					5	..	..	..						..		4	2						
28	10	..	2			..				..	..	..		2	..		..	..	..	..		3	..		1	8						
33	5	..		..	5									5			20				..				0	0						
14	..	..		..		10	..		..					10	..	150	..	..	..		..		..		8	4						
82	19		..		..	..		9	..		..	..		9	..	..		..	..	..		..	..		9	0						
		..	..	..			..	9		..		..	..	9	..		..	..	..			..			9	9						
91	17	..	..	..					..	..	7		..	7	..	5	..					..	..		5	10						
45	18			..	..	..		..				..	3	3				..	..			..	..		1	6						
55	32	..			..	..		..		..	..		5	5				..	..	..		..			2	6						
110			..				10	..	..	..	..		..	10	..	..					..				9	2						
112		..	..			..	15		..	..		..	..	15	..						5	..			13	9						
120	..				..				..	..	..		..	2	..	..	..						2		1	0						
																														3	6	8
																155	..	..		..		..						15	3			
																	20				..		..	..				13	4			
																					5								10			
																						3							4			
																														1	9	9
																								5 % ..							1	6
														82 hrs.										*Establishment* ...							13	8
			7		5	10	25	18			7		8	at 2d.										*Manufacturing Cost*						£5	11	7

FIG. 4.

ESTIMATING.

The work of the estimating department is to ascertain the cost of production based upon experience, if available, supplemented by good guessing. In the business of estimating it is necessary to find (1) the amount of raw material needed; (2) the time requisite for the work done on the raw material; (3) the amount of charges that must be added to meet the cost of delivery, maintenance, &c., required by the contract; (4) the share of the establishment cost that will be incurred in executing the contract.

Obviously therefore the work of estimating is very similar to that of prime costing, save that the time sheets and stores requisitions must be guessed. This business of guessing is made easy if the prime costs are accurately recorded on a suitable basis for use. Frequent collaboration is necessary between the departments concerned, so that all work done in the shops is suitably split up into separate orders, to assist the estimators in guessing their answers to future enquiries.

Materials.—The amount of raw material required is usually calculated from the drawings without much difficulty, and the results obtained may be usually treated without any corrections as finished weights. When there are no drawings of the work proposed then guessing in some form or other must be done. If there are no precedents available, an approximate design must be made so that the principal dimensions are known, then by guessing the details an approximation can be made. If precedents are available, then a curve can be constructed which, after being smoothed, can usually be relied upon to assist in obtaining a fairly truthful guess. Curves of weights and costs should be laid down and kept constantly up to date.

As each successive article is made, its weight, &c., should be spotted upon the curve, thus in time the average weight as well as the maximum and minimum variations from it will be well known, and any unusual deviation would automatically call attention, and enquiry would be made to learn the cause of the discrepancy.

Guessing in many instances proceeds along the lines of a stress formula. For example, a steam cylinder usually consists of a barrel and two covers, with a steam chest. The strength of the cylinder is determined by the formula

$$t = \frac{pr}{f} + k;$$

and assuming that the safe stress (f) remains the same, and that the maximum pressure (p) would be the same for a series of sizes, then it is clear that the thickness (t) would increase proportionately to the radius or diameter of the cylinder. Consequently if the cylinder had to be twice the diameter of the nearest precedent available, and the stroke increased one-half, then the weight of the large barrel would be six times that of the smaller. Similar reasoning would also allow the cover weights to be guessed quite accurately enough.

In bridgework, roof construction, &c., formulæ for weights in terms of stress are frequently useful for estimating the amount of raw material needed. Prof. Claxton Fidler gives an account of the derivation of such formulæ for use in bridge design. In machines, however, such formulæ cannot be generally used, for the determination of the proportional dimensions does not depend upon the intensity of the stress alone, so that the estimator must use such data as may be available, and afterwards test his result in every way that the precedents recorded will allow, supplemented by any stress formulæ applicable to that class of work.

Time.—This item of time is at first sight one that appears should be readily calculated by the draughtsman from the drawings which show the surfaces which require tooling. Castings, however, do not usually come from the foundry with the core holes exactly concentric, as rattling and drawing the patterns cause considerable variations in the amount of metal that must be removed. Whilst in the machine shop time is lost in setting the work true, waiting for the crane, also labourers in most shops have a habit of being busy at a distance away just at the time their assistance is required, and factors to allow for these losses of time are very difficult to introduce into any formulæ for guessing. Probably on the whole the plan of making the foreman guess is as good as any other.

Charges for Completion.—The third item is an important one, for carriage is an item that easily mounts up, if care has

not been taken to discover the best route. Not only is it important to know the weight of individual parts, but their size must be determined. For example, the stern post of a large steamer may weigh, say 50 tons, but the rate per rail for that article may be very exceptional if its dimensions are such as to foul both roads, and so necessitate special traffic arrangements whilst it is being transported. Another difficulty, when shipping, is to pack the goods in such a manner that the weight per cubic foot is sufficient to ensure the minimum rates per ton. Crane capacities must not be lost sight of, otherwise extra costs will be incurred in handling. Any such extras are very irritating, especially if the tender had to be submitted with a very small margin.

Many contracts exact onerous terms of engineers, and much money has to be laid out upon the work before any payment becomes due. The clauses relating to the mode of payment require careful consideration, so that interest on all the sums outstanding may be included in the estimate. It is the practice in many cases to withhold sums up to 25 per cent. of the contract for six or more months after the plant has been put into operation; in such cases interest upon this outstanding sum must be added, together with from 4 to 8 per cent. for maintenance of the plant for the term. Some consulting engineers frame their specifications as though contractors are glad to lay out capital in the execution of their customer's work for six to twelve months, and maintain the plant free of cost, whereas the purchaser cannot evade the charges, however craftily the specifications are worded, if the estimator does his work properly.

Establishment Costs.—The proportion for establishment charges is quite easy, being an average value per hour, and 5 per cent. on value of the materials. In addition to the preceding items, guided by experience, some percentage must be added to cover the cost of incidentals, such as bad castings, wasters, &c. A certain proportion of such events occurring in every establishment with which the author has had acquaintance, and in spite of the best system possible, he feels confident that such luxuries will never wholly disappear.

It is the experience of the author that only some 5 per cent. to 8 per cent. of the tenders prepared are successful as a rule. Of course where there is some special line which is universally required, then a much larger number of tenders will be accepted, but these monopolies are very few and far between.

LOSS OF MINERAL AREAS IN SOUTH STAFFORDSHIRE.

AT a meeting of the South Staffordshire and Warwickshire Institute of Mining Engineers held at the University, Edmund Street, Birmingham, on the 19th ult., a paper was read by Mr. Isaac Meachem on "The loss of mineral areas in South Staffordshire." The author said the question of our national coal supply had for some years been a matter of deep interest. Its exhaustion appeared to be so rapid that to some extent a feeling of alarm had been raised. The Royal Commission on Coal Supplies had held its sittings, taken evidence, and made its report. One part of the work of the Commission had been to enquire into the question of waste in working, loss of coal in barriers, and support to buildings and other properties. In connection with the question of waste, there was one feature, relating more especially to the loss of coal left as support to the surface, which had not received the attention that it deserved, and was but lightly touched upon by the Commission; yet it concerned the South Staffordshire district to a serious extent. Despite all the care taken to protect buildings from damage, damage was often alleged; and the mine-owner was compelled either to pay extortionate compensation, or to fight out his case in the law courts.

In the South Staffordshire district the mineral outcrops were unusually extensive in proportion to the area. Early mining operations were all in the shallow mines round those outcrops, so that a large proportion of the area of the coalfield was broken ground, ready to receive the rain and pass it into the mines. Under the ægis of the South Staffordshire Mines Drainage Act, a scheme had now for some years been worked by a Board of Commissioners with the guidance of a capable engineer. The Commissioners, however, had been but partly successful in their task; and it would appear that under present conditions many million tons of valuable minerals would be irretrievably lost, unless another scheme, more far reaching and powerful than the present one, were formulated and adopted. Upwards of 40,000,000 tons of coal and ironstone were in the earth, which would be utterly lost unless some scheme was devised and set to work to rescue them. The loss of this mineral wealth was a serious matter.

The question of right of support was a serious one, as comparatively small properties required a considerable area of mine for support, the area increasing with the depth of the mine. To support a property of an acre in area required nearly 36½ acres of mine, and if there were but three seams of coal, each, say, 4ft. thick, the amount of coal lost would be 600,000 tons. The recent judicial decision in the case of the London and North-Western Railway Company v. the Howley Park Coal and Cannel Company, in which it was laid down that the railway company—and as a natural result canals also—are entitled to lateral support outside the prescribed limit of 40 yards, had added to the difficulty of the working of mines, as all were aware who were concerned in the working of mines near to railways or canals. That decision would also have the effect of forcing mine-owners to leave valuable minerals in the earth in order to avoid litigation.

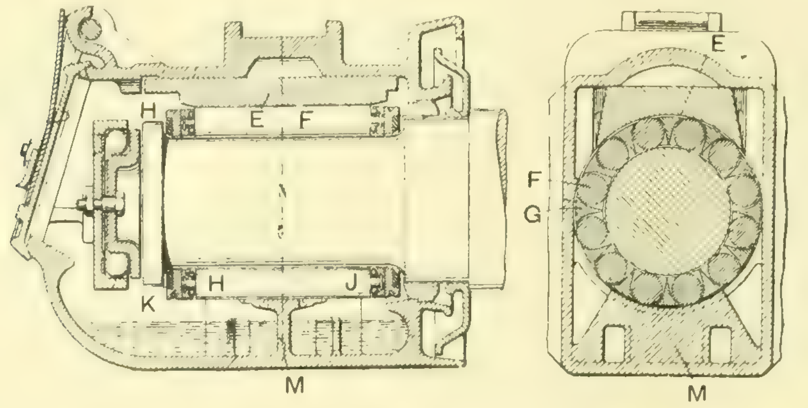
The question now was, could anything be done to lessen or stay this enormous loss of mineral, both in the areas lost in support of the surface and in respect of the areas submerged by water? His view was that if property should be threatened with damage or destruction by the working of minerals under, or subjacent to, the property, the property threatened should be valued by independent valuers appointed by the Government, and also the portion of the mines required for the support of the property to be valued. This valuation should be made on, say, two-thirds of the value of sale-tons at the low rate of 1,200 tons per acre. If the value of the mines on this basis exceeded the value of the surface property, then the mines under and subjacent to the property should be worked, and the surface-property owner compensated for the damage done to the property. Such damage should be estimated by the aforesaid values, and, in case the property were completely destroyed, the full value of it should be paid.

For the purpose of assessing the amount to be paid by the mine-owner or lessee, as the case might be, the area of the mine necessary for the support of the property, and the radius of such area from the property to be supported to be not more than half the depth of the seam should be estimated. An estimate based on the result of the previous year's working should be made of the profits per acre on the area indicated above. The mine-owner should pay a sum not exceeding one-third of the profits, as estimated on that area as his share, if the property were totally destroyed; but if the property were only damaged, then such a proportion of that sum as the amount of compensation for damage bore to the value of the property. The remainder of the compensation, if any, should be paid by the State as the share of the community generally. By some such means expensive litigation would be avoided, and property owners compensated, and that without crippling the mine-owner. The rights of the community generally in their share of the national wealth would be met, as it would profit by employment, by trade generally, by the rates and taxes paid, and by the benefiting of contingent industries through the working of minerals which would otherwise be lost.

As to the freeing of mines from water, if the State appointed a committee of experts to assess the value of the minerals submerged, at, say, two-thirds of the market value, the State should advance a sum of money not exceeding one-third of such value, for the purpose of freeing the mines from water. A rate, which should not exceed 6d. per ton, should be imposed on all minerals raised from the hitherto submerged area, the remainder of the cost, if any, to be the contribution of the community generally. Thus the money would be used absolutely for the purpose required, the interest and sinking fund being the additional national wealth recovered to the nation. If some such scheme could be devised for the South Staffordshire district, the benefit derived therefrom would be enormous; and the fear of an early exhaustion of the minerals in its area and consequent industrial ruin would be postponed for some generations.

JOURNAL BEARINGS FOR ROLLING STOCK.

A DESIGN of journal box for railway rolling stock, in which ball and roller bearings are employed, has recently been patented by J. A. Perkins, Omaha, Douglas, Nebraska, U.S.A. The general construction of the bearing is clearly shown in the sectional views. A roller raceway is employed, comprising a body member E having a bearing surface concentric with the journal. Interposed between the journal and the raceway E are a plurality of solid rollers F, mounted in a cage H provided with a plurality of ribs G forming roller spaces having reduced guiding recesses at the ends thereof for the reception of cups H carried at the roller ends and having interposing balls J, to prevent friction and consequent wear upon either the journals or raceways, or upon the rollers themselves at the ends thereof, and to permit, because of the radial movement possible to the roller ends, automatic adjustment of the roller bearings to diametrical differences in the journals, raceways,



JOURNAL BEARINGS FOR ROLLING STOCK.

and rollers, and to structural inequalities and imperfections therein, and permitting also independent end movement of the rollers. To take the impact of the cage against the shoulders of the journal, annular rings of fibre K are provided, as shown.

In view of the fact that the external diameter of the journal is not as great as the internal diameter of the assembled bearings, the rollers clear the journal when beneath the same, and bear directly upon the track M, this release from the journal being possible because of the radial movement of the rollers in the cage. The release, and subsequent engagement, being gradual because of the slight difference in the radii of the bearings and of the track and raceway block, permits the journal and rollers to clear themselves of scale or other matter, and permits also the lowermost rollers to adjust themselves previous to another cycle of movement

Fatal Steam Pipe Explosion.—An explosion occurred about six o'clock on Saturday, the 9th inst., at Messrs. Ellis and Everard's stone quarry at Bardon Hill, Leicestershire. A number of men were standing in the boiler-house just prior to commencing work, when one of the steam pipes burst. The men scrambled to get out of the building, but two of them took a wrong turning, and so lost their lives. One died almost immediately, and the other was so badly scalded that he died about five hours later. Immediately the pipe burst the boiler attendant shut the boiler stop valve, and injured himself in so doing, though, happily, only slightly.

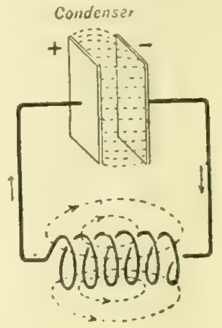
New Battle - Cruiser.—The Admiralty have, we learn, provisionally accepted the tender of Messrs. John Brown & Co. for the construction of the battle-cruiser for which financial provision is made in the Navy Estimates for 1911-12. The contract is for hull and machinery. Very few authentic particulars of the design of the new ship have been allowed to appear, but it is understood that she will be the largest, the fastest, the best protected, and the most powerfully armed ship of the type in the world. The vessel will probably have a length of between 670ft. and 680ft. between perpendiculars, and the designed load draught about 28,000 tons. The estimated shaft horse-power for the designed speed of 28 knots will be between 90,000 and 100,000.

RADIO-TELEGRAPHY.*

BY PROF. G. W. OSBORN HOWE, M.Sc., M.I.E.E.

IT is not my intention to describe in detail any of the apparatus employed in the various so-called systems of radio-telegraphy, but rather to explain, in as simple a way as possible, the general principles underlying all these systems, and to indicate the directions along which improvements have been made during the last few years.

Before considering the question of radio-telegraphy itself, one should have a clear idea of what is meant by an electrical oscillation, for electrical oscillations constitute the alpha and



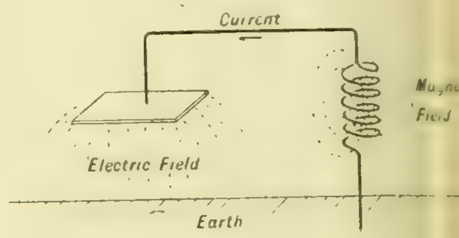


FIG. 2.

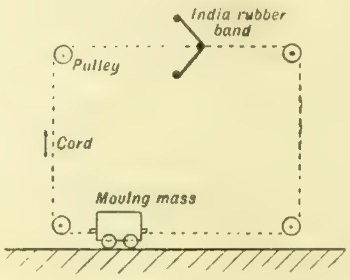


FIG. 1.

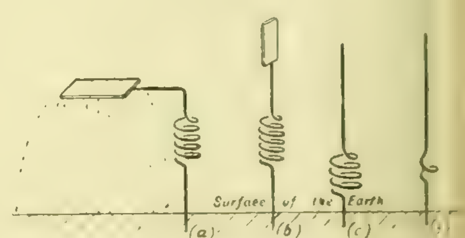


FIG. 3.

the omega of radio-telegraphic communication. We are all familiar with examples of mechanical oscillations such as occur with the pendulum, the vibrating reed, and the violin string. If we examine these well-known phenomena a little more closely, we find that in every case there is a continual transformation of energy. At one moment the oscillating mass is moving rapidly, and possesses, therefore, a store of kinetic energy depending on the mass and its velocity. The next moment the moving mass is brought to rest, its kinetic energy having been all expended in overcoming gravity, or in stretching or compressing a spring. The energy has not been lost, however; it is stored in the spring, or, in the case of the pendulum, stored as the potential energy of the bob, which is now at its highest point. The next moment this static energy is once more retransformed into kinetic energy as the heavy mass is set into motion, and so the transformation goes on until, failing a continual supply, the energy is all dissipated in the unavoidable frictional losses, and the oscillation is damped out. The rate at which it is damped out is called the decrement of the oscillation. We see that the two essentials to mechanical oscillation are—(*a*) kinetic energy associated with motion; and (*b*) static energy associated with displacement.

Now the electrical oscillation is in every respect analogous to the mechanical. It is the electricity which oscillates or moves backwards and forwards. At one moment the electricity is in motion, producing what we call an electric current, at the next moment the electricity is at rest, and for a moment there is no current, but merely a stationary charge. When the electricity is in motion, the current passing round a coil of wire produces through and around the coil a magnetic field, and this magnetic field represents, or is the manifestation of, a storage of energy in the ether. Just as the kinetic energy of the moving mass is proportional to its mass and to the square of its velocity, so the energy of the magnetic field is proportional to what is called the inductance of the coil and to the square of the electric current.

In circuit with the coil is some form of condenser, often one or more Leyden jars, consisting simply of two metal plates

* Paper read before the Royal Society of Arts, January 31st, 1912

separated by air, glass, or oil, or some other insulating material. The result of the current is a transfer of electricity from one plate to the other until, when the current, and with it the magnetic field, finally falls to zero, all the energy which a moment ago was stored in the magnetic field is now stored in the space between the two plates as an electric or electro static field. There is at this moment a large pressure difference or potential difference between the two metal plates, and the potential difference causes a current to flow through the coil in the reverse direction, until, a moment later, the condenser is completely discharged, and all its energy is once again stored in the magnetic field of the coil, only to be once again re-stored in the condenser in the reverse direction. Here, again, the oscillation will be gradually damped out, the frictional resistance of the mechanical analogies being replaced by the electrical resistance of the circuit.

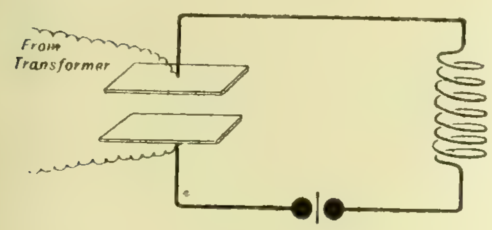


FIG. 4.

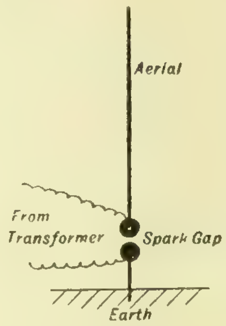


FIG. 5.

The frequency of the mechanical oscillations—*i.e.*, the number of oscillations per second—depends on two things, viz., the mass, m, of the moving part and the yield or displacement, y, of the spring to unit force. In the electrical oscillation, the frequency depends on the two analogous quantities, viz., the inductance, L, of the coil and the capacity, K, of the condenser, by which we mean the electrical displacement or quantity of electricity transferred from one plate to the other by the application of unit potential difference.*

If the plates of the condenser in Fig. 1 be pulled further apart we merely decrease its capacity and increase the frequency of the oscillation. No fundamental difference is made by using the earth as the lower plate of the condenser (see Fig. 2). Figs. 3 (a), (b), and (c) show successive alterations to the shape of the upper plate and its distance from the earth or lower plate, until it has ultimately degenerated into a mere continuation of the wire of which the coil is made. Similarly, by decreasing the number of turns in the coil (Fig. 3 (d)) we decrease its inductance and still further increase the frequency. The limit is reached when our oscillatory circuit has become a vertical straight wire. The upper part of the wire acts as one plate of the condenser, while the lower part fulfils the functions of the coil. The two functions of the wire gradually merge into one another, and only at the extreme ends can the wire be considered either a pure condenser or a pure inductance. A plain vertical wire will therefore have a natural frequency of oscillation, which can be shown to be 75 million divided by the height of the wire in metres. This gives the number of complete double swings per second. The natural frequency of a given vertical wire can be reduced by increasing its inductance—*i.e.*, by inserting a coil of wire at its foot as in Fig. 3 (c).

To set up oscillations in any of these circuits, the circuit is broken by means of a spark-gap, and the condenser is connected to the high-tension terminals of a spark coil or of an alternating current transformer (Fig. 4). This charges up the condenser and raises the potential difference across the spark-gap to a very high value (5,000 to 30,000 volts) many times per second. If the distance between the spark balls be suitably adjusted, the tension in the air-gap will succeed in breaking it down, and the oscillatory circuit will be completed through the spark. The condenser will discharge through the spark and the inductance, and the electricity will surge backwards and forwards in the way we have already considered.

This must all occur during the very short interval that the spark-gap is bridged by the spark, for when the spark ceases the circuit is opened, and no further oscillation is possible until the condenser is once more charged, and the potential difference raised once again to the value required to break down the spark-gap.

In Marconi's earlier stations the aerial was set oscillating in this way (see Fig. 5). This was called working with a plain aerial, but is now more generally known as a precharged aerial. It is little used at the present time.

There is an important difference between the oscillations set up in such a circuit as that shown in Fig. 4, and that set up in the aerial in Figs. 3 (d) and 5. In Fig. 4 the disturbance is confined to the immediate neighbourhood of the circuit, and the energy alternates between the magnetic field of the coil and the electrostatic field of the condenser with only one source of loss, viz., that due to the resistance of the circuit. In Figs. 3 (d) and 5, however, where the electric and the magnetic fields alternately occupy the same space, the disturbance is more far-reaching, and the train of oscillations occurring with each spark causes a train of waves in the ether to spread out from the aerial in all directions, like the ripples from that point in a lake where a stone has just entered the water. These pulses or waves carry with them, and are the manifestations of, energy, so that the oscillations in the aerial are damped out more rapidly than would be the case were the only loss of energy that due to resistance.

The arrangement shown in Fig. 5 was soon given up in favour of another arrangement known as a coupled aerial, and shown in Fig. 6. This figure may be taken as representing diagrammatically the sending apparatus of almost every radio-telegraphic station in commercial use at the present day. Here we have two oscillatory circuits—one called the primary, containing an inductance, L_1 a condenser, K, and a spark-gap, G, exactly as in Fig. 4; and the other the aerial itself with a coil or inductance, L_2 at the base exactly as in Fig. 3 (c). The coils L_1 and L_2 are coupled together—*i.e.*, they are placed so near that the magnetic field produced by a current in L_1 passes to a certain extent through the turns of L_2. L_1 and L_2 constitute the primary and the secondary

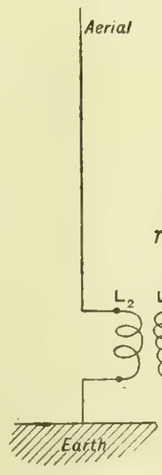


FIG. 6.

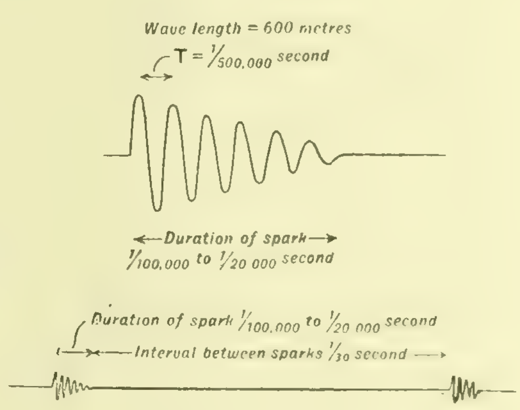


FIG. 7.

of a transformer, and the oscillatory currents occurring in L_1, whenever a spark passes at G, induce electromotive forces in L_2, and set up oscillations in the aerial, especially if the two circuits are adjusted to have the same natural frequency. This latter operation is called tuning the circuits, and is exactly analogous to the adjustment of a violin string until it has the same natural frequency of vibration as the corresponding string in the piano.

Each spark causes a damped oscillation in the circuit, L_1, K, G (Fig. 6), and this causes a somewhat similar oscillation in the aerial, from which electro-magnetic waves are radiated in every direction over the earth's surface. The total time occupied by the aerial in sending out the train of waves may be from $\frac{1}{100000}$ to $\frac{1}{5000}$ of a second, as shown in Fig. 7, where the oscillatory current is represented as making about six complete oscillations before being completely damped out.

* Kinetic energy $= \frac{1}{2}mv^2$. Energy in spring $= \frac{1}{2}yf^2$.
Magnetic energy $= \frac{1}{2}LC^2$. Electrical energy $= \frac{1}{2}KV^2$.
Frequency $= n = \frac{1}{2\pi\sqrt{m.y.}}$ or $\frac{1}{2\pi\sqrt{KL}}$.

Nothing further will happen until the next spark occurs, which in Fig. 7 is supposed to be one-thirtieth of a second later.

Let us now turn from the sending apparatus and follow the damped train of waves which, as the result of the spark, has been sent out from the aerial, and is travelling in all directions through the ether with the velocity of light—viz., 300,000 kilos. per second.

Every vertical conductor, whether lightning conductor, rain-water pipe, or radio-telegraphic aerial, encountered by

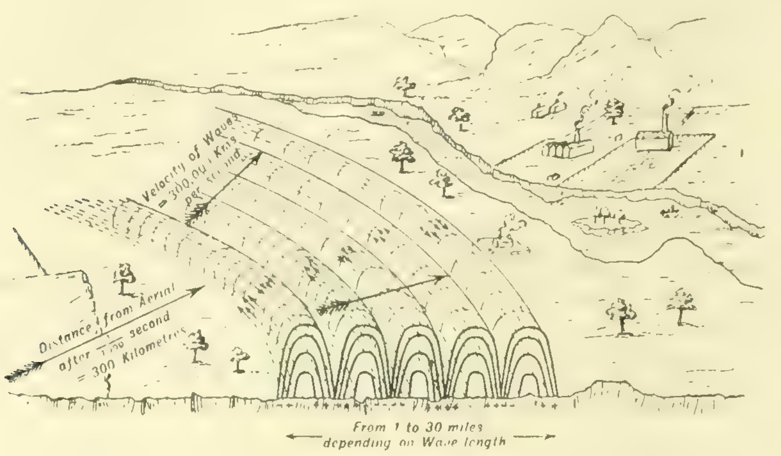


Fig. 8.

the electro-magnetic wave has electromotive forces induced in it, and extracts a little energy from the wave. If the vertical conductor, which we have already seen to be an extreme form of oscillatory circuit, be tuned so that its natural frequency is equal to the frequency of the passing wave, the effects of successive impulses will be cumulative, and the oscillatory current produced in it will be large compared with the current which would be produced were the aerial not tuned to the received wave.

To complete the communication between the two stations, it only remains to detect the presence of this minute high-frequency current in the receiving aerial. The most sensitive and probably the most widely used method is shown diagrammatically in Fig. 9. The currents in the coil L_3, at the foot of the aerial, induce currents in the circuit, K, L_4, which is tuned to have the same frequency and loosely coupled with L_3. The tuning is carried out by means of the adjustable condenser, K, which is varied until the best results are obtained. After what has been said it will be readily understood that in transferring the energy from the aerial to the loosely-coupled tuned circuit K, L_4, there will be a weeding-out of all electro-magnetic disturbances which have not the correct frequency.

The detector shown is of the mineral contact type, consisting simply of a piece of zincite in contact with a piece of pyrites. Many other minerals can be used, but nothing seems to exceed these two in sensibility. A telephone receiver is placed in series with the detector across the terminals of the condenser K. The telephone receiver is shunted by a condenser of such a capacity that it acts as a conductor to the high-frequency oscillations, enabling them to pass through the detector without passing through the highly inductive telephone receiver; to currents of telephonic frequency it must act as an insulator, thus forcing them to pass through the telephone receiver. The cell B is sometimes used to improve the action of the detector, but it is not essential. Whenever high-frequency current passes through the detector, the point of contact is heated, thermal electromotive forces are produced, and a small current is sent through the telephone receiver. This current ceases as soon as the point of contact returns to its normal temperature. The sounds thus produced in the telephone receiver constitute the signal.

Having thus glanced at the receiving station, let us now return to the sending station, and consider the various points a little more in detail. With the ever increasing number of radio-telegraph stations, it is essential to avoid, as far as possible, interference with other stations, and since the waves emitted by an ordinary aerial radiate equally in every direction over the earth's surface, the receiving apparatus should be very discriminating and respond to those waves intended for it, while remaining relatively unaffected by waves possibly far more powerful, but sent out by other aerials. To make this possible it is essential that the waves sent out by every station should be of such a nature that discrimination is possible.

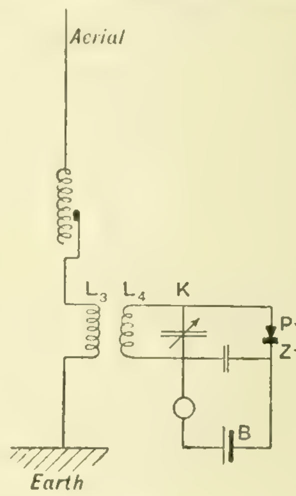


Fig. 9.

Now we have seen that to discriminate against any wave which we do not wish to receive, we must tune our receiving apparatus—both aerial and secondary circuit—to some other frequency, either higher or lower, than that of the disturbing wave. If the sending station with which we wish to communicate is sending with exactly the same wave-length as the disturbing station, we shall tune out both stations at the same time, unless one is much stronger than the other, but if the wave-lengths differ it may be that, when tuned up to the required station, the interfering station is tuned out—*i.e.*, if not inaudible it is so soft as to cause no trouble. The sharpness of tuning which can be obtained, or the amount by which the two sending stations must differ in wave-length to allow of the tuning out of one of them, depends entirely on the nature of the train of waves sent out as the result of each spark. If it be a well-sustained train—*i.e.*, if the damping or decrement be small—very sharp tuning will be possible, but if it be very rapidly damped out the disturbance will be more of the nature of an explosive shock than of a train of waves, and it will be found impossible to tune it out. A plain or pre-charged aerial must always be a great offender in this respect, for, whatever the nature of the subsequent train of waves, it always commences with a sudden shock of no definite frequency, whereas in the coupled aerial the shock is confined to the primary circuit and the oscillatory current is gradually built up in the radiating aerial.

Consider now the effect of varying the coupling between the two coils, L_1 and L_2, in Fig. 6. If the coupling be loose—*i.e.*, if the coils be far apart—the transfer of energy from the primary circuit to the aerial will be slow, the reaction of the aerial on the primary circuit will be small, and the currents will be as shown in the oscillogram, Fig. 10, where the

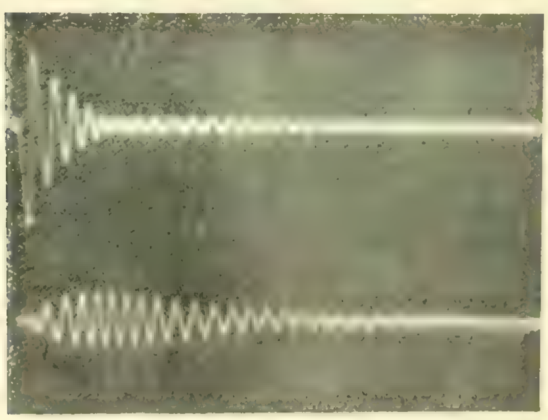


Fig. 10.

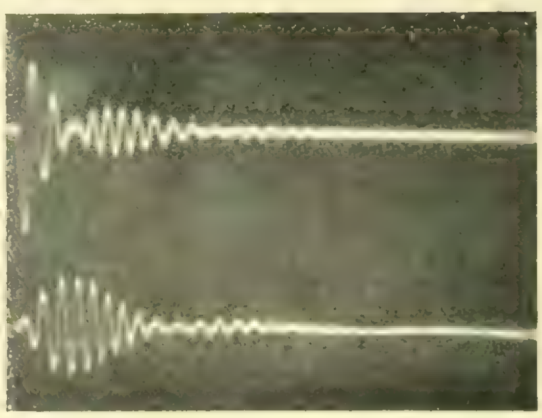


Fig. 11.

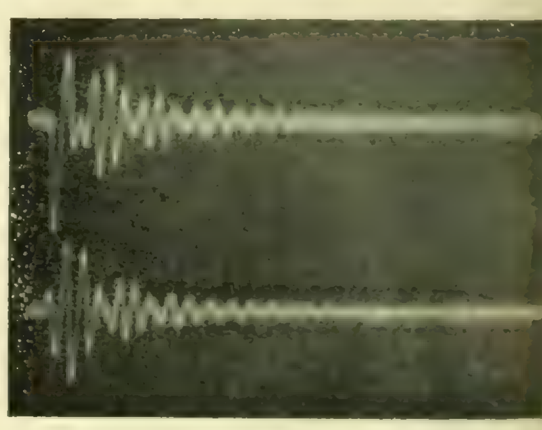


Fig. 12.

upper curve represents the current in the primary circuit, K, G, L_1, and the lower curve that in the aerial. The lower curve will, therefore, indicate the nature of the train of waves sent out by the aerial. The transfer of energy being slow, much of it will be dissipated in the spark-gap, and it is impossible with such an arrangement to transfer more than about 30 per cent. of the primary energy to the aerial. If we try to improve the efficiency by coupling the coils L_1 and L_2 more closely, and thus hastening the transfer of energy to the aerial, a new difficulty arises. When all the energy has been transferred to the aerial the current in the primary oscillatory circuit will have fallen to zero, but the primary circuit is still closed through the hot spark-gap, which does not instantly lose its conductivity, and the aerial coil L_2 will now act as the primary of the transformer and L_1 as the

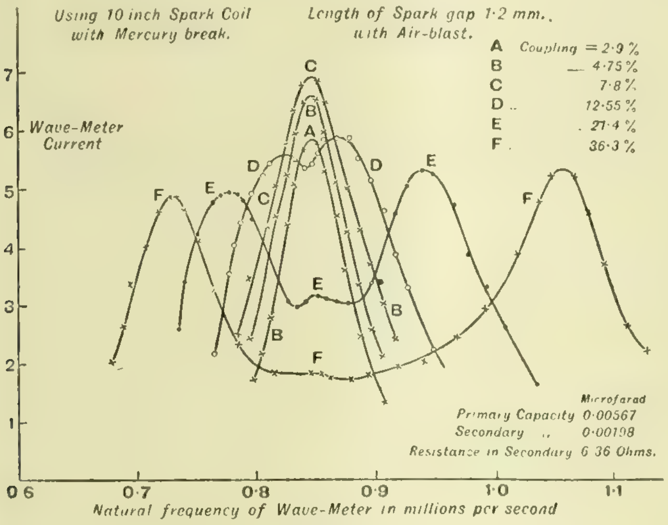


FIG. 13.

secondary, and the energy, or what remains of it, will surge back into the circuit, L_1, K, G. This phenomenon is well known in all coupled oscillatory systems, and can be easily shown by suspending two pendulums from the same flexible support. The oscillograms, Figs. 10, 11, and 12, were taken under identical conditions, except that the coupling was made successively closer. The lower curve of Fig. 12 shows, then, the nature of the waves emitted by the aerial with tight coupling. There is no sustained train of waves of one definite frequency, but a succession of surges or beats. A similar result would be obtained from two aerials side by side, sparking simultaneously, but of different wave lengths. When we

little increase of efficiency to be obtained by increasing the coupling beyond this value. Most stations are working at present in this way with loose coupling, and consequent low efficiency.

In Fig. 13 it will be noticed that when the coupling is tight, the aerial oscillation contains waves of three definite frequencies—one high and one low, corresponding to the constituents of the beats—and one of the natural frequency of the aerial alone. This last shows that during a part of the time the aerial oscillated freely, uncoupled from the primary circuit. The reason for this can be seen from the oscillogram, Fig. 14. In the experiment to which Fig. 13 refers, the spark-gap was exposed to an air-blast, so that whenever the amplitude of the current in the primary oscillating circuit was small, there was a tendency for the air-blast to remove the column of hot air and metallic vapours, and thus extinguish the spark. This will obviously occur at a moment when all the energy is oscillating in the aerial, and will prevent it surging back into the primary circuit. The aerial will now continue to oscillate at its natural frequency until the energy has been radiated or dissipated. In Fig. 13 not only was there an air-blast, but the electrodes were comparatively large and the spark-gap short, so that no part of the spark was far removed from a large mass of cold metal tending to cool the heated air, and condense the metallic vapour, and thus lower the conductivity of the spark. This quenching of the spark was discovered in 1906 by Prof. Max Wien, and was afterwards taken up by the Telefunken Company, who are using a form of gap which has a strong tendency to quench. If the quenching of the spark is perfect, the currents will be as shown in oscillogram, Fig. 15. The gap acts as a very quick-acting minimum-current cut-out, and opens the primary oscillating circuit at the first opportunity—viz., when all the energy has been transferred to the aerial. The time during which the two circuits are coupled is very short, the loss in the spark-gap is reduced, and the major portion of the energy oscillates freely in the aerial and is radiated as a damped train of waves at its natural frequency. In this way it is claimed that 75 per cent. of the output of the alternator is transferred to the aerial.

It is obviously advantageous to shorten the duration of the spark as much as possible by tightening the coupling between the coils L_1 and L_2, and thus hastening the transfer of energy to the aerial. If this be overdone, however, the gap will fail to quench at the first minimum, and we may get the conditions shown in Fig. 16, or even Fig. 14, with a great loss

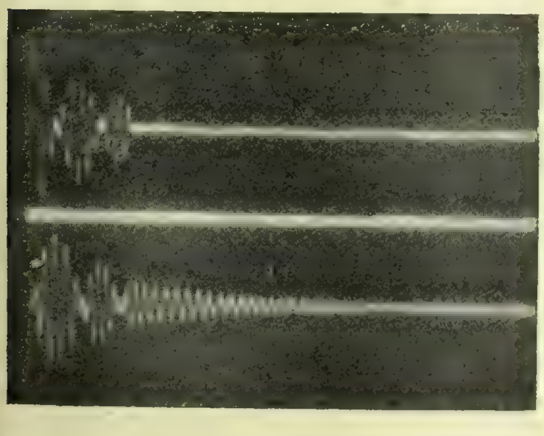


FIG. 14.

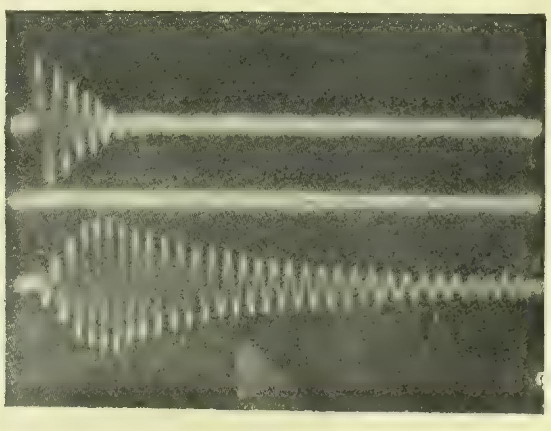


FIG. 15.

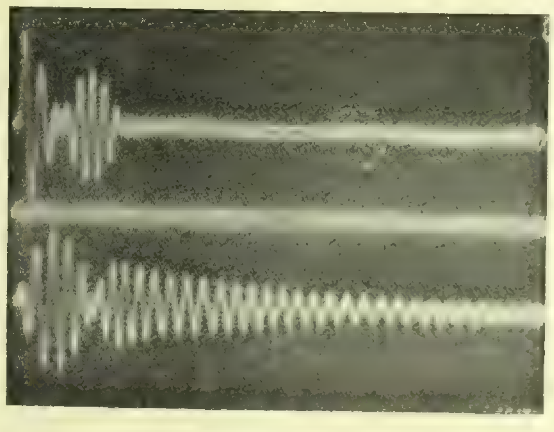


FIG. 16.

remember that the receiving apparatus is really a harmonic analyser, picking out and responding to waves of its own natural frequency, it is easy to see that the best result will not be obtained when the receiving aerial has the same natural frequency as the sending aerial. If the magnitude of the signals received, as the natural frequency of the receiving apparatus is altered, be plotted, curves are obtained similar to those in Fig. 13, where each curve refers to a certain given coupling in the sending apparatus.

With the ordinary spark-gap it is thus seen to be impossible to increase the coupling much above 7 or 8 per cent. without sacrificing sharpness of tuning, and thus causing undue interference with stations working at other wave lengths. Apart from the question of interference there is

both in efficiency and in sharpness of tuning. Wien first obtained quenching by the use of very short spark-gaps, and this is the method used by the Telefunken Company, although other methods have since been discovered. The spark is made to occur between the parallel faces of discs of copper or silver, placed about $\frac{1}{100}$in. apart, the discs being separated by thin annular rings of mica, which also serve to shut the sparking spaces off from the air. The number of these discs in series depends on the voltage and power required. This form of gap is undoubtedly complicated and expensive, not only in first cost, but also in upkeep, and the increased efficiency is obtained by the sacrifice to a certain extent of reliability and simplicity.

In addition to the interference from other stations, there

are the atmospheric disturbances due to lightning flashes somewhere on the globe. Each flash sends out a powerful electro-magnetic pulse of explosive suddenness. It is practically impossible to tune these out, as any frequency they may have is quite indefinite, and they are often much louder than the signals being received. It is here that great improvements have been made by giving the signals a clear musical note, easily distinguishable from the crackling noises due to atmospheric disturbances. A study of Fig. 17 will show that the pitch of the note heard in the telephone receiver depends entirely on the number of sparks per second, while

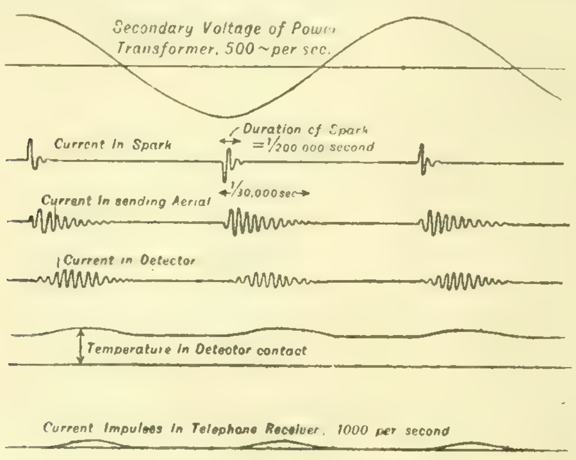


FIG. 17.

the purity of the note depends on the regularity of the sparks. By using a high spark frequency—*i.e.*, a large number of regularly occurring sparks per second—a clear musical note is obtained, but, contrary to expectations, the telephone receiver shows no greater sensibility than with the low spark frequency.

By using an alternating-current generator giving 500 cycles per second as the source of supply, and adjusting the voltage or gap until we get a spark every half-cycle, a pure note, with a pitch of 1,000 will be obtained—that is, a high, piping note easily distinguishable from other sounds. To

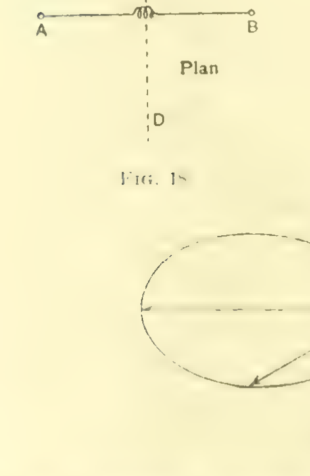


FIG. 18.

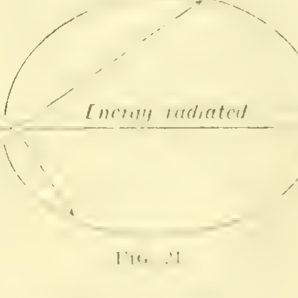


FIG. 20.

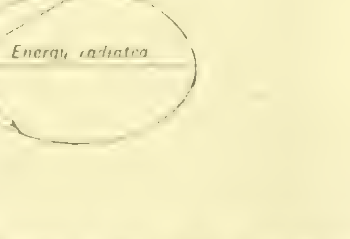


FIG. 21.

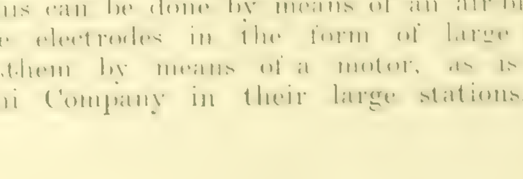


FIG. 19.

ensure regularity the gap must be kept cool, and the after effects of each spark quickly removed. With the ordinary long gap this can be done by means of an air blast or by making the electrodes in the form of large discs, and revolving them by means of a motor, as is done by the Marconi Company in their large stations. In the short, quenched spark-gaps the spark has to be quenched about $\frac{1}{200000}$ second after it has jumped across, so that after $\frac{1}{1000}$ second the gap should have lost all traces of the spark. The quenching action has thus to play a double part, the first affecting the nature of each spark and the resulting oscillation, and the second affecting the regular succession of sparks.

One cannot but be struck by the inefficiency of radio-telegraphic communication when looked at from the point of view of the transmission of energy. In some recent experiments made on ships of the United States Navy, it was found that at a distance of 500 miles the current in the sending aerial had to be 30 amperes to produce in the receiving aerial the current of 40 micro-amperes, which was found to be necessary for good signals. This great loss is mainly due to the world-wide radiation of the energy from the sending aerial. Seeing that the electro-magnetic wave is of the same nature as light, one would naturally suggest putting a reflector behind the aerial so as to throw the ray forward. It must be remembered, however, that a reflector must be large in comparison with the length of the wave, so that whereas a reflector as large as the head of a pin is quite efficient for light with a wave-length of $\frac{1}{2000}$ mm., an efficient reflector for a wave-length of 6 k m., or even of 300 m., is out of the question. Attempts are being made, however, to direct the electro-magnetic waves in the desired direction. Two methods have been successfully employed—one due to Bellini and Tosi, the other to Marconi.. The former is easily understood, and is based on well-known principles. The reasons for the directive action of Marconi's bent antenna have been much discussed, and several possible theories have been worked out. In the simplest form of apparatus employed by Bellini and Tosi two vertical antennæ are employed, joined at their lower ends by a horizontal insulated wire, in the middle of which is inserted the secondary coil of the sending transformer (Fig. 18). When the A antenna is charged positively the B antenna will be charged negatively, so that when A is send-

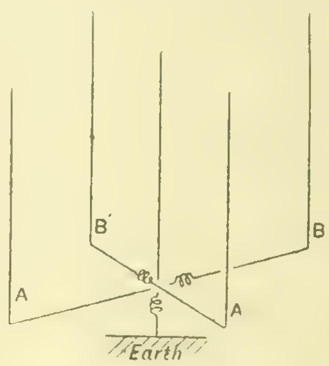


FIG. 22.

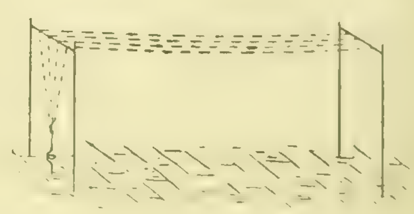


FIG. 23.

ing out a wave-crest, B will be sending out a wave-trough, and vice versâ. Anywhere on the line C, D these two waves will neutralise each other, but if the distance A, B be rightly chosen the crest emitted by A will arrive at B just as B is also emitting a crest. As the same moment A is emitting a trough, and the trough which half a period before was emitted by B will just have arrived at A. Hence, anywhere in the line A, B, produced in either direction, the waves emitted by the two antennæ are additive.

A diagram representing the energy radiated in various directions will be somewhat like Fig. 19. With this arrangement the radiation is equally powerful, both in the desired and in the opposite direction. If we wish to alter the direction, we must either arrange to rotate the whole aerial, or we must duplicate the whole arrangement at right angles. There will then be four vertical antennæ used in diagonal pairs (Fig. 20). The primary coil of the sending transformer is capable of rotation, so that it can influence either the secondary coil of A, B, or that of A^1, B^1, or partly one and partly the other.

In this way the line of maximum radiation can be rotated at will. Bellini and Tosi have gone a step further, however, and have done away to a large extent with the backward radiation as shown in Fig. 21, which shows the actual results obtained. This has been attained by erecting an ordinary

vertical antenna half-way between the outer antennæ—*i.e.*, immediately over the transformer coils, Fig. 22. This antenna is earthed through a separate secondary coil, which is acted on by the same primary as the other secondary coils, but the best results are obtained by slight modifications, into which we shall not enter.

The radiation from this central antenna will be uniform in every direction. If now, just as the crest of a wave, emitted by the central antenna, reaches the outer antennæ A and B, the former is emitting a trough and the latter a crest, the radiation in the direction A, B will be strengthened, and that in the direction B, A weakened. The whole action depends on the correct magnitudes and phase relations of the waves emitted by the central and outer antennæ.

With the Marconi bent antenna (Fig. 23) the results obtained are somewhat similar, although not so pronounced. The maximum radiation is in the opposite direction to that in which the upper horizontal part of the antenna points, and this direction cannot be altered, but must be decided when the antenna is erected.

THE MATHOT SUCTION PRODUCER.

THE reactions which take place in a gas producer, namely, the dissociation of steam for generating hydrogen, and of carbonic acid for producing carbon monoxide, as well as the generation of steam, are endothermic operations; that is, operations absorbing heat. It is, of course, essential for good efficiency to abstract the minimum possible heat from the burning fuel for performing these operations and also to recover the heat from the gas generated by utilising it for evaporating water, or for superheating the steam and preheating the air required for combustion.

In certain producers the steam is generated in a compartment or vessel surrounding the lower part of the gas generator by means of part of the heat liberated by the combustion of the fuel. This process is detrimental to economy unless required for preventing formation of clinker when using certain coals.

In other cases, when working at reasonable loads, the gas leaves the outlet of an ordinary generator at a temperature ranging from 600° to 700° Fah., and for cooling this gas before entering the engine a large amount of water is required in the scrubber (from three to four gallons per brake horse-power-hour). Consequently, much sensible heat is wasted which could be partly recovered and used to advantage in generating steam and assisting the endothermic conversions of the CO_2 and H_2O, at the same time reducing the quantity of water used in the scrubber.

The foregoing considerations have led Mr. R. E. Mathot, the well-known Belgian engineer, to work out what he designates a recuperative producer. The construction of the generator is illustrated by the accompanying sectional drawing in which A is the fuel chamber, lined with brick and provided with the usual hopper; B is a water vaporiser; C, C are pipes by which the steam goes down from the vaporiser B to the ashpit D; E is a basket grate; F is an opening for depositing ash and clinker; G is a gas chamber surrounding the brick lining of the fuel chamber; H is a dust collector, and J is the gas outlet.

The grate is hung freely under the firebrick lining and is formed with a series of flat horizontal bars, stepped to form the "basket"; the fuel and ash rest both on the bars of the grate and on the heap formed under the opening F. Mr. Mathot states the distinctive features of the producer as follows:—

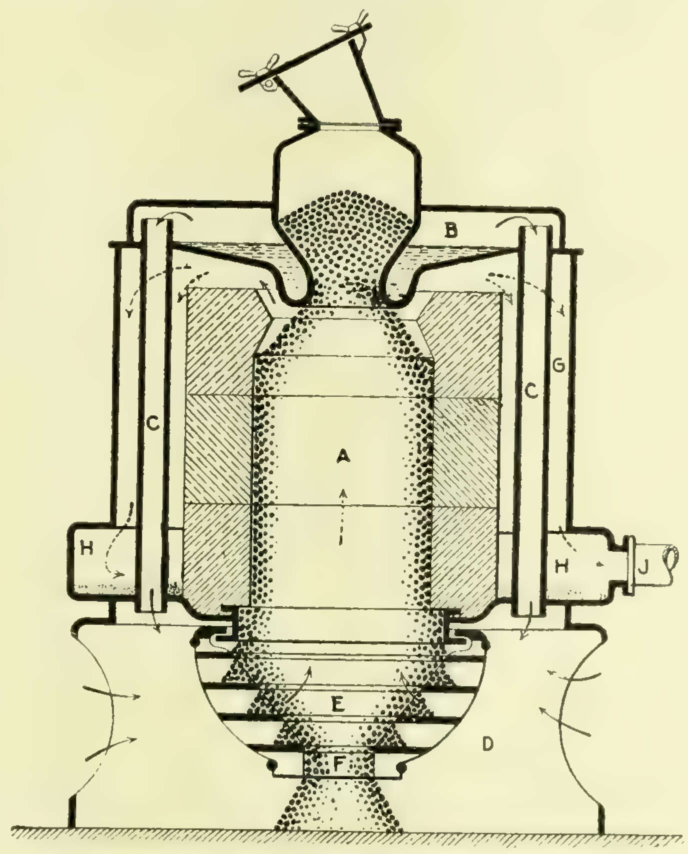
The basket grate affords an area of air inlet about double the cross-section of the fuel bed and four times that of the free space between the bars of the ordinary flat grate. This, as well as the shape of the bars of the basket grate, Mr. Mathot states, allows burning any kind of low-grade coal of the smallest size without unduly restricting the air passage.

The steam being fed to the fuel independently of the air and the latter being always freely admitted in the open ashpit, the proportion of steam to air cannot be disturbed by cleaning out the ashpit; in the ordinary suction producer, opening the ashpit permits a large volume of air to get in without a corresponding increase in the steam, and the gas is impoverished.

The gas, instead of being withdrawn from the top, leaves the generator shell at the bottom after having passed around the brick lining for preventing external radiation of the heat of the combustion zone. In passing down to the exit, the gas gives up sensible heat to the steam, which is therefore superheated before reaching the fuel bed, allowing a greater quantity of steam to be dissociated without cooling down the fire. This, of course, gives a greater amount of hydrogen in the gas and a higher calorific value. Mr. Mathot informs us that some tests made with his producers have shown the following chemical composition and heat value compared to those of the ordinary type of suction producer:—

	Ordinary Type. Per cent.	Mathot Producer. Per cent.
CO_2	6	7
CO	23	24
H	15	22
N	52	49
B.t.u. per cubic foot	132	157

The ashpit being always open and the fire visible from the outside, supervision and cleaning are possible at any time. The fire can be poked and the ash and clinker removed while



MATHOT'S SUCTION-GAS PRODUCER.

the engine is at work without impairing the quality of the gas, since steam and air are always supplied in the same proportions.

In an ordinary producer a sudden dropping of incandescent matter in the water of the ashpit causes an increase of steam without a corresponding increase of air, with the consequence that an excess of hydrogen is put in the gas, which may cause difficulties at the engine. This does not take place with the Mathot producer because the air entering the ashpit is saturated with the superheated steam coming down the tubes C and any additional steam occasionally produced by clinkers dropping in the water escapes through the openings of the ashpit.

With almost all ordinary types of producer, when the engine slows down or the load drops suddenly, the rate of gasification does not decrease accordingly, and an excess of gas may escape in the engine room. This does not take place with the producer under discussion, it is said, because any surplus of gas, being in contact with the air of the open ashpit, burns slowly as it escapes the fire without causing any explosion or smell.—"Power."

THE PROTECTION OF PUMP VALVES.

IN connection with pumping installations few matters cause more trouble and annoyance than those arising out of the deficient working of pump valves. Whether made of hard or flexible material these valves have frequently to be discarded before the body is worn out, owing to the enlargement of the central hole as a result of wear caused by the vertical movement of the valve on the stud. A general idea of the kind of trouble developed in this way is illustrated in Fig. 1, where it will be seen the valve is rendered useless, as in the condition shown portions of the holes in the grating would be exposed

FIG. 1.

and the vacuum in the pump seriously impaired, if not altogether destroyed. Various methods have been resorted to with a view to overcome the difficulty arising from this local wear. Fitting the valves with separate bushes has been tried, but the result has not been satisfactory. Even when the bushes are vulcanised into the rubber the trouble soon recurs, and once the bush becomes loose the hole rapidly wears and allows the bush to fall out, with the result that the valve is often destroyed after very short service, the effect of this state of things being illustrated in Fig. 2.

To remedy these well-known and very objectionable failings of flexible valves as they are ordinarily fitted the Dermatine Company, Ltd., of 95, Neate Street, London, S.E., have introduced some distinct improvements in valve construction which deserve the attention of all pump makers and engineers-

FIG. 2

in-charge who are responsible for the satisfactory running of pump installations. The improvements in question, which are constructed in accordance with Hart & Fiegehan's patent and are the result of long experience and experiment, have solved the trouble in a very satisfactory manner. As will be seen from Figs. 3 and 4, the bush is embedded and vulcanised into the valve in such a way that, it is claimed, it cannot under any circumstances work loose and, while preventing wear on the central hole, allows the valve to bed itself nicely on the seating. In the case of flexible valves the arms of these anchor bushes are hinged so as to allow the valve to "saucer" readily (see Fig. 3). With hard valves, again, there is just sufficient flexibility with the wire loops (as in Fig. 4) to prevent the beat on the seating or guard from cracking the valve, which it is liable to do with the old method of metal bushing. The new bush has been adopted by a number of well-known engineering firms and corporations, including amongst others the Metropolitan Water Board, and the municipal corporations of Brighton, Bournemouth, and Aston Manor.

The above remarks in regard to this method of bushing valves suggest a reference to the firm's special valves for air pump and other purposes. These valves are made of the

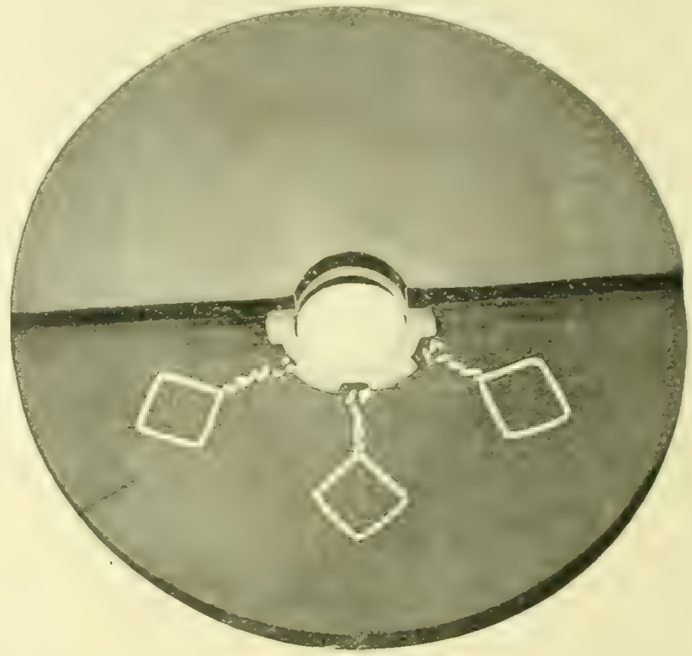


FIG. 3.

well-known patent material called "Dermatine," which has attracted much attention owing to its great durability and other qualities. Amongst other uses it has been largely applied to belts, which are extensively used in various parts of the world, and which, owing to their uniform width and thickness, it is claimed, enable them to well withstand heat, cold, damp, or steam, while they are at the same time of great tensile strength and durability, do not slip on the pulleys, and are practically non-stretching. "Dermatine" belting is made of the best long staple flax 3-ply warp, and the very strongest cotton duck weft. The flax yarn is specially

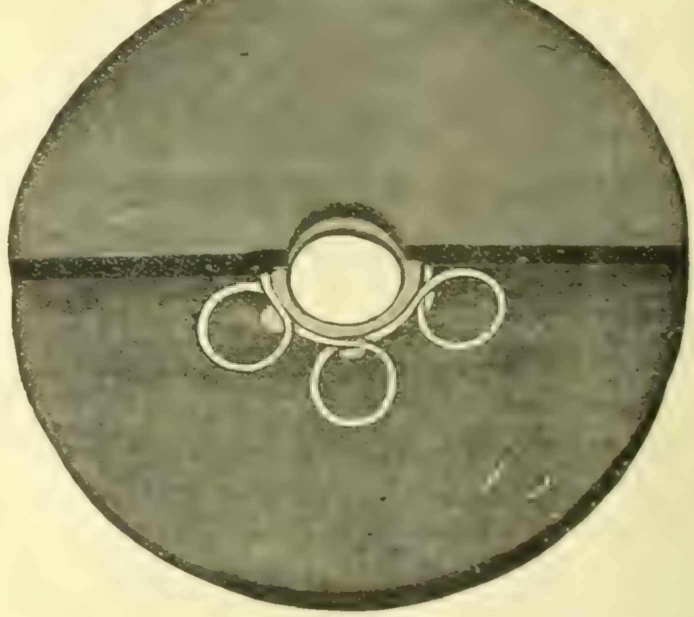


FIG. 4

selected, and the whole woven to stand hard wear. The fabric, after a special preparation, is incorporated in "Dermatine." A special feature of the belting is that it is sewn with several rows of special strong thread, so as to render laminating, a common failing with many belts, an impossibility. Other important applications of "Dermatine" to which reference may briefly be made are hose, and cup, ram, and pump rings. "Dermatine" hose is extensively used by local authorities for flushing, sewage pumping, fire brigade, and other purposes, though these by no means exhaust its utility

THE SUPPLY AND TRANSMISSION OF POWER IN SELF-CONTAINED ROAD VEHICLES AND LOCOMOTIVES.*

BY J. C. MACFARLANE AND H. BURGE.

ELECTRIC VEHICLES.

AT the present time the popular means of driving heavy commercial vehicles in this country is by the petrol engine, and this is fairly satisfactory where long non-stop runs have to be made through level country. The inflexibility of the petrol engine makes it a difficult matter to design heavy vehicles to withstand the continual starting and stopping that is necessary in city traffic, where in nearly every case (depending on the number of stops) the energy consumed during acceleration is considerably more than that required to get from point to point at constant speed. This necessitates a large engine, generally three to four times the size that would be required to drive the vehicle on the level, which, when running at high speed and developing low power, must be very inefficient. Other disadvantages of the petrol engine for this service arise out of the multiplicity of parts, all liable to get out of order, due to shock, vibration, and the continual variation in engine speed.

The authors have no doubt that the remedy lies in adopting secondary batteries as a source of power for heavy vehicles of all kinds for city traffic, more especially if complete regenerative control is adopted and the batteries are maintained by the makers. The reasons for this are briefly as follows, and are applicable to any electrically-driven vehicle: (1) The absence of shock and vibration greatly reducing the wear and tear. (2) The reduction of rates following on the supply of current for battery charging from municipal stations. (3) From the owner's point of view there are many advantages, some of which are: Lower cost of insurance and freedom from insurance limitations; instant readiness of vehicle and less depreciation, resulting in less time in the repair shop, so that a larger percentage of vehicles are kept running. This involves a reduction in capital, rates, rent, and taxes, insurance, supervision, and establishment charges. In the case of omnibuses, due to better lighting and other public advantages, the takings are bound to be considerably augmented, and further additions to revenue might be obtained from novel forms of advertisement and electric signs on the vehicles.

The conditions being so favourable to electric 'buses, there must be reasons why these have not made headway. One of these is unquestionably that of weight as laid down in the police regulations. Hitherto traction batteries for a 6-ton vehicle have weighed about 2 tons (consuming energy at well over 1 unit per mile, *i.e.*, 2 units per mile for charging purposes), and it was therefore impossible to construct omnibuses carrying a sufficient number of passengers to be remunerative. A more important reason, however, was the unsatisfactory working of the battery itself, which now appears to be preventible with proper care as exemplified by the fact that there are some 10,000 electric vehicles of all kinds constructed annually in America. It has been recognised, however, that the battery is the weakest link in the chain of the electrically-driven vehicle, and one of the objects of this paper is to describe a system which to a great extent removes the weaknesses of the battery and considerably strengthens the position of the battery vehicle from other points of view.

System which Eliminates Battery Difficulties.—Apart from minor alterations in the battery itself, most of the improvement has been obtained by raising the vehicle efficiency, with a consequent reduction in the size of the battery for a given mileage. Resulting from this, the initial and upkeep costs are reduced in almost direct proportion to the reduction in the size of the battery, but more important still, the ratio of the live to the dead load has been increased almost as the square of the reduction in battery weight. Some of the methods that the authors have adopted to bring about this result comprise: (*a*) Braking entirely by regeneration, the battery absorbing the energy returned. (*b*) A controller in the shape of a very efficient rotary transformer or automatic electric valve (only transforming half the power supplied to the wheel motors) which automatically limits the current that can be drawn from or returned to the battery, displacing the usual series-parallel type of controller. (*c*) A motor with special shunt-field windings, having a torque speed characteristic similar to a series motor.

The scheme as applied to the driving of heavy electric vehicles is shown in Fig. 1. The automatic electric valve A B, used as a controller, possesses the further property of acting as a power limiting device between the battery and the motor. The action of this machine under full speed conditions is as follows: The upper half A of the armature acts as a motor, and is coupled directly across the battery. The lower half of the machine B acts as a generator and is coupled in series with the driving motor C, so that the latter is receiving across its terminals twice the battery voltage. The motor C is provided with two shunt-field windings, one of which D is connected across the battery, providing a constant excitation, and the other E across the terminals of B. The winding E is arranged so as to assist the winding D during the acceleration period, and to oppose D when running at full speed. The part B of the electric valve is provided with a variable and reversible excitation by the winding F and controlled by the regulator G. When the regulator arm is over to the right, say, B adds its voltage to that of the battery, but when the regulator arm is to the left this voltage is subtracted from that of the battery. With the regulator arm in the mid-position B is not excited. An additional winding H is also provided on the field of B in series with the driving motor C, which opposes the winding F when B is acting as a generator delivering power to C.

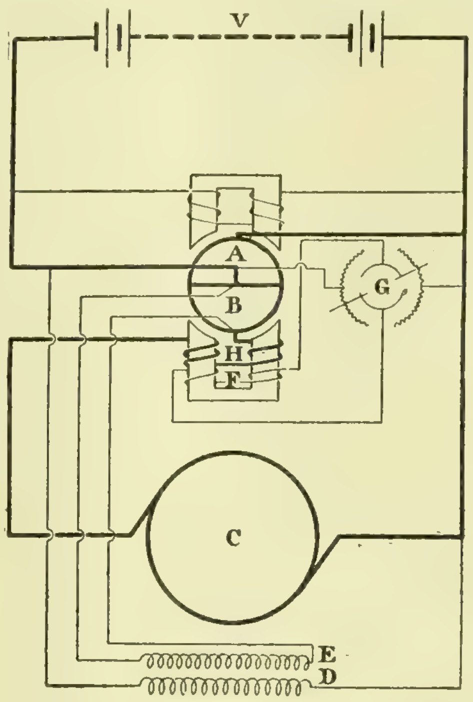


FIG. 1.—DIAGRAM OF CONNECTIONS BATTERY VEHICLE.

The advantages of this arrangement are as follows: During the period of negative acceleration, when the motor is returning energy, the field of the motor is strengthened so that the electrical braking tendency is largely increased, whereas when the motor is being accelerated and is rotating rapidly its field strength is diminished so that acceleration is facilitated. The design of the motor is such that due to the action of the field winding E the torque produced is nearly proportional to the square of the current passing through the motor armature. Thus, when starting or hill-climbing, with the controller "full on," the torque is four times that on the level, with only two and a half times the normal current in the armature.* Moreover, by means of the series winding on B the current to the motor C is always kept within safe limits when it is driving as well as when it is braking.

The entire control is carried out by means of a foot-pedal and a single reversing lever which is also employed to start up the machine A B. The pedal controls the reversing field regulator G, and when in the "off" position the arm is over to the extreme left, and if allowed to come quickly to this position a very powerful braking effect is produced, which continues even after the vehicle has been brought to rest. The latter effect is obtained by arranging the resistance of the regulator G so that B gives a back electromotive force slightly in excess of the voltage of the battery, producing a negative current of no power through the armature of the driving motor, and giving a torque in the backward direction. This torque is arranged to be of such a magnitude that it holds the vehicle on a comparatively steep downward gradient, and yet has not sufficient power to cause the vehicle to start backwards on the level. If, however, the vehicle is facing uphill with the controller in the "off" position it is necessary, in order to prevent the vehicle from moving backwards, to depress the controller pedal slightly and give the driving

* Abstract of paper read before the Institution of Electrical Engineers

* The C^2R losses throughout are therefore kept low, resulting in a high efficiency even at low speeds. Besides reducing the losses, this arrangement is valuable because the electric valve can be made smaller

motor a positive torque, tending to drive the vehicle uphill. This torque can be arranged to keep the vehicle stationary on the hill, thereby dispensing with the use of any mechanical brakes.

It will be readily seen that a vehicle equipped with such a system has the advantage that the speed is adjusted auto-

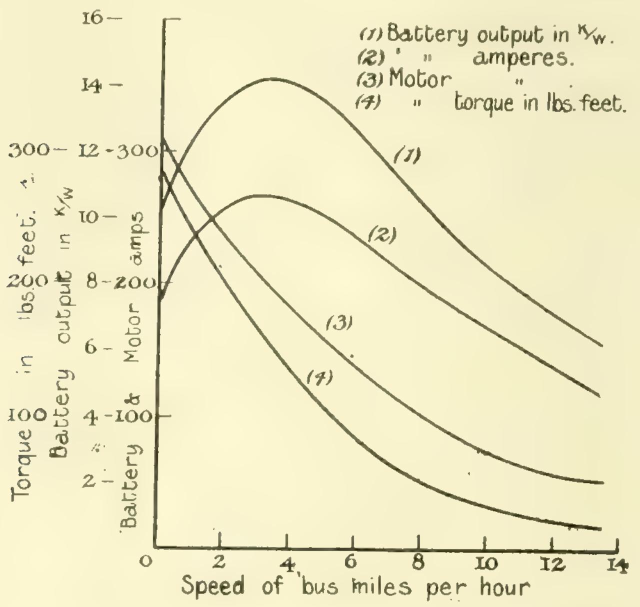


FIG. 2.—BATTERY VEHICLE CHARACTERISTICS. CONTROLLER PEDAL "FULL ON."

matically to the gradient of the road. In fact, the speed is a definite function of the torque required to drive the vehicle. The above statement applies to all positions of the controller pedal. Fig. 2 shows the electrical characteristics of the system for maximum power position of the controller as a function of the vehicle speed.

Due to the economical acceleration, regeneration, high torque per ampere, and other causes, it is possible to obtain a higher efficiency, and therefore reduced battery weight and size (*i.e.*, about half the energy consumption and weight for the same number of passengers and mileage as in previous battery omnibuses). Further, as the voltage of the battery is only half that of the motor, the number of cells can be reduced without additions to the weight of other parts. This admits of a further reduction in the weight. Also, as the discharge rate of the battery is limited, the capacity is greater under working conditions, *i.e.*, the ampere-hour efficiency is high. Further, it is obviously not necessary to use two motors or a double commutator-driving motor to obtain economical speed control; therefore a further increase in order in the efficiency of the system is obtained. Thus the energy, initial and upkeep costs are reduced, and the ratio of live to dead load is very much increased.

The control is very simple, the whole operation being effected with one foot-pedal. It is fool-proof, and any prearranged maximum battery currents are obtained for definite vehicle speeds. Pressing down the pedal increases the speed; raising the pedal reduces the speed, and at the same time applies regenerative braking. The acceleration or retardation is proportional to the rate of forcing down or raising the pedal, and these have been arranged as a maximum to get up speed from standstill in about one and a half to two bus-lengths, and to brake to a standstill from full speed in the same distance.

One brake can be dispensed with if police regulations permit, and it is not even necessary to use any mechanical brake when driving in the ordinary course. The system of braking reduces the tendency to skid on greasy roads, and as the controller always returns to the braking position, this action brings the vehicle to a standstill if anything happens to the driver.

An omnibus constructed at Chelmsford and equipped with the system outlined above is now running in London, and conforms in all points with the Metropolitan Police Regulations, and when loaded with 34 passengers it has a total weight of 5 tons 18 cwts. It is fitted with a 28-cell battery weighing 19 cwts. including acid and terminal connectors, having a capacity of 500 ampere-hours on a 5-hour discharge rate. The battery is mounted in front in the position usually occupied by the petrol engine.

Fig. 3 shows the outline of the chassis of the latest design of omnibus, to which is fixed the automatic electric valve and motor, all in one case and marked A, B, C. The case is hung to the chassis frame by means of suspension hooks and eyes and is stayed to the sides of the chassis by rods. The motor drives direct through the cardan shaft to the worm-reduction gearing mounted on the usual construction of live axle. The regulator G is fixed on one side of the electric valve, while the starter K is mounted on the other side. The foot pedal L and the starting and reversing lever M are linked up to the regulator and starter respectively by means of rods, as shown. The dimensions of the battery over cells when packed closely are 49in. by 31in. by 16¼in.

Energy Consumption.—A loaded omnibus (6 tons weight) was run from Chelmsford, a distance of 6 miles out and 6 miles home. There were one or two fairly steep hills to be negotiated. The readings were taken with the controller pedal on the "full-on" position the whole of the time, the omnibus speed only varying due to the contour of the road. The average speed was just under 13 miles per hour, the average current consumption on the outward journey was 125 amperes, and on the back journey 115 amperes, making a total average of 120 amperes. The ampere-hours per mile, therefore, work out at just under 10, and as there are 28 cells giving a discharge of 120 amperes at about 53 volts the energy consumption per mile was equal to 0·53 of a unit, or, in other words, 88 watt-hours per ton-mile, and the average horse-power required to drive the vehicle at a speed of 12¾ miles per hour was just under 8½ h.p. It will therefore be

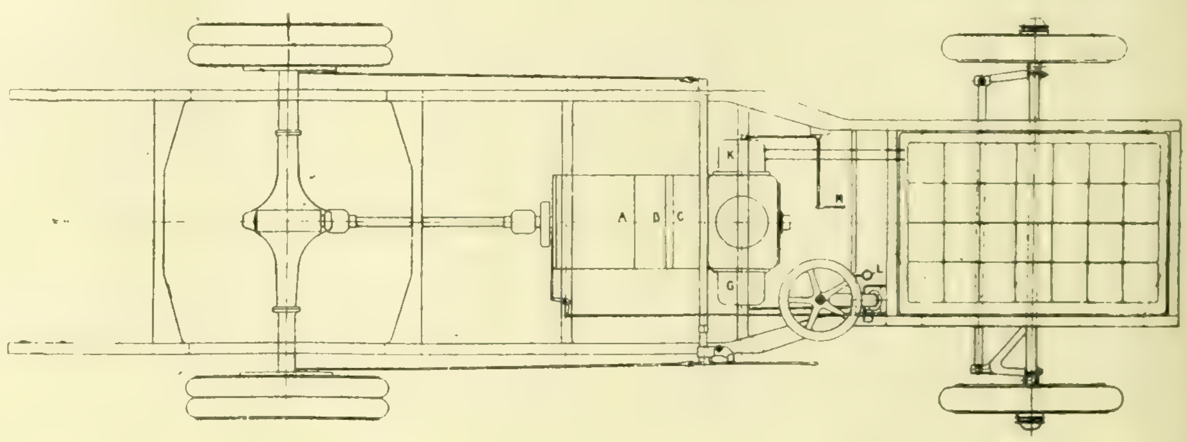


FIG. 3.—PLAN OF CHASSIS. BATTERY VEHICLE.

seen that as the battery has an average capacity of 500 ampere-hours the total range of the vehicle is 50 miles.

Comparative Cost of Running Electric and Petrol Omnibuses in London.—The following items in the cost of running are common to both types, although not necessarily equal in each type—*i.e.*, tyre maintenance, drivers, conductors, body upkeep, traffic expenses, washing, rent, rates, water, gas and lighting, depreciation, taxes, supervision and establishment charges. Other items that are widely different in cost are as follows:—

	Electric Vehicle (Pence per 'Bus-mile).	Petrol Vehicle (Pence per 'Bus-mile).
Battery maintenance...	2·00	—
Power or petrol	0·50	1·25
Chassis maintenance...	0·10	1·00
Lubricating oil and paraffin... ...	0·01	0·22
Vehicle lighting	–	0·10
Insurance (not including third party risk)	0·10	0·20
Washing and preparing for running	0·17	0·90
	2·88	3·67
Depreciation (explained below) ...	0·72	1·03
Comparative cost	3·60	4·70

As regards the above comparative cost the important

figures are quite definite, those for the petrol vehicle being obtained from the best actual practice. On the other side the battery maintenance and power figures are already fixed by the battery manufacturers and the electric supply companies respectively. In comparing the chassis maintenance in the two cases the maintenance of the engines, gear box, clutches, and mechanical brakes are to be set against a low-voltage electrical equipment consisting of two machines, a starter, and a shunt regulator. On a basis of 30,000 bus-miles per annum, a sum of £13 per bus per annum is allowed for the electrical equipment, gearing, &c., a figure very much on the high side when it is remembered that there is no wear on mechanical brakes and the retardation is uniform.

The preceding table shows roughly that the electric omnibus is the cheaper to run, and when items of cost which are common to both types are reviewed, the case for the electrical vehicle is still better. Taking these in detail, the cost of tyre maintenance, drivers, and body upkeep is undoubtedly less, and the following argument will show that rents, rates, supervision, establishment charges, and depreciation are less. Out of a fleet of petrol vehicles a large percentage (as seen by the maintenance figure), roughly 25 per cent., will be out of commission, and more space in the garage and larger repair shops are required as compared with the electrical omnibus. This also means a greater capital expenditure per bus-mile.

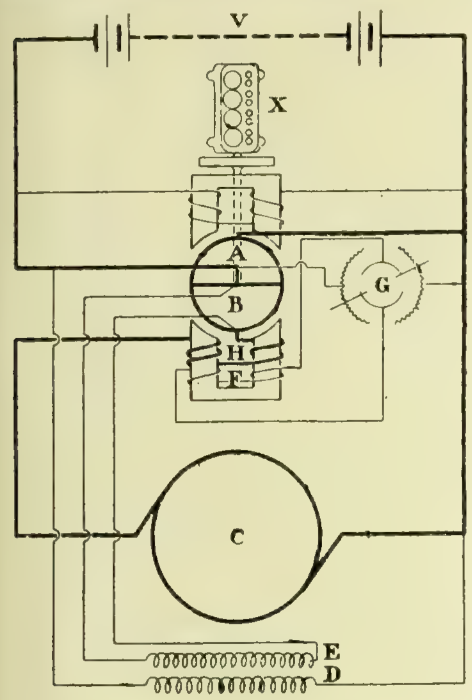


FIG. 4.—DIAGRAM OF CONNECTIONS. PETROL ELECTRIC VEHICLE.

As regards depreciation, the two cases have to be compared on the same capital basis, for although the electric vehicle will be rather more expensive when the battery cost is included, the battery makers maintain this at its full value, and thus depreciation of the electric vehicle is undoubtedly less than the petrol vehicle. Suitable figures for these are 10 per cent. and 15 per cent. per annum respectively, making the figure for the depreciation of the electric bus 0·72 and the petrol bus 1·03 per bus-mile. It would appear, therefore, that the electrical omnibus can be run for at least 1d. per bus-mile less than the petrol.

PETROL ELECTRIC VEHICLES.

There are two conditions necessary and essential to successful battery traction for heavy road vehicles. In the first place, the charging stations must be within a definite range, and secondly, the battery should always be kept under the supervision of the makers, otherwise the cost of its maintenance would be prohibitive. It is obvious, therefore, that the electrical vehicle is unsuitable for travelling long distances or working in outlying districts.

It is suggested that the all-electric system modified by reducing the battery to one-fifth the capacity, and by adding a 9 h.p. air-cooled engine, would meet the case. Fig. 4 shows the arrangement, and the method of operation is very similar to that of the all-electric system. The engine X is coupled to the electric valve A B and takes the average load, the peaks being supplied by the battery V, which also absorbs the energy returned during braking. When the output of the battery is equal to that of the engine (a condition which holds during middle portion of the acceleration period, and when climbing hills) A carries no current, resulting in a very high overall efficiency, about 86 per cent., through the electric transmission gear. In order to make the battery respond to the varying loads without appreciable variation of the engine speed, the part A has a field winding which gives it a falling electromotive force when the motor demands large power and a rising electromotive force when the motor is regenerating.

Besides acting as an equaliser, other important functions of the battery are: (*a*) To start up the engine from the driver's seat, a very great convenience, and to supply current to the sparking coils. (*b*) To enable the vehicle to run to a garage in the event of an engine breakdown. (*c*) To light the vehicle and to provide current for electric signs and advertisements. (*d*) To allow of electric breaking down to any speed.

The engine runs practically at constant speed, and has only to supply the average power required to drive the vehicle. It is well known that to drive a 6-ton loaded vehicle on the level at 12 miles per hour, 9 b.h.p. is required. Now, when running at about half-speed uphill, in this system the gear ratio automatically changes, enabling the full 9 h.p. to be utilised; the torque, therefore, under this condition is twice that developed on the level. Further, with the aid of the battery, the motors are enabled to develop an additional 9 h.p., making a total of 18 h.p. at this speed, thus giving four times the normal running torque. A petrol vehicle, however, running up the same hill at half-speed on the top gear would have to be equipped with a 36 h.p. engine on the normal full-speed basis, because at half-speed it would only just be able to develop the 18 h.p. required. It may be argued that an earlier change of gear would enable a smaller engine to be used, but even this will not necessarily compensate for the falling off of power due to loss of compression and inefficient action of the carburetter, and it is a fact that 36 h.p. to 40 h.p. engines are actually fitted to such vehicles.

In the proposed petrol-electric system the engine power necessarily is not large, and its speed being constant, air-cooling for the engine is possible, with its attendant advantages—*i.e.*, simplicity, reduction in space and weight, and the absence of freezing troubles. A governor is used to keep the engine speed constant, thereby removing all sources of shock and inertia stress, due to the manipulation of the spark or sudden variation of the engine speed when clutching or changing gear, and allowing an engine design with high initial compression. The load factor being approximately 100 per cent., the consumption of petrol will not be more than half that of the ordinary petrol vehicle, the engine of which works on the average at only one-third full power.

The operation is as follows: The starting switch is put over either in the forward or reverse position, as required, and the engine is thus started up and begins to fire, charging the battery at normal current. The pedal is then depressed and the motor is fed by the combined power of the engine and battery, the opposing series coil on A allowing the battery to give its share. On reaching full speed the power absorbed by the motor falls to the average—*i.e.*, 9 b.h.p.—which is given by the engine while the battery floats. On raising the pedal the motor returns energy to the battery, and in so doing tends to raise the speed of the machine A B, and the governor meanwhile cuts off the power from the engine. When the regeneration has ceased the engine continues to charge the battery. Due to economical acceleration, high torque per ampere, and regeneration, the efficiency of the system is very high, and also one mechanical brake can be dispensed with.

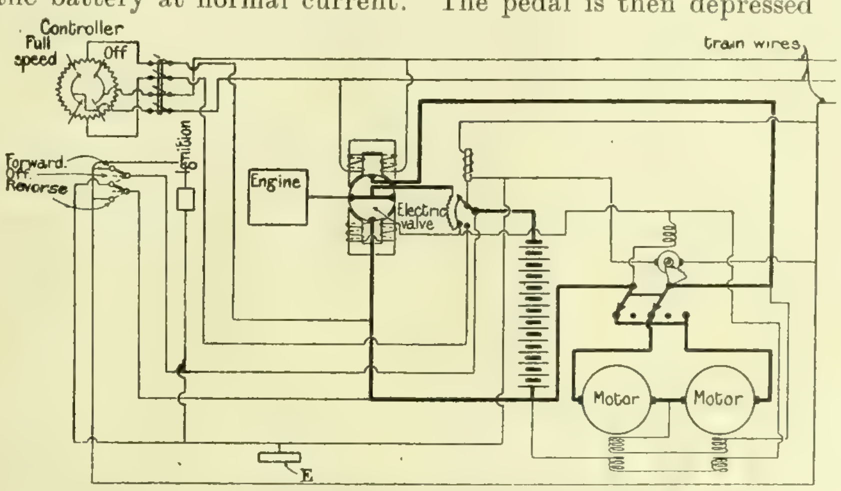


FIG. 5.—DIAGRAM OF CONNECTIONS. OIL ELECTRIC MOTOR COACH.

Comparative Weights.—In order to obtain a comparison between the petrol-electric and the petrol vehicle, the case of the 34-passenger omnibus will again be considered. The weight of the modern petrol vehicle complete with lubricating oil, petrol, and water is, including passengers, 5 tons 18 cwt. The weight of the petrol-electric vehicle constructed on the above system is, including passengers, 5 tons 5 cwts.

Cost of Running.—The engine is designed to give 9 h.p., which should be large enough to give a mean speed of 12 miles per hour. The petrol consumption of such an engine would be about 0·75 pint per brake horse-power per hour, and therefore the vehicle would travel approximately 14 miles with a gallon of petrol, making a cost of 0·75d. per mile for power, taking petrol at 10½d. per gallon. With regard to the battery, a suitable capacity would be 50-ampere hours at a 1-hour rate (*i.e.*, one-fifth of the capacity of the all-electric battery) capable of giving discharges of 225 amperes for 5 mins., and providing for that time an additional 16 h.p., making the total power available 25 h.p. at any speed, if required. This battery is only discharging at the average rate of 17½ amperes, which is one-third of its normal, and therefore the life in vehicle-miles is three times that of the all-electric vehicle battery, the maintenance figure for which was 2d. per mile. Compared on the same basis, the maintenance figure for this battery should be one-fifteenth part of 2d., *i.e.*, 0·134d., but owing to the fact that the discharge rates are sometimes high the figures will be increased to 0·35d. per vehicle-mile.

The following table gives the comparative cost of those items which are widely different in the petrol-electric and the petrol systems. Depreciation is assumed for the petrol vehicle at 15 per cent., against 12 per cent. of the petrol-electric vehicle. It would appear that the petrol-electric vehicle, constructed on the above lines, would cost less to run than the present vehicle by at least 1¼d. per mile.

	Petrol-electric Vehicle (Pence per 'Bus-Mile).	Petrol Vehicle (Pence per 'Bus-Mile).
Battery maintenance	0·35	—
Petrol	0·80	1·25
Chassis maintenance, including engine and transmission gear	0·50	1·00
Lubricating oil and paraffin	0·10	0·22
Vehicle lighting	—	0·10
Washing and preparing for running...	0·50	0·90
	2·25	3·47
Depreciation	0·9	1·03
Comparative cost	3·15	4·50

OIL-ENGINE ELECTRIC SYSTEM FOR SUBURBAN RAILWAYS.

Many railway companies have been looking into the question of electrifying their suburban lines, to meet more successfully the competition of tramcars and omnibuses; but the companies have been unable or disinclined to face the enormous outlay involved in the installation of generating station, sub-stations, third rails, &c., and for existing lines, apart from the cost of converting, the complication of conducting rails or overhead wires at large junctions and termini is generally objectionable.

It is suggested, therefore, that a self-contained electric train with complete regenerative braking would meet the case, and it will be shown as far as possible that the capital outlay, apart from the cost of a generating station, would only amount to approximately two thirds of that required where the power has to be transmitted from generating stations and fed to the train by conducting rails.

The trains would be made up of any number of motor coaches and trailers on the multiple unit system, a diagram of connections for such being illustrated in Fig. 5, from which it will be seen that it is possible to drive from any motor coach in the usual manner, and that only three relay train wires are necessary. The motor coach is equipped with a spirit or oil engine and electrical equipment similar to that just described, but to provide in suburban trains the very large additional power required during acceleration, and to absorb the returnable energy, a larger proportion of battery is carried on the train. The question may be raised that the battery will make the equipment very heavy, but it will be seen later that this is not necessarily the case. Allowing this to be so, however, the possibility of recovering at least 75 per cent. of the energy stored in the train minimises the objection to additional weight.

In order to determine the size of the battery, the acceleration and retardation rates will be assumed constant and of equal period, also the speed after acceleration is finished will be assumed constant until retardation begins.

Let

D = average distance between stations in feet.

t = time of acceleration or retardation in seconds.

V_{av} = average speed between stations in feet per second.

V_{max} = maximum constant speed attained between the stations in feet per second.

M = mass of train in tons.

The distance to be travelled at constant speed

$$= \left(\frac{D}{V_{av}} - 2t\right) V_{max}$$

The total distance traversed D

$$= \left(\frac{D}{V_{av}} - 2t\right) V_{max} + V_{max}\, t$$

$$\therefore\ t = D \left(\frac{V_{max} - V_{av}}{V_{max} \cdot V_{av}}\right)$$

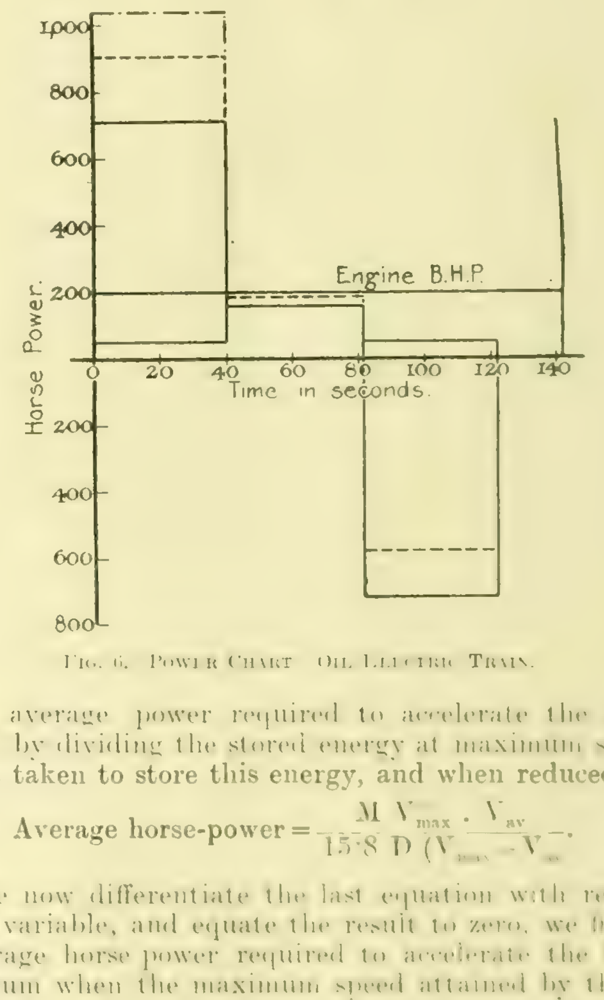


FIG. 6. POWER CHART OIL ELECTRIC TRAIN.

The average power required to accelerate the train is obtained by dividing the stored energy at maximum speed by the time taken to store this energy, and when reduced—

$$\text{Average horse-power} = \frac{M\, V_{max} \cdot V_{av}}{15 \cdot 8\, D\, (V_{max} - V_{av})}.$$

If we now differentiate the last equation with regard to V_{max} as variable, and equate the result to zero, we find that the average horse power required to accelerate the train is a minimum when the maximum speed attained by the train between the stations is 50 per cent. greater than the average, viz., when $V_{max} = 1 \cdot 5\, V_{av}$, an interesting and important result.

Using the above, the size of the engine and battery required to operate a train on any given schedule can now be estimated, and it may be of interest to compare the cost figures for two hypothetical cases of electric traction, one on a series parallel control continuous electricity third rail system, and the other on the system suggested above. The comparison will only be made with the direct current system, as it is well known to be at the present time the most economical from all points of view for suburban traffic. The figures are based on a service with a schedule speed of 2[illegible] miles per hour including stops, with 1 mile between the stops and 10 miles of double track. A 12 minute service is maintained each way for 18 hours per day, and a 24 minute service on Sundays. A suitable number of trains to employ is 11, each consisting of two 60ft. motor coaches and one 60ft.

trailer coach. The cost of such a service on the series parallel system has been worked out very completely by Mr. Hobart,* and we have reproduced these figures for comparison with the proposed system in the accompanying tables:—

Capital Outlay and Weight Table.

	Third-rail Direct current System.		Oil-electric System.	
	Weight per Train in Tons	Cost of 11 Trains, &c.	Weight per Train in Tons.	Cost of 11 Trains, &c.
		£		£
Car bodies and trucks ...	90	56,200	90	56,200
Electrical equipments ...	24	33,000	12	16,300
Engines	—	—	6	17,500
Batteries	—	—	10	12,500
Assembling	—	6,280	—	10,000
Sub-stations	—	30,000	—	—
Tracks and feeders	—	40,000	—	—
Tools, buildings, &c.	—	10,000	—	10,000
Totals	114	175,500	118	122,500

Annual Charges for 11 Trains.

	Per Cent. on Capital.	Total.	Per Cent. on Capital.	Total.
		£		£
Rolling stock	8	7,640	—	20,000
Sub-stations	6	1,800	—	—
Track and feeders	5	2,000	—	—
Drivers' and inspectors' wages	—	4,550	—	3,500
Power	—	24,600	—	10,250
Interest on capital	—	7,030	—	4,900
Total	—	47,620	—	38,700
Total per train-mile ...	—	18·8d.	—	15·3d.

The weight of the third-rail continuous-electricity train was 114 tons, and this figure will be used in estimating the engine power and battery size. The diagram, Fig. 6, shows a complete chart of the average power required during the various periods over the whole cycle of operations between station and station, including the standing time. The full-line curve shows the actual power required at the wheels, and the dotted curve shows the power required when all losses (except that of the battery, which is shown chain dotted) are taken into consideration. The horizontal straight line across the diagram shows the average brake horse-power required to be developed by the engine in order that the train may complete the cycle of operations in the desired time.

As the power is split up into two locomotives, the size of each engine will be 100 h.p., and each battery will be required to discharge at the average rate of 360 h.p. over 41 secs. out of every 2·4 mins. The details of the engine and battery, weights, and costs, &c., are given in the table along with the weights and costs of the electrical equipment, which includes the electric valve, motors, controlling gear, and cables.

The capital outlay and annual charges have been given in the accompanying tables alongside those of the third-rail system in order to make a comparison, and items such as the capital outlay for car bodies and trucks, tools, and buildings, &c., should be common to both systems. The capital cost for the electrical equipment for the proposed system, as well as the cost of the engine, battery, and assembling, have been estimated separately.†

With regard to the annual charges on the rolling stock, it may be stated that the maintenance of the controller and of the third-rail has been set against that of the engine, and an entire addition has been made to the annual charges above that of the third-rail system for the battery maintenance. The latter figure has been estimated on the assumption that both batteries are completely used up per annum per train.

* "Electrical Engineer," Vol. 46, p. 575, 1910.

† The power-cost is estimated on a consumption of 0·8 pint of oil per brake horse-power hour at 4d. per gallon, allowing for 25 per cent. idle running.

INDUSTRIAL AND TRADE NOTES.

Clyde Shipbuilding Consolidation.—The policy of consolidation which has recently been apparent in the Clyde shipbuilding industry has been carried a step further by the acquisition of the old established shipyard at Port Glasgow belonging to A. Rodger and Co. by Russell & Co. Russell & Co. have for many years been the largest producers on the Clyde, and this absorption materially enhances their position. The business of A. Rodger & Co. was established 22 years ago, and negotiations have been proceeding for some time for the reconstruction of the concern.

A New Substitute for Hemp.—The British Vice Consul at Leipzig reports the discovery of a new substitute for hemp for the textile and cord industries, in the fibre of the hop vine, from which the wooden and gummy substances are separated. The treatment is said to differ but slightly from that of hemp, and to have the advantage that the preliminary treatment can be undertaken by the hop-grower himself. It is thought that, although the process as a whole is more troublesome than in the case of hemp, the cheapness of the raw material will more than compensate.

British Chamber of Commerce for Portugal.—A British Chamber of Commerce has recently been established at Lisbon, the objects of which are to consider all questions connected with the trade, commerce, and manufactures of the British Empire so far as they relate to British commercial interests in Portugal, and to assist members or other British subjects engaged in trade with, or commercial enterprise in, Portugal to attain objects of commercial advantage, and to promote the interests of British trade and commerce in Portugal. The secretary of the Chamber is Mr. G. J. C. Henriques, 97, Rua da Magdalena, Lisbon.

Gas Plant for an Electricity Generating Station.—The gas-producing plant and other machinery which the Accrington Corporation is installing in the electricity generating station, to cost £32,400, consists of gas-producing plant, gas engines, and extra high tension generators, main generating switchgear, extra high-tension mains, and sub-station equipment. The gas plant, which consists of two units, each of 1,000 h.p., will be used for dealing with the steady night and day load, while the existing steam plant will be employed on the peak load. By-product recovery is also arranged for, and as the steady load increases more gas plant will be added.

Midland Iron and Steel Wages Board.—The annual meeting of the Midland Iron and Steel Wages Board was held at Birmingham on the 4th inst. The report stated that the Board consisted of 53 firms, comprising 28 in South Staffordshire and Shropshire, three each in North Staffordshire, Lancashire, North and South Wales and Cheshire, and Derbyshire, and five in South Yorkshire. From December 3rd, 1910, to February 4th, 1911, the rate paid for puddling was 8s. 6d. per ton. Under the sliding scale the rate had been varied to 8s. 9d. from February 4th to April 1st, 1911, and had remained at that figure up till February 3rd last, when the period covered by the annual report ended.

American Tinplate Production.—According to an American Consular report, the output of the tinplate mills in the United States has shown a rapid rise in the past two decades. In 1892 the total output of American mills was 18,803 tons, in 1900 it had risen to 302,665 tons, and in 1910 it reached 725,000 tons, making the United States the world's chief producer of tinplate. The total world output for the latter year was 1,175,000 tons, the other leading producers being the United Kingdom with 600,000 tons, and Germany with 50,000 tons. The export and import statistics indicate that this growth in the American output continued during 1911, and that the American makers succeeded in filling a large part of the home demand formerly supplied by foreign makers.

A Mountain Railway.—The railway which has been in course of construction by Sir John Jackson, Ltd., between Chile and Bolivia has just been completed. The railway covers a distance of 275 miles, crossing the Andes from Arica to Las Pas, the capital of Bolivia. It is one of the highest railways in the world, being at an altitude of 14,000ft. above sea level. This altitude, as well as the difficult nature of the country, rendered the construction of the line very difficult. The contract was for £2,950,000, and the time allowed for its execution was three years, but the work has progressed so rapidly that five months have yet to elapse before that time has expired. The line is of great importance, inasmuch as it shortens the distance to the Pacific coast from Las Pas by about 400 miles.

Proposed Reconstruction of the Thames Ironworks.—A meeting of preference shareholders of the Thames Ironworks was held in London on Friday last for the purpose of passing resolutions to be placed before the First Lord of the Admiralty. It was stated that the First Lord had expressed his readiness to place orders on the Thames provided the company was satisfactorily reconstructed.

and assurances given that the new management was of a first-class order. There was an offer before the Receiver of £300,000 for the purchase of the company's effects, lock, stock, and barrel. The properties of the company had however been valued at £800,000, with other effects amounting to £200,000. The first resolution to be proposed asked the receiver not to sanction this project. The second resolution asked the preference shareholders to assess themselves at the rate of 5s. in the £ for the purpose of carrying the reconstruction into effect. The first resolution was carried unanimously, and the second was carried by 14 votes to 12.

Turbine Contract for John Brown & Co.—Messrs. John Brown and Co., Clydebank, have, according to "The Glasgow Herald," received the contract for the turbines of one of the two Chilian battle-ships which have been ordered from Messrs. Sir W. G. Armstrong, Whitworth, & Co., Elswick. The turbines will develop a shaft horse power of 37,000, which is expected to produce a speed of about 22 knots. The displacement of the vessels will be about 23,000 tons. The turbines will be in three engine-rooms, the low pressure in the centre and the high pressure in the wings on the sides. In the new Chilian battle-ship an interesting departure will be made. Combinations of turbine and reciprocating machinery have been common within recent years, but in the Chilian vessel there will be, in all likelihood, a combination of Parsons and Brown-Curtis turbines. The vessel will, of course, have four shafts; but while the low-pressure turbines will be of the Parsons type the high pressure will be Brown-Curtis.

Bill for Nationalisation of Railways and Canals.—The Labour Party Bill for the nationalisation of railways and canals, which has been presented by Mr. Will Thorne, M.P., has just been published. According to the memorandum, the objects of this Bill are: To confer upon the Board of Trade powers to acquire the ownership of railways and canals, certain powers of user of the property so acquired, and for leasing it, and to prevent the property falling into private ownership again. The scope of the Bill is limited to England and Wales. Under one of the clauses the Board of Trade is to use, manage, and conduct all or any of the said property or properties for the national advantage, while another clause states that "the Board of Trade may depute all their powers under the Act to a Board of Control." It is proposed that the purchase moneys shall be raised by the Board of Trade by the issue of consols or by the creation of nationalisation bonds, bearing interest at 3 per cent. or such other interest as may be arranged.

South African Trade.—His Majesty's Trade Commissioner for South Africa (Mr. R. Sothern Holland) reports that the published figures of trade for the year 1911 afford striking evidence of prosperity. The total value of merchandise imported (exclusive of Government stores) increased from £25,900,000 in 1907 to £36,400,000 in 1911. The United Kingdom's share in these imports rose from £14,800,000 in 1907 to £21,300,000 in 1911. Even better results would be shown if the value of the Government stores imported were added. Export returns are no less satisfactory. Their total value, inclusive of diamonds, but exclusive of specie, amounted in 1907 to £48,200,000, and in 1911 to £58,800,000. The share of the United Kingdom was £45,300,000 in 1907, and £53,500,000 in 1911. As regards imports, all classes of mining and electrical machinery and material show decreases. These, however, indicate simply the approaching completion of important development works. The magnitude and prosperity of the mining industry is attested by the record output of gold for the year, amounting to £35,000,000.

The Manchester Chamber of Commerce and the Trades Disputes Act.—At the last meeting of the Chamber the minutes of a joint meeting of the Executives of the Chemical and Engineering Sections along with representative cotton manufacturers recorded the views of the Joint Committee on the Trades Disputes Act Amendment Bill—a measure which had been prepared by the Trades Disputes Act Reform League—were presented. The Bill proposes, among other things, to restore the right of action against trade unions for acts done in their name—a right which was taken away by the law of 1906. It also proposes to define more closely the picketing which may be recognised as peaceful. The committee recorded (1) regret that the Government had not so far appointed a Special Commission to enquire into the Trades Disputes Act of 1906, as suggested by the Association of Chambers of Commerce at their meeting in Dublin in September last; and—without committing themselves to details—approved generally of the Bill, particularly as to (*a*) the immunity of trade unions from actions for torts, and (*b*) picketing.

Imperial Wireless Telegraphy.—Marconi's Wireless Telegraph Company, Ltd., state that they have received the acceptance from the Postmaster General of its terms for the construction of all the long distance wireless stations which will be required within the next few years for the Imperial wireless scheme, and which will be erected for the purpose of conducting a commercial telegraph service. The construction of the following stations will be proceeded with forthwith: England, Cyprus or Egypt, Aden, Bangalore (India), South Africa, Singapore, while others will follow in the near future. The company will operate the stations on account of the Government for the first six months, when the Government will enter into possession. The payment for each station, exclusive of site, buildings, and machinery foundations, will be £60,000, and the company will for the term of the agreement (which will be in force 28 years from the opening of the first three stations) receive 10 per cent. of the gross receipts of all the long distance messages. The Government may end the agreement after 18 years, but in that event would lose the right to the use of the company's patents.

Zinc Refining Industry in Japan.—A recent report on zinc refining in Japan, by H.M. Vice Consul at Osaka, states that, although zinc ore is mined in many localities within the Japanese Empire, it has hitherto been found impossible to attempt to refine it on a commercial scale owing to the difficulties of the process. Chief among these is the high temperature required and the inability of Japanese furnace-makers to construct suitable furnaces. Consequently the greater part of the zinc ore produced in Japan has been exported, chiefly to Belgium. The exports amounted to 14,793 tons in 1908, 18,206 tons in 1909, 22,151 tons in 1910, and 22,735 tons in 1911. The demand for refined zinc has, on the other hand, been entirely supplied by imports, which amounted to 8,828 tons in 1908, 8,493 tons in 1909, 10,341 tons in 1910, and 11,408 tons, valued at £315,000, in 1911. Within the last year or two, however, improved processes have been invented for the refining of zinc ore, among them one discovered in Japan by which the temperature is materially reduced and the period for which the ore is exposed to intense heat shortened by several hours. Several projects for refining zinc in Japan have accordingly been conceived. None of them has so far reached the point of producing refined zinc in commercial quantities, but no efforts will be spared to make the industry an important one in Japan.

The Workmen's Compensation Act and Frivolous Claims.—At the annual meeting of the Employers' Liability Assurance Corporation, Lord Claud Hamilton made some interesting observations on the working of the Workmen's Compensation Act. He said the average cost of a death to the company in 1908 was £135. 8s., in 1910 it was £111. 8s., and last year it was £113. 4s., so that the average showed a tendency to decrease. Permanent disablement, however, told a different story. In 1908 the average cost was £104. 6s., in 1909 it was £112, in 1910 £123. 4s., while last year it was £142. 5s., while the average cost of temporary disablement rose from £4. 1s. in 1908 to £5. 3s. last year. Figures showing the relation of accidents and claims to wages insured showed a steady increase. One reason was that throughout the country there was a certain type of solicitor who took up cases speculatively, and who encouraged workmen to bring frivolous claims in the hope of winning. If they won, the solicitor got his share of the damage, and if they lost the lawyer stood the shot. This conduct put a very strong temptation before workmen. Another reason was that in certain districts county court judges gave decisions not based on the evidence before them, but rather on sentimental grounds, and he had known in certain districts where it was hopeless to win, and instanced one town where claims against the company were steadily rising for this reason. Then the judge retired, and ever since then decisions had been given on the evidence submitted, with the result that there was a diminution in the damages against employers and in the claims made.

Strike of Engineers at Messrs. Cammell Laird's, Birkenhead.—On the ground that Messrs. Cammell, Laird, & Co., the Birkenhead shipbuilders, had refused to advance wages by 2s. weekly, the engineers and members of other kindred trades in the firm's employment went on strike last week. The men contend that recently there has been an advance in wages in virtually all competing centres, and that centres where wages have been lower than in the Mersey district are now catching up. It is also argued that the volume of work now passing through the yard of Cammell, Laird, & Co. warrants an increase being given. It is further pointed out that the Mersey Repairers' Association has agreed to an advance of 2s., and the men contend that there should be no differentiation between classes of work. The employers' case is that there is an essential distinction between repair work and new construction, and they would be handicapped by having to pay higher rates than elsewhere. The present Birkenhead rates of 37s. for a 53 hour week are higher than those in force in Barrow, equal to those on the Tyne, and less than those on the Clyde. Cammell Laird's employes at Birkenhead number nearly 8,000, of whom about 2,000 are involved in the dispute. In a published statement, the firm say the prin

ciple involved is of vital importance, not merely to the firm but to the whole of the Mersey district. If it is to be recognised that wages are to be higher in that district than in all others, the shipbuilding industry on the Mersey is doomed. If unfair differentiation is to be made against them the firm say they will be obliged to recognise that the Mersey is no more suitable for shipbuilding than the Thames, and make arrangements accordingly.

Mineral Production of the United Kingdom in 1911.—The following table, showing the output of certain minerals in the United Kingdom at mines worked under the Coal and Metalliferous Mines Regulation Acts during the year 1911, with comparative figures for the preceding year, are extracted from an advance proof (subject to correction) of the Mines and Quarries General Report and Statistics for 1911:—

	1910,	1911.
	Tons.	Tons.
Coal	264,417,588	271,878,924
Fire-clay	2,484,069	2,482,846
Ironstone	7,979,750	7,886,898
Copper ore and copper precipitate	4,160	3,244
Gold ore	6,154	2,752
Iron ore	1,851,351	1,823,795
Lead ore	28,493	23,864
Manganese ore	5,467	4,987
Tin ore, dressed*	6,624	6,545
Zinc ore	11,238	17,652

* In addition, 2,720 tons of undressed tin ore were obtained in 1910, and 1,721 tons in 1911.

It must be borne in mind that the above figures do not in all cases represent the total production of the minerals for the year. Large quantities of several important minerals are obtained from quarries under the Quarries Act and from other open workings, the returns from which are not yet available. The totals for coal and for the ores of copper, lead, and zinc may, however, be regarded as substantially complete.

Eight Hours and Bonus Systems in Shipyards.—A conference of the Shipbuilding Employers' Federation and of the trades signatory to the National Agreement met at Edinburgh on the 8th inst. to discuss two important questions to workers in the industry in the federated area. One was an appeal from the central conference to the grand conference on the part of the joiners employed at Barrow shipyard to terminate a premium bonus system recently introduced, and the other was a movement to secure an eight-hours day in shipyards. The bonus system at Barrow was taken first, and after a lengthy discussion an amicable arrangement was arrived at. The Barrow firm, it appeared, had offered the joiners a bonus for increasing their output of work. The system was immediately opposed, and a settlement was attempted through the medium of negotiations with the employers and by local conferences. These efforts failed, and thus the question ultimately reached the grand conference. The attitude of the Shipyard Trades Committee was that the bonus system introduced into a single yard constituted a breach of custom under the National Agreement, and therefore the men's representatives sought to have it discontinued. After the whole situation had been reviewed, the employers agreed to withdraw the system, and thus the matter ended without further trouble. The consideration of the eight-hours day question was discussed well into the evening. At 8 o'clock the conference ended, when the following official report was given to the Press by the joint secretaries: "A grand conference between representatives of the Shipbuilding Employers' Federation and of the various trades signatory to the National Shipyard Agreement was held to-day. The principal subject discused was a request for a reduction of hours, and this has been adjourned for further consideration at a subsequent grand conference. Various other subjects were brought forward, but were of a minor nature, and dealt with, some being adjourned. There is no necessity for details in these cases."

A Permanent Exhibition of Inventions.—Many appliances - undoubtedly fail to prove successful to their inventors or beneficial to the public owing to the difficulty of their securing adequate consideration. The occasional exhibitions that are held do, it is true, afford some opportunity in this direction, but unless an appliance is fairly well developed and pretty well known it often fails to receive in such displays the prominence its excellence deserves, or runs a risk of being so overshadowed as to fail to attract the attention of those who would be interested. This regrettable difficulty must have often been impressed on capitalists, inventors, and patentees. Many ideas undoubtedly sink into obscurity through lack of financial support, for genius and capital are seldom found in combination. For this reason the Permanent Exhibition of Inventions, which has been opened at Holborn Bars, London, E.C., will, we think, meet a long-felt want in the commercial and engineering world. It has been specially organised to bring together these two parties to the advantage of both. Its central position in the City of London, and its objects, is sure to secure a wide attendance of visitors from the engineering world and thus accord to inventors the opportunity of criticism and publicity which are the first avenues to commercial success. The staff is organised on lines which inventors seeking publicity will find exceedingly advantageous. The exhibition comprises an information bureau where particulars of specifications of exhibits, as well as prices and other details respecting British and Foreign patents, are conveniently filed and at the disposal of visitors for reference. As each exhibit has a reference number any negotiations respecting it may be carried on if desired with the strictest secrecy. Another department, replete with the most modern equipment, is devoted to the making of models, so that intending exhibitors may have them made at reasonable rates. A third is devoted to the sale and exploitation of patents at home and abroad. Not the least important feature of the exhibition is the installation of an Inventors' Society and Club, fitted with every modern convenience for the benefit of its members on exceedingly reasonable terms. The exhibition and its accessories, in fact, present so many advantages to a large section of the engineering world that we doubt not it will be widely appreciated. Any person interested and desiring fuller information can obtain the same on application to The Organiser, London Permanent Exhibition of Inventions, Holborn Bars, London, E.C.

METAL QUOTATIONS.

TUESDAY, MARCH 12TH.

Aluminium ingot	65/- per cwt.
,, wire, according to sizes, &c. ......from	102/- ,,
,, sheets ,, ,, ... ,,	120/- ,,
Antimony ... £27/-/- to	£27/10/- per ton
Brass, rolled	7¾d. per lb.
,, tubes (brazed)	9⅞d. ,,
,, ,, (solid drawn)	8d. ,,
,, ,, wire	7¾d. ,,
Copper, Standard	£64/7/6 per ton.
Iron, Cleveland	50/7½ ,,
,, Scotch	56/7½ ,,
Lead, English	£16/3/9 ,,
,, Foreign (soft)	£15/17/6 ,,
Mica (in original cases), small	6d. to 2/- per lb.
,, ,, ,, medium	2/6 to 4/- ,,
,, ,, ,, large	4/6 to 8/6 ,,
Quicksilver	£8/12/6 per bottle.
Silver	27d. per oz.
Spelter	£26/10/- per ton.
Tin, block	£192/10/- ,,
Tin plates	13/7½ ,,
Zinc sheets (Silesian)	£29/10/- ,,
,, (Stettin; Vieille Montagne)	£29/5/- ,,

New Engineer-in-Chief of the Post-Office.—The Postmaster-General has appointed Major O'Meara, C.M.G., R.E., to be engineering special commissioner charged with the duty of examining and reporting upon the telegraph and telephone systems of Europe. Major O'Meara has been engineer-in-chief of the Post-office since April, 1907, but unfortunately the state of his health is not such as to enable him to retain this office. Mr. W. Slingo, one of the assistant engineers-in-chief of the Post-office, has been appointed to be engineer-in-chief in succession to Major O'Meara.

The Testing and Certifying of Steam Boilers in Russia.—The Commercial Intelligence Branch of the Board of Trade states that a law has come into force in Russia giving power to Russian Boiler-owner Associations to take over from the Government inspectors the testing and certifying of steam boilers. Steam boilers in the control of these associations are subject to only half of the Government boiler tax. Under this law 10 associations have been formed, and have by mutual agreement divided European Russia into a number of spheres of action. The associations are as follows: St. Petersburg Association, Northern Association (St. Petersburg), Baltic Association (Riga), Warsaw Association, Moscow Association, Volga Association (Saratov), Southern Association (Kharkov), Kiev Association, Odessa Association, Baku Association.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Rotary engines. McDonald. 1160.
Textile belting. Maxwell & Christie. 1300.
Valve mechanism of internal combustion engines. Coats and Cameron. 1499.
Valve mechanism for internal combustion engines. Reinhard. 3851.
Rotary valve mechanism for internal combustion engines. Sanchez and Baradat. 4061.
Prevention of coal dust explosions in coal mines. Warr. 4227.
Multiple effect evaporating apparatus. Lillie. 4261.
Fire bars for use with corrugated furnaces. Morgan & Smith. 4429.
Briquette machinery. Yeadon & Yeadon. 4449.
Chain grate stokers. Babcock & Wilcox, Ltd. 4468.
Multi stage centrifugal pumps. Akt. Ges. Brown, Boveri, et Cie. 4478.
Fluid pressure turbines. Knight. 4500.
Starting gear for internal combustion engines. Cowey. 4712.
Signalling and speed controlling apparatus for railway trains. Dammond. 4882.
Pistons of rotary engines. Call. 4913.
Ventilating fans or propellers. C. Whittaker & Co., and Tattersall. 4981.
Split belt pulleys. Nyberg. 5038.
Internal combustion engines. Wright. 5100.
Frictional gearing. William Beardmore & Co., and Bremburg. 5891.
Hand-operated bending and cutting tools. Jones. 6134.
Valve mechanism for internal combustion engines. Soc. des Etablissements Lyonnais Rochet Schneider. 6447.
Scraper for cleaning economiser tubes. Moverley. 6469.
Lubricant axle boxes for railway rolling stock. Soc. Générale Diamond Calypsol, and Pierronne. 6640.
Means for burning liquid fuel. Tollemache. 6828.
Liquid fuel burners. Altmann. 7084.
Tramway rails with removable faces. Steel, Peech, & Tozer, Ltd., Allott, and Watson. 7711.
Petrol air gas generators or producers. Rowell & Rowell. 7911.
Coal cutting machines. Anderson, Boyes, & Co., Anderson, and Shield. 8954.
Combined steam-generators and gas producers. Smith. 9085.
Positive reversing motion for machines for milling double or multiple helical wheels. David Brown & Sons (Huddersfield), Ltd., and Brown. 10280.
Feed water heating fuel economisers. Burkill. 11176.
Method of cleaning the combustion chambers of internal combustion engines. Richards. 12236.
Method of and apparatus for treating ores. Mills. 12305.
Steam superheaters. Fowler & Anderson. 12331.
Rock drills. Purcell. 12465.
Internal combustion engines. Veitch. 12672.
Rotary injector. Zuckermann. 13206.
Railway signalling apparatus. Burns. 13354.
Steam traps. Cleland & Stewart. 13458.
Steam superheaters. Fergusson Superheaters, Ltd., and Fergusson. 13600.
Two stroke internal combustion engines. Albion Motor Car Company, and Murray. 13915.
Tachometers. Wille. 14417.
Grooved pulleys. Bright. 14967.
Production of oil gas. Burdon, Burdon, & Burdon. 15520.
Liquid transmission of power. Barbey. 15578.
Reversing means for 4 cycle internal combustion engines. Dusenbury & Chappell. 15609.
Valve gear for steam engines. Sallingre. 16030.
Cooling apparatus for internal combustion engines. Soc. M. Goudard Mennesson. 16042.
Carburetters for internal combustion engines. Bohne. 16368.
Point shifting devices for railway and tramway lines. Hashagen. 17266.
Automatic turret lathes. Potter. 17428.
Carburetters for internal combustion engines. Seymour and Knight. 17785
Explosion engines. De Dory. 18525.
Automatic car couplers. Willison. 18869.
Wind motors. Gillotin. 19155.
Screw propellors. Simon. 19997.
Apparatus for the expansion and heating of gases. Lajoie. 20252.
Multi-cylinder internal-combustion engines. Anzani. 21251.
Construction of the cylinders of internal combustion engines. Jaenisch. 22116.
Apparatus for the manufacture of briquettes. Soucek. 22224.
Carburetting apparatus. Garner. 22345.
Chaplets for metal casting. Heesemann. 22918.
Ball bearings. Benz & Co. 24319.
Heating and ventilating apparatus. Iliff. 24606.
Power applying mechanism for gas generators. Schmidt. 26000.
Valves for internal combustion engines. Parker. 26221.
Wrenches. Crolla & Schmitz. 27092.
Rotary engines. Call. 28379.
Pumps. Jennings. 28834.

ELECTRICAL, 1911.

Electric current distributing systems. Merz & Hunter. 4004.
Electric connections and switch control. Joel. 4019.
Automatic telegraph transmitters. Judd, Fraser, and Eastern Telegraph Company. 4050.
Vapour electric apparatus. Leblanc. 4266.
Control of electric regulators. Akt. Ges. Brown, Boveri, et Cie. 4915.
Electric wall plugs. Martyn. 5986.
Electric heaters. Monnot. 8023.
Direct current electric machines. Carrick, and Greenwood and Batley, Ltd. 8589.
Mechanism for timing electro-magneto machines for explosion motors. Soc. René Gillet et Cie. 9948.
Means for electrically indicating or recording the position, time, and speed of trains on railways. Jones Miller. 11495.
Electric switches. British Thomson Houston Company, and Wallace. 12919.
Portable electric fuse wire carrier. Chase. 15564.
Arc lamp electrodes. British Thomson Houston Company. 13124.
Electric motor control systems and aparatus therefor. British Thomson-Houston Company. 15322.
Earthing devices for electrical circuits. Siemens Bros. Dynamo Works. 16907.
Safety device for electric cables. Siemens Schuckertwerke Ges. 17046.
Terminals for electric storage batteries. Oldham. 17612.
Transmitter for wireless telegraphy. Ditcham. 18271.
Direct current motors. Vlaminck. 20298.
Circuits for telephone systems. Siemens Bros. & Co. 21164.
Storage battery electrodes. Hubbell. 21692.
Storage battery electrodes. Hubbell. 21784.
Alternating current electro magnets. Barbour. 24977.

1911.

Electric accumulator electrodes. Pape. 728.

Tariffs for Electrical Energy.— At a recent meeting of the Edinburgh section of the Institute of Electrical Engineers Mr. W. W. Lackie, Glasgow, read a paper on "Tariffs for Electrical Energy, with Particular Reference to Domestic Tariffs." He said that owing to the ever-changing aspects of the subject, and to the growth of exact knowledge with regard to the various factors concerned, the methods of charging still invite fresh consideration and treatment. After dealing with the systems of charging, Mr. Lackie said that with the problem of black smoke and atmospheric pollution in one's mind it was incumbent to devise a scheme which would enable the domestic consumer to get a supply of electricity for heating, cooking, &c., at a lower rate, without being put to the expense of separate wiring, with a separate meter, &c. It was now admitted, he said, that the domestic chimney was mainly responsible for atmospheric pollution. Municipalities must, therefore, as a branch of their activities in connection with the general movement towards public health, recognise the importance of nursing their electrical undertakings by encouraging the use of electrical energy for all domestic purposes.

Aeronautical Society of Great Britain.—As the result of the ballot for the election of the first Associate Fellows of this Society, the following have been elected: H. Barber, Griffith Brewer, Captain A. D. Carden, R.E., T. W. K. Clarke, J. W. Dunne, R. L. Howard Flanders, Prof. A. K. Huntington, Leo Jezzi, J. H. Ledeboer, Archibald R. Low, W. O. Manning, Mervyn O'Gorman, Alexander Ogilvie, F. Handley Page, Prof. J. E. Petavel, F.R.S., Horace L. Short, Captain M. F. Sueter, R.N., Lieut. N. F. Usborne, R.N., Lieut. C. M. Waterlow, R.E., E. T. Willows.

The Mechanical Engineer.

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Prime Costs and Estimates.

PRIME costing and estimating are important departments in most engineering works, and though occasionally related, their objects and methods in many ways differ considerably. Prime cost aims, or should do, at an accurate determination of what is the actual cost of a job in the shop to serve as a check on the estimate, which is a more or less approximate guess at what the cost is likely to be. With care the first permits of almost exact calculation. It cannot do more than this, and can only affect the profit or loss of work in hand in so far as it provides the management with a means of ascertaining current costs and thus of preventing leakage of material or labour, or suggests improvements in organisation to those who correctly interpret the figures. To the bulk of under-managers and foremen engaged in practical workshop supervision the filling up of the time-forms and schedules is apt to appear a waste of time or an elaboration of system designed to find occupation for the office staff, while the workman often suspects the system as a check on his tally to dodge which without discovery is meritorious rather than otherwise. Between this contempt and suspicion detailed "time-work" forms are apt to get filled up with a perfunctoriness that in many cases greatly depreciates their value for subsequent use in the office and probably justifies to some extent the contention that it is a waste of time and an addition to establishment charges which could very well be dispensed with. Certainly the ascertainment of prime cost, unless well done, is better left alone, but its value in a works where varied classes of work is done needs no demonstrating to those who are familiar with general management or are called upon to prepare estimates for new work. It not only permits of comparisons between different men, different tools, and different management, but often forms a more reliable basis in whole or in part when fresh estimates are required than was probably available in the past. The uncertainty as to when such information may be required and the imperative need that it should be accurate as far as possible are the

factors which make prime costing in some form necessary. Systems vary considerably with the nature of the work and the extent to which reference is required, and it is impossible to lay down any hard and fast outlines for them or to assert any one is superior to the rest. What any system should give, however, for the principals is an accurate record for each contract of the cost of labour and material, with sufficient detail to enable responsibility for past errors in estimating to be rightly apportioned and future ones to be avoided. Notwithstanding its unproductive aspect, therefore, more attention might often be profitably bestowed on prime costing, as was shown by Mr. G. James Wells in a paper read before the Manchester Association of Engineers and reproduced in our last issue (see page 326 ante). This may be admitted without endorsement of the precise details of the system he suggested. In some ways it is characterised by simplicity, and educational, in so far as it shows the benefits to the management not only for future reference but for daily shop control when thoughtfully interpreted. On one point some managers will probably differ from Mr. Wells. Alluding to the filling in of particulars of work on time sheets, he suggests a system of reference numbers exclusively for denominating machine tools used and particulars of work done as simpler for both workman and bookkeeper. In the abstract, simple figures, no doubt, present advantages over the distorted caligraphy with which clerks have occasionally to wrestle, but, on the other hand, they easily open the door to mistakes, for figures are often hieroglyphic in appearance and a slight mistake in a single symbol might create errors in accounts which would be automatically corrected by handwriting, however crude, while the number of reference figures that would be required for the separate items of orders in some shops would multiply the possibilities of mistake. This, however, is a criticism which does not affect the value of accurate system of prime cost accounts. They cannot of course counteract the evil of bad estimating, but if carefully applied they can confine the "guessing" on which estimating must always to some extent depend, within narrower limits and by so doing bring probability more within the range of certainty. Prime costing in short is a means to a valuable end, *i.e.*, correct estimating, which in its turn is a means to the final end of all manufacturing establishments, viz., the obtaining of orders and the making of profit.

Roller and Ball Bearings.

The lesser frictional resistance of roller and ball bearings as compared with plain journals is well known, and experience has shown their use to be often worth the extra cost. There are, however, numerous matters in connection with their design and working which have only been evolved slowly and at great expense, and opinions on some of them still differ. For this reason we welcome the paper by Prof. Goodman recently read to the Institution of Civil Engineers. It records results of investigations which have been conducted by him for a number of years and embodies data and conclusions which will doubtless prove of great value to those who are interested either in the design or working of these appliances. The tests were made mainly with a view to determine the effect of speed, lubrication, and temperature, as well as endurance. The full detailed record of them would require more space than we can afford, but a summary of his main conclusions are worth noting. Within certain limits the tests of the roller bearings appear to show that their behaviour may be expressed by certain general laws—firstly, that the friction is greater at low than at high loads, but is more constant than in plain journals; secondly, that the friction where there is pure rolling is nearly constant at all speeds, except when there is end thrust, in which case the friction decreases as the speed increases; thirdly, temperature does not affect the friction unless end thrust is excessive; fourthly, there is very little difference between "starting-effort" and "running-effort," while lubrication has little effect on a well-designed roller bearing, and in cases where excessive wear occurs it is usually due to the rotating parts and casing not being hardened and well finished. The frictional resistance of roller bearings is of a complex character and made up of many separate resistances. Rolling pure and simple appears to be quite independent of speed, and hence, when there is no end thrust, *i.e.*, sliding friction, the resistance of a roller bearing remains constant at all speeds. In ordinary bearings temperature we know does affect the friction because the viscosity of the lubricant gets less as the temperature rises, but in a roller bearing this obviously has little effect unless end thrust becomes excessive and brings sliding friction into play. The reason why the "starting-effort" is always greater than the "running-effort" in a plain bearing is that the lubricant is squeezed out when the bearing is at rest, so that the friction is between metal and metal until an oil film becomes established between the two surfaces, whereas in a roller bearing this action does not occur. Theoretical considerations would suggest that large rollers would give less friction resistance than small ones, but it would appear that the difference is not very great for they were so masked by other disturbing causes in the author's experiments that no definite conclusions could be drawn. The investigations of ball bearings were free from most of the troubles experienced with roller bearings, as the question of end thrust was practically eliminated, and Prof. Goodman found, speaking generally, that the frictional resistance was much lower than with rollers, owing doubtless to the fact that all the motion approximated to a purely rolling character, though in some of the early types of ball bearings and even in certain modern examples this, owing to bad design, does not pertain to the extent it ought to do. In comparisons of the relative advantages of roller bearings and ball bearings the advocates of the former often contend that the advantage of the latter is counterbalanced to a great extent by its lower load-carrying capacity for a given area of surface, inasmuch as balls only bear on a spot, whereas rollers bear on long, narrow strips of greater area, but while there is an element of truth in this, the disadvantage is more imaginary than real, because balls are usually of harder material than rollers and capable of withstanding a higher pressure per unit area of bearing surface. It might be suggested of course that rollers could be made of equally hard material, but experience shows that if this is done the rollers are liable to break transversely. The demerits of four-point bearings where balls are used have been previously noted and discussed, and the tests made confirm the generally accepted opinions with regard to their defects. Three point bearings gave better results, and are frequently used in order to take an end thrust as well as a radial load, but the tests show they are not altogether satisfactory and that where an end thrust has to be met it is better to use a separate bearing. In conclusion, Prof. Goodman expresses the belief that there are very few instances in which roller or ball bearings may not be used to advantage, and considers that the extra first cost is soon repaid by the reduction of friction and the saving of oil. Such bearings require far less attention, are more "foolproof," and as the wear is extremely small, do not upset the alignment of the shaft. To ensure success, however, ball bearings must not be overloaded, and must be carefully fixed in the first instance.

ELECTRIC DRIVING IN TEXTILE FACTORIES.

AT a recent meeting of the Huddersfield Technical College Textile Society, an interesting lecture on this subject was delivered by Mr. John Shaw, of Manchester.

Some 10 years ago, he said, the advocates of electrical driving for textile mills first began their campaign in this country. Since that date the pioneers had by their strenuous and persistent efforts overcome the early opposition and difficulties, and had demonstrated the justice of their early claims by having set to work successful installations in all parts of the kingdom and in all branches of the industry. He could confidently assert that electric driving by polyphase induction motors had firmly established itself as the best-known means for transmitting unaltered the regularity of speed from the prime mover to the driven machine. It was seven years since the first contract was given in the United Kingdom for the complete electrical driving equipment for a new mill, viz., the Acme Spinning Company's mill at Pendlebury. Many important contracts had since been carried out by various firms, and to-day statistics showed that upwards of 50,000 b.h.p. in motors had been installed in this kingdom alone. The earliest installations were all carried out on the so-called group system of driving, and the motors were consequently of large individual capacity. The reason for the adoption of that course was obvious; capital cost had to be kept down. Greater subdivision of mills into smaller sections had always been advocated by electrical engineers, in order to provide closer supervision and greater control over the output, and it was interesting to note that in the seven years the average size per motor had dropped from 45 h.p. in 1905 to just over 20 h.p. in 1911.

Since the main characteristic of polyphase induction motors was to reproduce exactly the turning moment with which the main generator was driven, it followed that a shaft so driven had the same regularity of speed as the main engine. That method of procedure had necessarily involved reconsideration and special designing of millwrighting work to be used in connection with these motors, by reason of the fact that the shafts were required to run at higher speeds than obtained in the mechanically-driven mills. Speeds increased and shaft and pulley diameters decreased, bearing centres merely being the determining limit of both speed and size of shaft. The largest diameter of shaft in the Acme Spinning Company's mill, which contained 1,350 h.p. in motors, was 3in., transmitting 200 h.p. at a speed of 585 revs. per minute, and driving cotton mules. In another large mill containing over 1,700 h.p. in motors, 300 h.p. was being transmitted through a shaft 3½in. diam. running at a speed of 585 revs. per minute, driving cotton and doubling frames. The same thing applied also to other branches of the industry, such as woollen, worsted, jute, flax, &c., particularly as regards the spinning and twisting sections. In two different woollen mills line shafts 2½in. diam., were running at 585 revs. per minute, driving woollen mules, one transmitting 175 b.h.p., and the other 150 b.h.p. Both mills were of shed construction, and the shafts were carried from the roof gutters. The first drive was installed on the understanding that should any difficulty arise due to vibration, the motor should be taken down and the rope pulleys and ropes provided free of cost to the purchaser for driving the shaft at ordinary speed. Both drives had been running with perfect success for over two years.

Experience had, the author said, proved it to be equally essential in obtaining good results that the shafting should be right as well as the motors and electrical equipment. More troubles had been experienced in electrical installations due to those details than from any other cause. Work which might be good enough to run at 300 revs. to 350 revs. would not be satisfactory when running at 580 revs. or 725 revs., although by giving due attention to all the details it was just as easy to make it satisfactory and capable of running without vibration and with a minimum amount of friction loss. Bearing on the friction loss in shafting at those high speeds, one shaft installed in 1905, transmitting 150 h.p. at 485 revs., 3in. diam. to 2½in. in 13 bearings, and with 25 ropes on loose pulleys, ran for 4min. 20secs. after current was shut off from the motor. The natural result of the adoption of such line shaft speeds was to reduce the diameters of the driving pulleys, making them more nearly the same size as the machine pulleys. The lecturer's experience proved to him that the smaller the ratio between driver and driven pulley, the better and sweeter the drive, and the smaller the slip, with consequent longer life to the driving belt or rope.

Subdivision of mills into sections or departments had, of late years, been carried out to a much greater extent than originally obtained. Whether it was commercially sound to carry it so far as to drive each machine by its own motor he was not prepared to say. In his opinion, based on the results of experience with both the group and individual driving of textile machines, each case required consideration on its own merits; while it might be right to adopt individual driving in one case, it might be equally wrong to adopt it in another.

By far the majority of electrical installations were for the conversion of old mills to the newer driving method, and naturally the question arose as to the time lost in making the alterations. Necessarily, there was some time lost in each instance, as it was almost impossible to carry through a complete reorganisation of all the driving arrangements of a large mill without interfering with its working. In four mills recently converted, one containing over 1,800 h.p. in motors, the second 1,100 h.p., the third 1,700 h.p., and the fourth 1,300 h.p., the average total stoppage of the mill due to the substitution of electrical for mechanical driving was one day in each case.

A very great proportion of the benefits derived from electrical transmission was dependent on the regularity of turning of the prime mover driving the electric generator. The steam turbine was a prime mover which provided a turning moment of practically perfect regularity. It was peculiarly well adapted to the requirements of electrical driving, although, owing to its speed of rotation, necessary to obtain good economy, not well adapted to driving by any other known means. When considering such delicate fabrics as were found in textile mills of all descriptions, the advantage of such a turning moment was self-evident. Its economy, steam consumption, and first cost were at least equal, if not superior, to those of the best reciprocating sets, and present-day practice was towards the adoption of the turbine for all industrial purposes. Practice favoured the adoption of large units from 1,000 kw. to 5,000 kw. capacity. It was a significant fact that, of the total of 50,000 h.p. of motors installed in textile works, probably more than one-half was driven from the mains of either corporations or public supply companies. Wherever it was possible, there was no doubt that taking power from an outside source was commercially sound. Instead of sinking capital in non-producing boilers and engines, consumers might invest that capital in producing machinery, and be relieved of all anxiety and worry as regards the maintenance of their power source and the keeping of it abreast of the times. Capital locked up in producing machinery was much more remunerative than the same amount sunk in boilers and engines.

Even, however, in those cases where an outside supply was not available, the steam turbine held its own in competition with other methods of generating power. Apart from its superior turning moment, so valuable in connection with textile work, its cost to-day was no more than that of the steam engine. Its applicability and facility of providing, without loss, steam for heating for such places as required it, was unequalled. Further, the steam turbine lent itself peculiarly well to those cases where the existing engines, already overloaded, were required, owing to exigencies of trade, to provide power for extensions.

Institute of Marine Engineers.—The annual meeting of the Institute of Marine Engineers was held on March 15th. The annual report showed a membership of 1,284 at the end of the session, an increase of 56 on the previous session. The ballot for office-bearers and members of council for session 1912-1913 resulted as follows: President, Mr. Summers Hunter; hon. secretary, Mr. Jas. Adamson; hon. treasurer, Mr. Alex. H. Mather. Members of council: Messrs. J. Clark, J. Falcon, J. Gravell, J. McLaren, and J. Peacock. The other members of council, who did not retire, are: Messrs. J. Blackett, K. C. Bales, P. T. Campbell, W. E. Farenden, J. Hallett, W. Veysey Lang, J. T. Milton, H. Ruck-Keene, J. H. Silley, and F. M. Timpson.

THE BALANCING OF LOCOMOTIVES.—V.

BY JAS. DUNLOP.

Yarrow-Schlick-Tweedie Balancing.

The system of balancing generally known by the hyphenated title above has only a limited interest for locomotive engineers. When 4-cylinder compound locomotives were introduced on the French railways some 26 years ago all the possibilities of the system were investigated and put in practice, but the conditions of locomotive operation are so variable

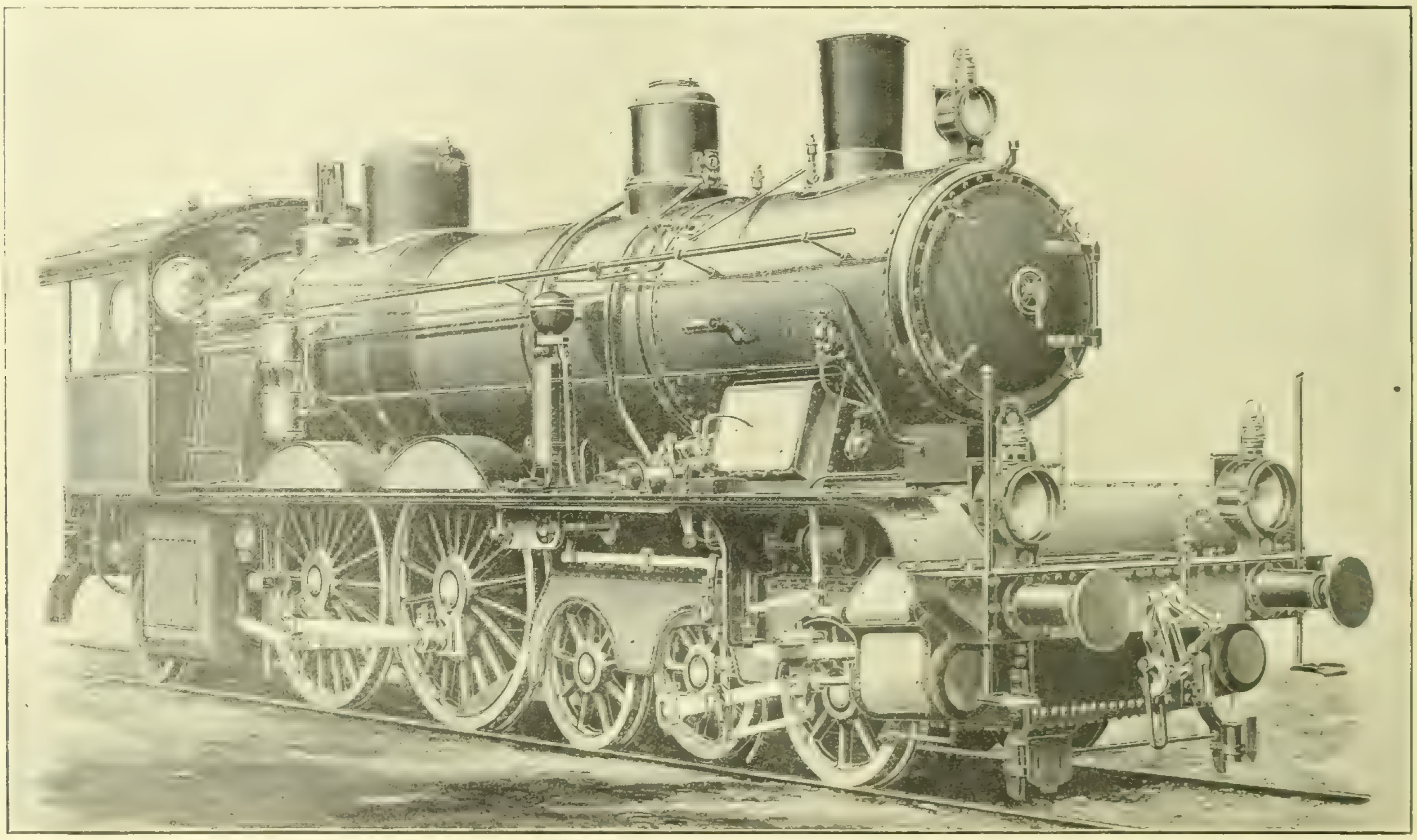


Fig. 43.—Inside 2-cylinder, Four-coupled Driver Locomotive, with Yarrow-Schlick-Tweedie Reciprocating Balance Weights.

that any advantages the system possesses were more than discounted by the inconveniences of operation the use of the system involved. To be in strict order, any discussion of the system should be left until the balancing of 4-cylinder engines is being dealt with, but it happens that for exhibition purposes an inside 2-cylinder engine with four coupled drivers was built with its reciprocating parts balanced on this system. This engine is illustrated in Fig. 43, from which it will be seen that in addition to its four coupled drivers the engine was provided with an additional pair of independent drivers operated by outside cylinders. As in the case of the engine illustrated in Fig. 19, the independent driving wheels were only used intermittently at starting and when working on inclines, in fact both engines were built by the same firm, Messrs. Krauss, of Munich. The engine was exhibited by them at the Paris Exhibition of 1900, and was illustrated in the technical press at that time, but, beyond stating the balancing was a modification of the Yarrow-Schlick-Tweedie system, no description was given in sufficient detail to enable engineers generally to understand exactly how the balance was produced.

To those who have recollections of the floods of mathematical symbols and formulæ let loose in discussions that have taken place over this system the following graphical demonstration will no doubt be acceptable. For one thing, it will dispel all ideas that any special knowledge is required to understand the system.

In the first place, the system takes no account whatever of the wheels or of any balance weights in the wheels, the inside reciprocating parts of the engine on each side being balanced by a reciprocating cast iron block connected to the rod appearing through a slot in the casing seen behind the trailing driver. This rod is jointed to an eccentric rod, the end of which is supported by a short swing link on the trailing driver coupling pin. The other end of the eccentric rod is jointed to an eccentric formed on the coupling pin of the main driver. The coupling rod is placed outside the eccentric rod, as shown. Fig. 44 shows a detail of the reciprocating block and its slide bars, also the swing link connection. The inclination of the slide bar centre line and its position shown below the trailing axle is explained by the fact that the inside cylinders are inclined to the driving axle and the slide bar centre is on a prolongation of the inside cylinder centre. This also explains the use of the swing link on the trailing coupling pin, as otherwise the eccentric might have been formed on that pin and the connecting rod of the reciprocating weight jointed to it direct. To understand clearly the manner in which these parts balance the inside reciprocating parts it is necessary to refer to the cross-section drawing of the engine as illustrated in Fig. 45. Project downward the centres of the cylinders and of the reciprocating balance weights as shown. At right angles across these centres draw the line A B, cutting the balance weight centres at C and D. Through D draw D E at an angle of 45°, cutting the cylinder centres at F and G. Join C F and C G. Then, if C D—the distance between the centres of the balance weights—represents to any scale the weight of one set of inside reciprocating parts, C F and C G, which are equal, represent to the same scale the amounts of the

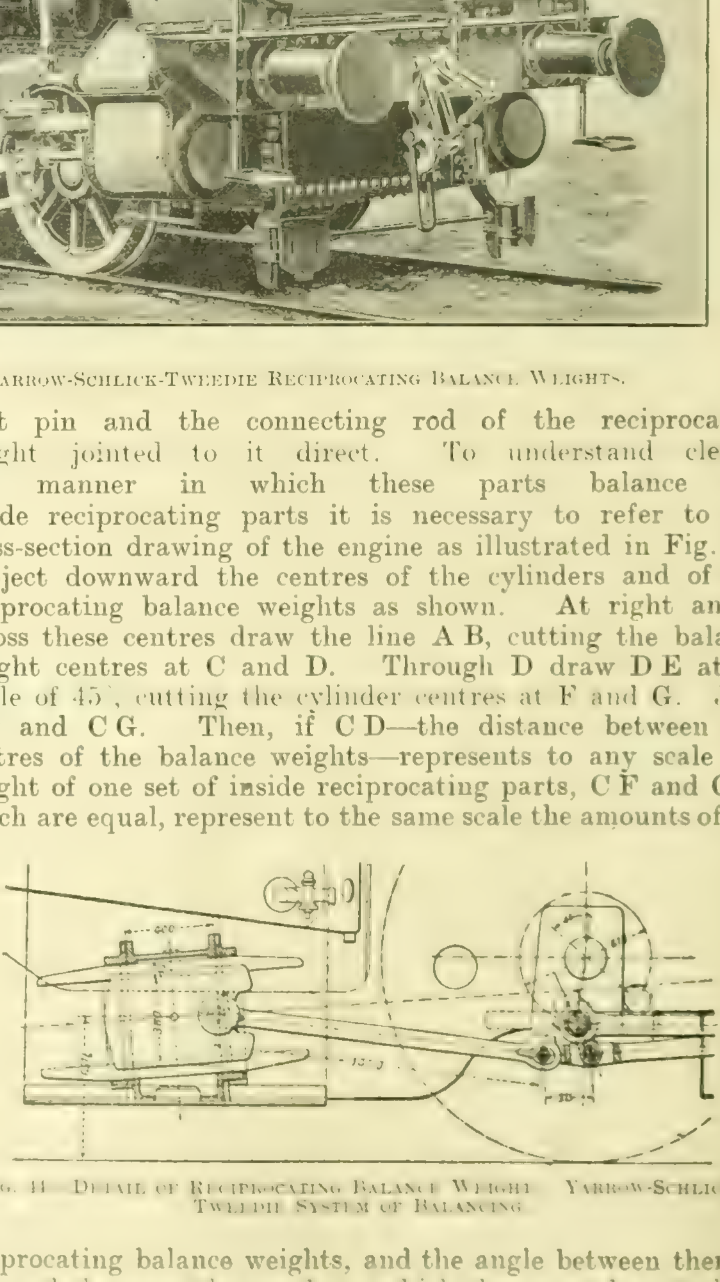


Fig. 44.—Detail of Reciprocating Balance Weight: Yarrow-Schlick-Tweedie System of Balancing.

reciprocating balance weights, and the angle between them is the angle between the cranks to which they must be attached. This angle is about 38°, which is too small for coupling rods to operate satisfactorily, so the designer decided that the least angle of coupling cranks he would risk was 56°, as indicated at H and J. To ensure, however, that the reciprocating

balance weights would move as if coupled to cranks at 38° he provided the eccentrics on the main coupling pins, the centres

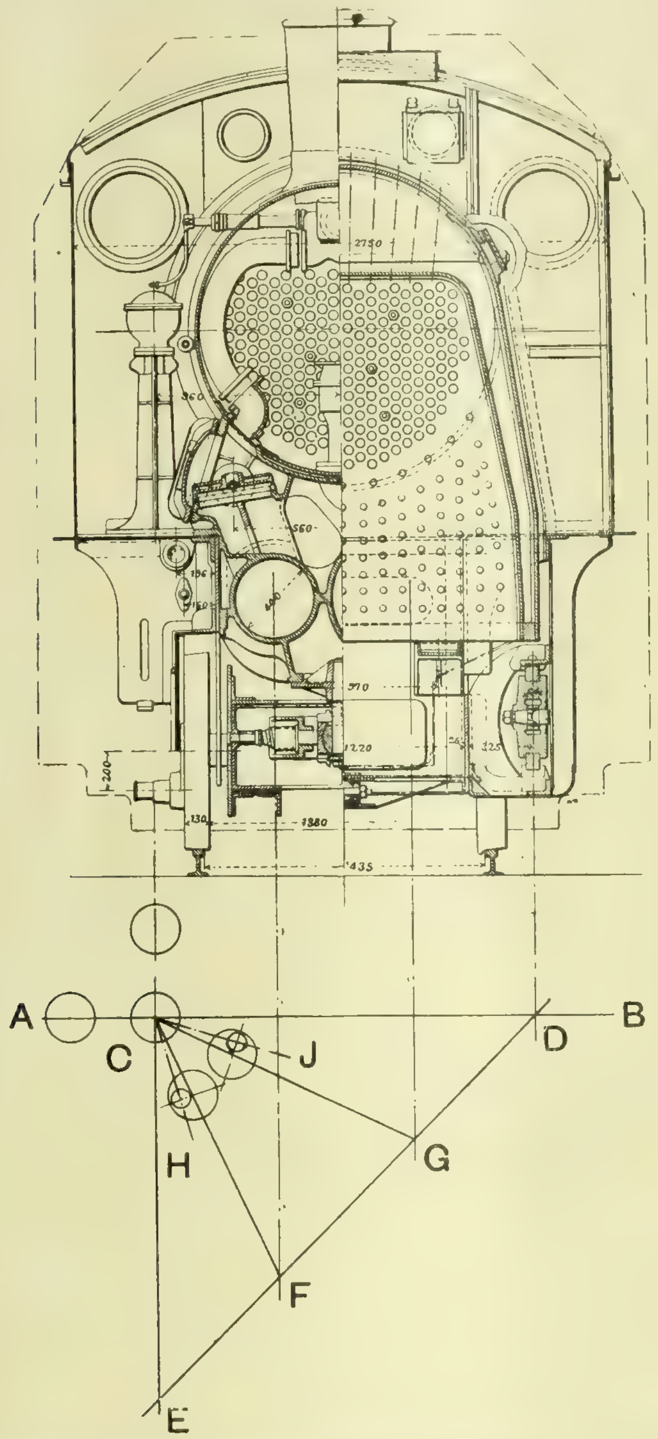


FIG. 45.—BALANCING DIAGRAM. INSIDE 2-CYLINDER LOCOMOTIVE WITH RECIPROCATING BALANCE WEIGHTS. YARROW-SCHLICK-TWEEDIE SYSTEM.

of the eccentrics lying on the lines C F and C G as shown. That is the whole explanation of the arrangement and proportioning of the Yarrow-Schlick-Tweedie system of balancing as carried out on this engine. From the fact that the reciprocating balance weights are at the opposite end of the engine to that at which the cylinders are placed it will be recognised that inertia effects are eliminated in just the same way as in the engine illustrated in Fig. 29. One good feature, whether intentional or not, is that the placing of the coupling cranks at 56° effected a very considerable economy in the amount of balance weight used in the wheels to balance the inside revolving parts, as may be seen from the comparatively small segmental weight at the rim of the main driving wheel. It is very doubtful whether the complete balance of the reciprocating parts and the consequent immunity from "hammer blow" could ever warrant an extended application of balancing mechanism such as described, on inside cylinder engines where the disturbing forces are acting at only short distances from the longitudinal centre plane of the engine.

Fig. 46 illustrates a peculiar construction of balanced locomotive in which the reciprocating weights mutually balance each other. Probably the correct term to use is oscillating weights, as the cylinders, instead of being placed parallel to the longitudinal centre plane of the engine, were placed transversely and provided with oscillating vane pistons fixed on shafts passing through the centres of the cylinders, the shafts being provided with double-armed rocking levers at their outer ends. To the ends of these levers connecting rods were attached to operate the driving wheels as shown. It will be seen the moving parts really balance each other longitudinally, but the upward and downward inclination of the connecting rods produced a certain amount of "pitching" due to steam reactions. This, however, would not be of sufficient

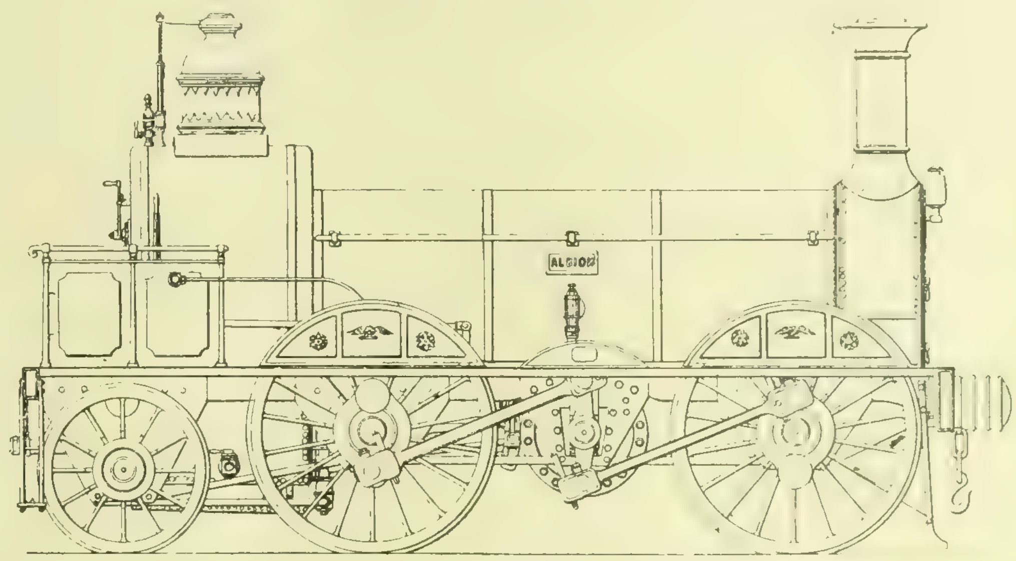


FIG. 46.—BALANCED LOCOMOTIVE WITH OSCILLATING VANE PISTONS AND OPPOSITELY MOVING CONNECTING RODS.

amount to condemn the arrangement. The really weak feature was the cylinder and piston construction, with its

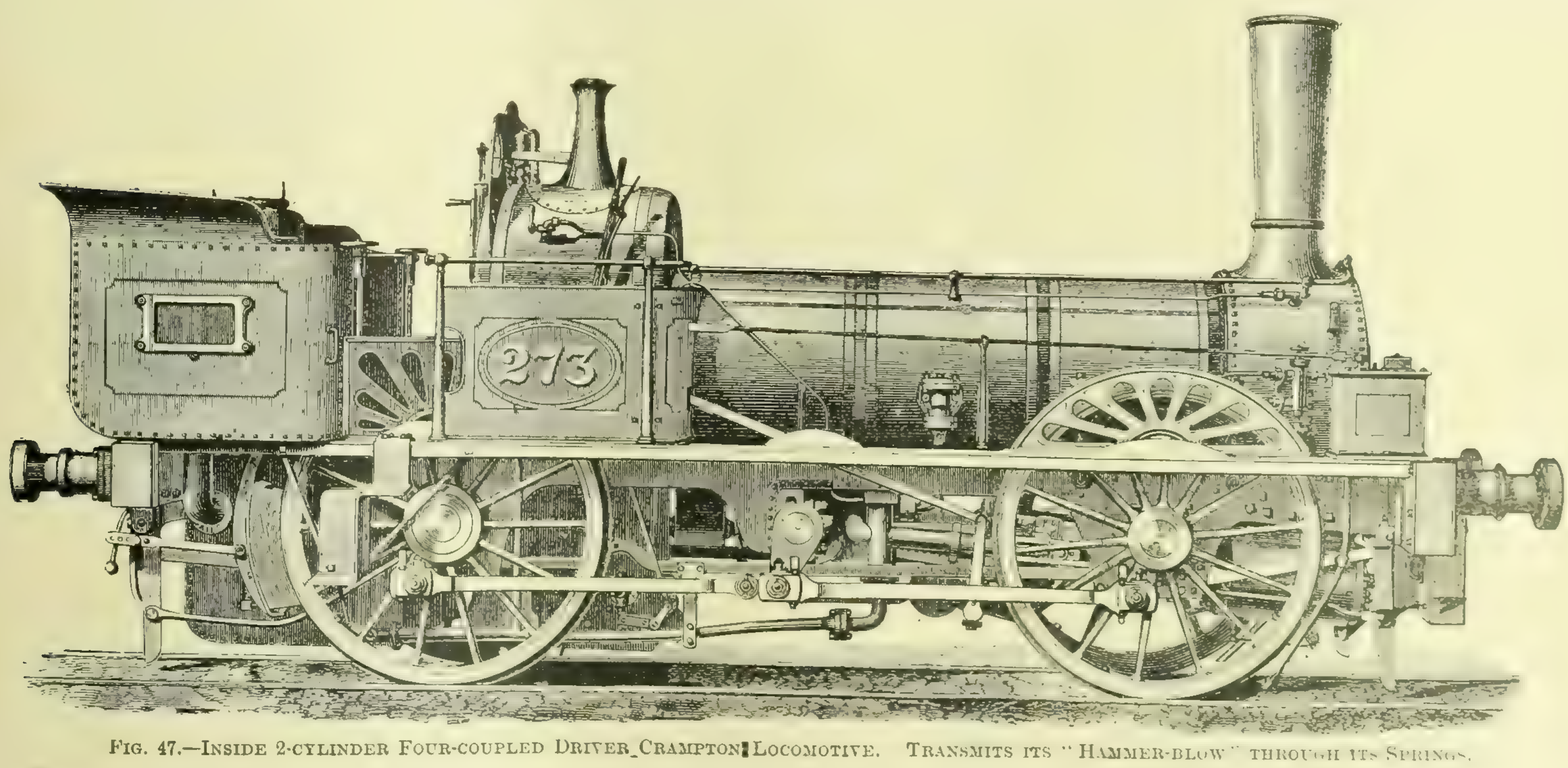


FIG. 47.—INSIDE 2-CYLINDER FOUR-COUPLED DRIVER CRAMPTON LOCOMOTIVE. TRANSMITS ITS "HAMMER-BLOW" THROUGH ITS SPRINGS.

AREA OF SEGMENTS OF A CIRCLE.

$\frac{\text{Versed sine}}{\text{Diameter}} = x$ Diameter^2 × y = area.

x.	y.	x.	y.	x.	y.	x.	y.	x.	y.	x.	y.	x.	y.	x.	y.
·001	·000042	·064	·021168	·127	·057991	·190	·103900	·253	·156149	·316	·212940	·379	·272890	·442	·334829
·002	·000119	·065	·021659	·128	·058658	·191	·104685	·254	·157019	·317	·213871	·380	·273861	·443	·335822
·003	·000219	·066	·022154	·129	·059327	·192	·105472	·255	·157890	·318	·214802	·381	·274832	·444	·336816
·004	·000337	·067	·022652	·130	·059999	·193	·106261	·256	·158762	·319	·215733	·382	·275803	·445	·337810
·005	·000470	·068	·023154	·131	·060672	·194	·107051	·257	·159636	·320	·216666	·383	·276775	·446	·338804
·006	·000618	·069	·023659	·132	·061348	·195	·107842	·258	·160510	·321	·217599	·384	·277748	·447	·339798
·007	·000779	·070	·024168	·133	·062026	·196	·108636	·259	·161386	·322	·218533	·385	·278721	·448	·340793
·008	·000951	·071	·024680	·134	·062707	·197	·109430	·260	·162263	·323	·219468	·386	·279694	·449	·341787
·009	·001135	·072	·025195	·135	·063389	·198	·110226	·261	·163140	·324	·220404	·387	·280668	·450	·342782
·010	·001329	·073	·025714	·136	·064074	·199	·111024	·262	·164019	·325	·221340	·388	·281642	·451	·343777
·011	·001533	·074	·026236	·137	·064760	·200	·111823	·263	·164899	·326	·222277	·389	·282617	·452	·344772
·012	·001746	·075	·026761	·138	·065449	·201	·112624	·264	·165780	·327	·223215	·390	·283592	·453	·345768
·013	·001968	·076	·027289	·139	·066140	·202	·113426	·265	·166663	·328	·224154	·391	·284568	·454	·346764
·014	·002199	·077	·027821	·140	·066833	·203	·114230	·266	·167546	·329	·225093	·392	·285544	·455	·347759
·015	·002438	·078	·028356	·141	·067528	·204	·115035	·267	·168430	·330	·226033	·393	·286521	·456	·348755
·016	·002685	·079	·028894	·142	·068225	·205	·115842	·268	·169315	·331	·226974	·394	·287498	·457	·349752
·017	·002940	·080	·029435	·143	·068924	·206	·116650	·269	·170202	·332	·227915	·395	·288476	·458	·350748
·018	·003202	·081	·029979	·144	·069625	·207	·117460	·270	·171089	·333	·228858	·396	·289453	·459	·351745
·019	·003471	·082	·030526	·145	·070328	·208	·118271	·271	·171978	·334	·229801	·397	·290432	·460	·352742
·020	·003748	·083	·031076	·146	·071033	·209	·119083	·272	·172867	·335	·230745	·398	·291411	·461	·353739
·021	·004031	·084	·031629	·147	·071741	·210	·119897	·273	·173758	·336	·231689	·399	·292390	·462	·354736
·022	·004322	·085	·032180	·148	·072450	·211	·120712	·274	·174649	·337	·232634	·400	·293369	·463	·355732
·023	·004618	·086	·032745	·149	·073161	·212	·121529	·275	·175542	·338	·233580	·401	·294349	·464	·356730
·024	·004921	·087	·033307	·150	·073874	·213	·122347	·276	·176435	·339	·234526	·402	·295330	·465	·357727
·025	·005230	·088	·033872	·151	·074589	·214	·123167	·277	·177330	·340	·235473	·403	·296311	·466	·358725
·026	·005546	·089	·034441	·152	·075306	·215	·123988	·278	·178225	·341	·236421	·404	·297292	·467	·359723
·027	·005867	·090	·035011	·153	·076026	·216	·124810	·279	·179122	·342	·237369	·405	·298273	·468	·360721
·028	·006194	·091	·035585	·154	·076747	·217	·125634	·280	·180019	·343	·238318	·406	·299255	·469	·361719
·029	·006527	·092	·036162	·155	·077469	·218	·126459	·281	·180918	·344	·239268	·407	·300238	·470	·362717
·030	·006865	·093	·036741	·156	·078194	·219	·127285	282	·181817	·345	·240218	·408	·301220	·471	·363715
·031	·007209	·094	·037323	·157	·078921	·220	·128113	·283	·182718	·346	·241169	·409	·302203	·472	·364713
·032	·007558	·095	·037909	·158	·079649	·221	·128942	·284	·183619	·347	·242121	·410	·303187	·473	·365712
·033	·007913	·096	·038496	·159	·080380	·222	·129773	·285	·184521	·348	·243074	·411	·304171	·474	·366710
·034	·008273	·097	·039087	·160	·081112	·223	·130605	·286	·185425	·349	·244026	·412	·305155	·475	·367709
·035	·008438	·098	·039680	·161	·081846	·224	·131438	·287	·186329	·350	·244980	·413	·306140	·476	·368708
·036	·009008	·099	·040276	·162	·082582	·225	·132272	·288	·187234	·351	·245934	·414	·307125	·477	·369707
·037	·009383	·100	·040875	·163	·083320	·226	·133108	·289	·188140	·352	·246889	·415	·308110	·478	·370706
·038	·009763	·101	·041476	·164	·084059	·227	·133945	·290	·189047	·353	·247845	·416	·309095	·479	·371705
·039	·010148	·102	·042080	·165	·084801	·228	·134784	·291	·189955	·354	·248801	·417	·310081	·480	·372764
·040	·010537	·103	·042687	·166	·085544	·229	·135624	·292	·190864	·355	·249757	·418	·311068	·481	·373703
·041	·010931	·104	·043296	·167	·086289	·230	·136465	·293	·191775	·356	·250715	·419	·312054	·482	·374702
·042	·011330	·105	·043908	·168	·087036	·231	·137307	·294	·192684	·357	·251673	·420	·313041	·483	·375702
·043	·011734	·106	·044522	·169	·087785	·232	·138150	·295	·193596	·358	·252631	·421	·314029	·484	·376702
·044	·012142	·107	·045139	·170	·088535	·233	·138995	·296	·194509	·359	·253590	·422	·315016	·485	·377701
·045	·012554	·108	·045759	·171	·089287	·234	·139841	·297	·195422	·360	·254550	·423	·316004	·486	·378701
·046	·012971	·109	·046381	·172	·090041	·235	·140688	·298	·196337	·361	·255510	·424	·316992	·487	·379700
·047	·013392	·110	·047005	·173	·090797	·236	·141537	·299	·197252	·362	·256471	·425	·317981	·488	·380700
·048	·013818	·111	·047632	·174	·091554	·237	·142387	·300	·198168	·363	·257433	·426	·318970	·489	·381699
·049	·014247	·112	·048262	·175	·092313	·238	·143238	·301	·199085	·364	·258395	·427	·319959	·490	·382699
·050	·014681	·113	·048894	·176	·093074	·239	·144091	·302	·200003	·365	·259357	·428	·320948	·491	·383699
·051	·015119	·114	·049528	·177	·093836	·240	·144944	·303	·200922	·366	·260320	·429	·321938	·492	·384699
·052	·015561	·115	·050165	·178	·094601	·241	·145799	·304	·201841	·367	·261284	·430	·322928	·493	·385699
·053	·016007	·116	·050804	·179	·095366	·242	·146655	·305	·202761	·368	·262248	·431	·323918	·494	·386699
·054	·016457	·117	·051446	·180	·096134	·243	·147512	·306	·203683	·369	·263213	·432	·324909	·495	·387699
·055	·016911	·118	·052090	·181	·096903	·244	·148371	·307	·204605	·370	·264178	·433	·325900	·496	·388699
·056	·017369	·119	·052736	·182	·097674	·245	·149230	·308	·205527	·371	·265144	·434	·326892	·497	·389699
·057	·017831	·120	·053385	·183	·098447	·246	·150091	·309	·206451	·372	·266111	·435	·327882	·498	·390699
·058	·018296	·121	·054036	·184	·099221	·247	·150953	·310	·207376	·373	·267078	·436	·328874	·499	·391699
·059	·018766	·122	·054689	·185	·099997	·248	·151816	·311	·208301	·374	·268045	·437	·329866	·500	·392699
·060	·019239	·123	·055345	·186	·100774	·249	·152680	·312	·209227	·375	·269013	·438	·330858		
·061	·019716	·124	·056003	·187	·101553	·250	·153546	·313	·210154	·376	·269982	·439	·331850		
·062	·020196	·125	·056663	·188	·102334	·251	·154412	·314	·211082	·377	·270951	·440	·332843		
·063	·020681	·126	·057326	·189	·103116	·252	·155280	·315	·212011	·378	·271920	·441	·333836		

attendant difficulties in the way of ensuring steam tightness between the rocking shafts and the cylinder abutments, also between the ends of the pistons and the ends of the cylinders. This engine, of which several were built, was constructed by Messrs. Thwaites Bros., of Bradford, in 1848.

Fig. 47 illustrates a somewhat similar-looking engine, but in this case the inside cylinders are of the usual construction, placed parallel to the longitudinal centre plane of the engine, and inclined upward to an intermediate crank shaft from a position low down at the smokebox end. As this engine has only leading and trailing coupled wheels and no driving wheels, in the usual acceptation of the term, the balancing is necessarily differently carried out to what it would be on an ordinary 4 coupled inside cylinder engine. So far as the various inside and outside revolving parts are concerned the procedure is as usual, but such remainder of the inside revolving parts as is not balanced by the outside cranks and parts of coupling rods attached to them, if attempted to be balanced by weights in the wheels would produce rather peculiar results. In the first place, the downward force of the inside parts if counteracted by weights in the wheels producing an upward force could only be so counteracted through

the springs. In the second place, the upward force of the inside parts would not be affected in any way whatever by weights in the wheels, and these weights consequently would produce an altogether unnecessary "hammer blow" on the rails. To balance this remainder of the inside revolving parts

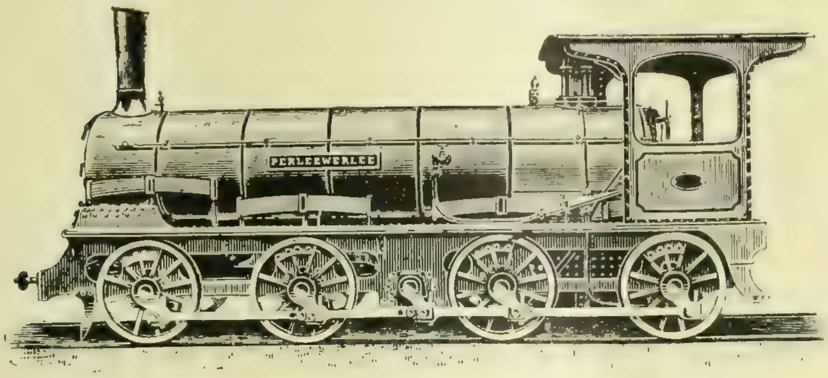


FIG. 48.—INSIDE 2-CYLINDER EIGHT-COUPLED DRIVER CRAMPTON LOCOMOTIVE.

it is therefore necessary to make the outside cranks purposely heavy or use tail weights on the inside cranks. As regards the reciprocating parts, the balance weights for these would necessarily be tail weights on the inside cranks, as by that means it would be ensured that the "hammer blow" on the rails would be softened in consequence of the fact that it is, under the circumstances, transmitted through the springs. This is the only type of inside cylinder engine that really requires tail weights on the inside cranks, any other engines, whether 2-cylinder or 4-cylinder, having tail weights on their inside cranks are balanced with no regard whatever to dead weight on the rails. The only reason that has been offered for the practice of using such weights in ordinary engines is that it relieves the crank axle of the centrifugal effect due to weights in the wheels. Such a reason for loading a crank axle with dead weight is simply preposterous. If an axle is of such dimensions that the centrifugal effect of the various inside and outside weights stresses it beyond the usual safe limit, such axle has no right whatever to be on the engine. This engine as a type is known as an inside cylinder, intermediate crank shaft, coupled Crampton engine, the only example of which with a greater number of coupled wheels is an 8-coupled driver engine built for an Indian branch railway in 1865 by Messrs. Sharp, Stewart, & Co., of Manchester. This latter engine is illustrated in Fig. 48 and shows the balance weights at one side of all the wheels.

As a concluding example of inside 2-cylinder coupled driver engines, Fig. 49 illustrates an engine built in considerable numbers many years ago for the Great Northern Railway when Mr. Sturrock was the locomotive superintendent. These engines were known as the Sturrock steam tender locomotives, the tenders as well as the engines being provided with driving cylinders and having six wheels coupled by separate outside cranks in the same way. The engines and tenders undoubtedly set up the "in and out of phase" effect previously noted in the case of independent driver engines. That this effect is a pronounced one may be understood by anyone who has watched the efforts of the drivers of "double-headed" trains to get their engines into step, as they term it.

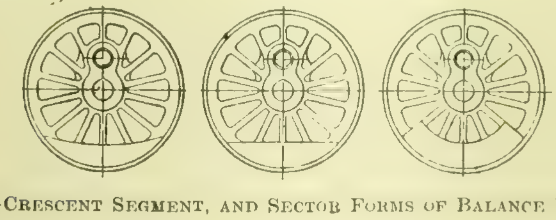


FIG. 50.—CRESCENT SEGMENT, AND SECTOR FORMS OF BALANCE WEIGHTS.

The forms given to the balance weights in the wheels of locomotives may be varied as the designer chooses, but the most usual forms are illustrated in Fig. 50. Of these the crescent form, in addition to providing the greatest balancing moment for a given weight, is also the one that provides the least abrupt change of section and consequently is the most satisfactory to use from the steelfounders' point of view.

AREA AND BALANCING MOMENT OF CRESCENTS.

Area of crescent $ABCEA$ = area of segment $ABCDA$ − area of segment $AECDA$.

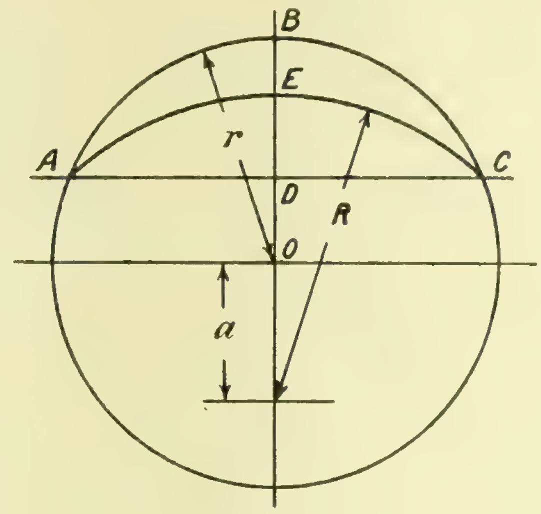
Balancing moment of crescent

= its area × distance of its centre of gravity from O.

= area of segment $AECDA$ × distance a.

$$\frac{\text{Balancing moment of crescent}}{\text{Area of crescent}} = \text{distance of its centre of gravity from } O.$$

Note.—This geometrical equivalent is exact, and is to be used in preference to any trial and error method of suspension of templets.



Centre of Gravity of a Segment.

$$\text{Distance of centre of gravity from centre} = \frac{\text{chord}^3}{12\ \text{area}}$$

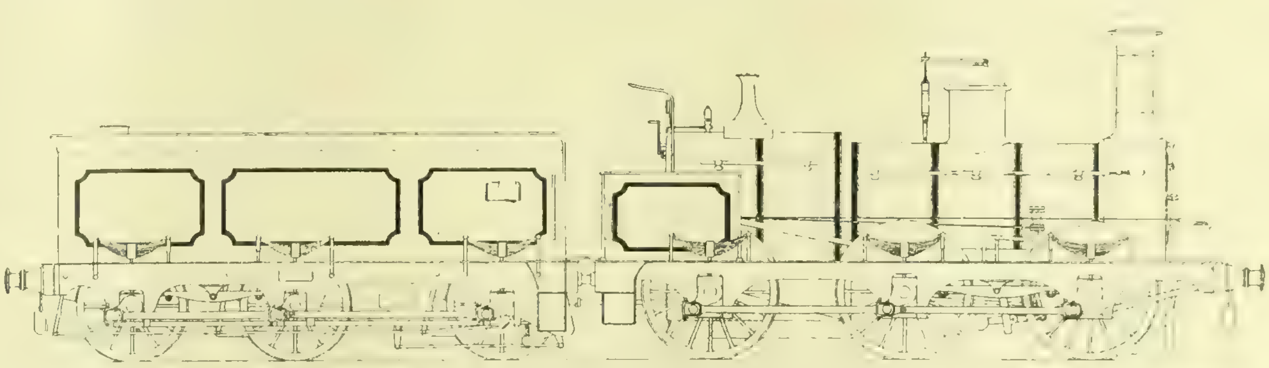


FIG. 49.—INSIDE 2-CYLINDER LOCOMOTIVE WITH INSIDE 2-CYLINDER ENGINE ON TENDER.

Centrifugal Force.

W = weight in lbs.
R = radius in ins.
D = dia. of wheel in ins.
M = speed in m.p.h.
C = centrifugal force in lbs.

$$C = 3 \cdot 2\, W R \left(\frac{M}{D}\right)^2$$

Speed in Miles per Hour.

$$M = \frac{D R_1}{336}$$

$$= \frac{D P}{56\, S}$$

$$\text{Max.} = \frac{24\, D}{S} \text{ for } 1344$$

ft. per min. piston speed.

Piston Speed and Revolutions per Minute.

S = stroke in ins.
P = piston speed in ft. per min. (not to exceed 1344)
R_1 = revolutions per min.

$$P = 56\, S \frac{M}{D} \qquad R_1 = 6 \frac{P}{S}$$

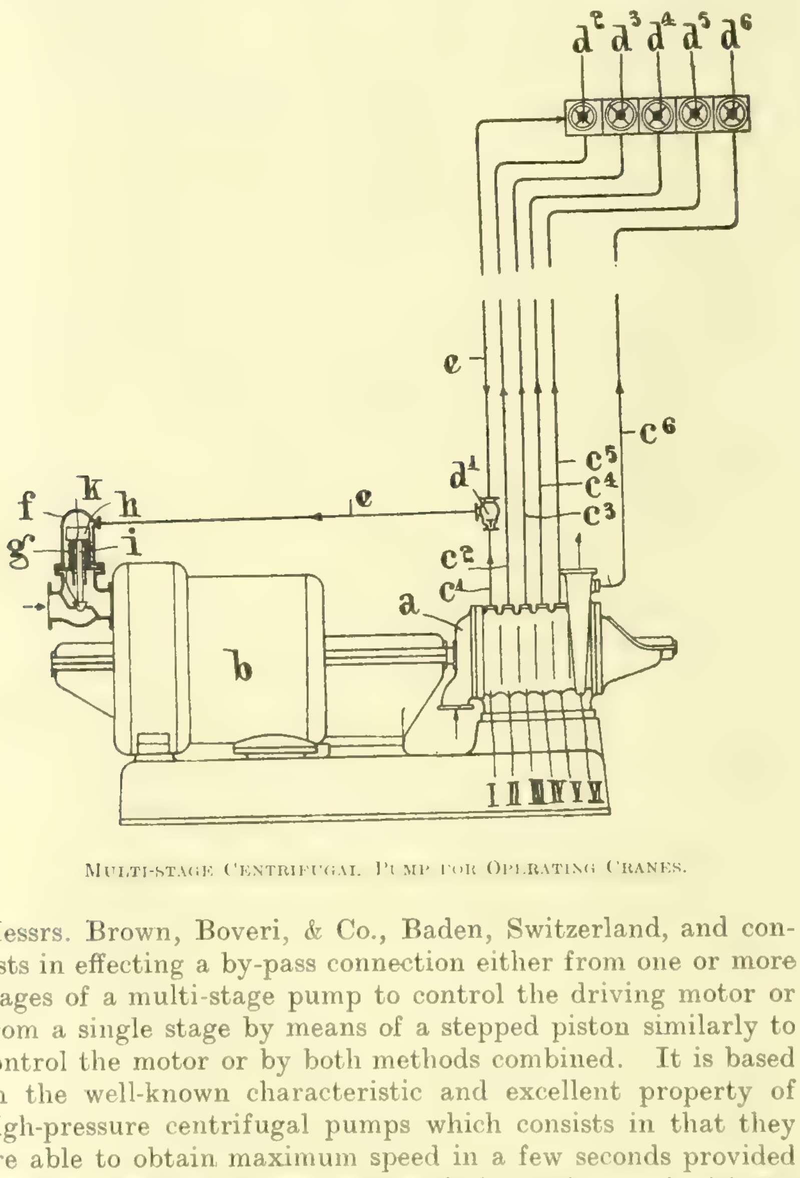
$$R_1 = 336 \frac{M}{D}$$

Hardening Platinum.—A new hardening ingredient for platinum has been found by W. C. Heraeus in the metal osmium. When iron or copper is present, the hardening effect of the osmium is considerably neutralised. The alloying of the platinum and osmium must be carried out away from the oxidising effects of the atmosphere, as osmium is highly oxidisable and gives off poisonous fumes. Platinum alloyed with more than 20 per cent. of osmium produces a brittle alloy.

MULTI-STAGE CENTRIFUGAL PUMP FOR HYDRAULICALLY OPERATING CRANES.

THE employment of multi-stage high-pressure centrifugal pumps for hydraulically operating cranes and similar apparatus working with temporary interruptions has hitherto been extremely difficult owing to the expenditure of energy during the period of running idle being extremely high, differing only very little from that required for full load. These losses of energy were caused by the fact that hitherto when working with a small load or during the intervals or interruptions in the working, a throttling valve arranged in the delivery or pressure conduit throttled the pressure fluid before it entered the apparatus to be operated, or cut the same off altogether so that it was necessary for the pump constantly to maintain in the pressure or delivery pipe in front of the throttling slide valve, a pressure which was equivalent to the pressure required for maximum power.

A method and means for the control or operation of apparatus of the class referred to above, which is claimed to be quick and efficient in operation, has been patented by



MULTI-STAGE CENTRIFUGAL PUMP FOR OPERATING CRANES.

Messrs. Brown, Boveri, & Co., Baden, Switzerland, and consists in effecting a by-pass connection either from one or more stages of a multi-stage pump to control the driving motor or from a single stage by means of a stepped piston similarly to control the motor or by both methods combined. It is based on the well-known characteristic and excellent property of high-pressure centrifugal pumps which consists in that they are able to obtain maximum speed in a few seconds provided that the revolving masses are already in motion, and with the arrangement illustrated it is possible to decrease the normal number of revolutions or speed, or to reduce the normal pressure to a suitably adjustable fractional value during the working intervals or during periods of small load, by which means the expenditure of energy is reduced in approximately direct or equal proportion; that is to say, it is no longer necessary for the pump to produce a higher pressure than is required for operating the crane or other similar apparatus. The centrifugal pump *a* is directly driven by the steam turbine *b*. All the stages I., II., III., IV., V., VI. of the pump are tapped by means of the conduits c^1 to c^6, which pass to valves d^2 to d^6, the conduit c^1 containing the valve d^1 also. A pipe *e* passes from the valves to a cylinder *f* and thus communicates with one side of a piston *h* moving in this cylinder and controlled on the other side by the action of a spring *g*. The rod *i* of the piston *h* operates the main inlet valve *k* of the steam turbine *b*. These elements *f*, *g*, *h*, and *i* form a pressure-regulating device.

In normal operation, that is to say with full load, the pressure of the first stage of the pump acts on the piston *h* by way of the conduit c^1, valve d^1 which is opened, and the pipe *e*. The dimensions of the spring *g* are so calculated that in this particular case the inlet valve *k* allows a quantity of steam to flow into the turbine which is just sufficient for the normal working of the centrifugal pump. If now stage II. of the pump is brought into communication with the cylinder *f*, for instance by opening the valve d^2 (the valve d^1 being automatically closed at the same time), so that a higher pressure acts on the piston *h*, then the latter completely shuts off the steam to the turbine and therefore regulates the same until the number of revolutions, *i.e.*, the speed has decreased to such an extent that in the stage II. of the pump that pressure prevails which previously prevailed in stage I. The pump therefore produces in two wheels the same amount of pressure which it previously produced in each separate wheel so that the pressure at the outlet pipe branch only amounts to half of the previous, that is, normal pressure. If stage III. is tapped and the valve d^3 opened, this pressure is reduced to one-third of the normal pressure, whilst if the valve d^4 is opened, it is reduced to one-fourth of the normal pressure, and so on.

HINTS ON MARINE ENGINE DETAILS.

AT the Institute of Marine Engineers on Monday, March 4th, a paper on "Details of a Marine Engine" was read by Mr. W. Veysey Lang (Member of Council). Mr. John McLaren, vice-president, occupied the chair. The author took as his subject the ordinary marine engines of a cargo steamer, developing from 1,000 i.h.p. to 2,000 i.h.p., of the triple-expansion, surface condensing type. In the course of the paper he said he considered that in many cases a size smaller engine and a size larger boiler or boilers would be a great improvement upon the usual practice. He had proved this by lining down the high-pressure cylinder from 24in. to $22\frac{1}{2}$in., or from 27in. to 25in., and the result had been a decided economy in fuel, while the speed was hardly affected.

Liners in the high-pressure and middle-pressure cylinders were most essential—in the low pressure they were negligible. The cylinder liner should undoubtedly be harder than the piston rings. In his opinion it was important that the piston rings should over-run the cylinder wall at either end of the stroke and so prevent "ridging." Cylinder clearances of $1\frac{1}{4}$in. and $\frac{3}{4}$in. were excessive. For cylinder lagging he preferred a good mortar non-conducting composition, put on when the cylinders were under steam and the steel sheets put on afterwards. The main feature in the piston or steam packing ring was suitability of metal. In piston rings which relied upon outward pressure by inclined surfaces, such surfaces soon became clogged and failed to act. Rings which were set out by steam or water pressure could not possibly give an equal pressure during the stroke and barrelling ensued. Strong springs exerting considerable outward pressure caused great friction and loss of power, as well as abnormal wear of the cylinder wall. For the plain, flat low-pressure ring he preferred volute springs to the D type. The lengths of the crank journals and pins were governed by the length of engine centres and were usually as short as possible. Increased diameter would in some degree make up for a more desirable length, and in this respect the crank pin was frequently found to be [illegible]in. larger in diameter than the journal ends. He firmly believed in the dowelling of built shafting.

For the thrust bearing he preferred a solid thrust carriage, with heavy horse shoes bolted down on both sides, and capable of slight adjustment by screws at both ends, the bearing faces to be loose on white metal shoes, carried on brass studs and adjustable by liners. With water circulation arranged in the shoes such a thrust would give no anxiety or trouble. Among other points discussed by Mr. Lang were stern tubes, condensers, pumps, tanks, valves, drainage, packing, rods, &c.

Messrs. W. McLaren, J. G. Hawthorn, F. M. Timpson, and W. Walker took part in the short discussion which ensued, and which was adjourned to Monday, March 18th.

THE DIESEL OIL ENGINE AND ITS INDUSTRIAL IMPORTANCE.*

BY DR. RUDOLPH DIESEL.

SINCE its first appearance about 14 years ago the Diesel engine has been built by the thousand in the best factories of all industrial countries, and has been set up in the most remote corners of the world. It has been proved to be a most reliable engine when properly built, the working of which is quite as safe as that of any other system of prime mover; and in general it is even more simple, since it does not require any auxiliary apparatus, and since the fuel in its natural and original form, without having previously undergone any transforming process, is directly converted into work in the cylinder of the engine. As early as 1897, when, after four years of difficult experiments, the author had put the first engine into working order in the factory of the Augsburg Works, experts who examined this engine expressed the opinion that it gave better heat utilisation than any known kind of heat engine. From experience gained subsequently by working many engines, by gradual improvements in the construction and manufacture, and by increasing the sizes, the results have been still further improved, and to-day the thermal or indicated efficiency reaches 48 per cent. in this engine, and the effective or brake efficiency reaches, in some cases, 35 per cent. of the heat value of the fuel. Fig. 1 shows the heat utilisation for 1 b.h.p. hour in the different kinds of prime movers known to-day.

The Diesel engine converts the heat of the natural fuel into work in the cylinder itself, without any previous transforming process, and utilises it as far as the present standard of science permits; it is therefore the simplest and, at the same time, the most economical prime mover. These two facts explain its success; it lies in the new principle of the internal working process and not in constructional improvements or alterations of older types of engines. There is no doubt that the careful working out of all the constructional details also plays a great part in the practical success of the Diesel engine, as in any other; but they are not the essential points, and above all they do not constitute the great importance of this engine to the world's industry.

A further reason for this importance is that the Diesel engine has broken the monopoly of coal, and has solved the problem of using liquid fuel for power production in its simplest and most general form. It has become for all natural liquid fuels what the steam engine and gas engine are for coal, but in a much simpler and more economical way. The truth of this statement was strikingly proved at the Turin Exhibition of last year. At this Exhibition, a steam turbine and a large Diesel engine, both made by Franco Tosi, of Milan, and set up on the same stand, were worked together with the same liquid fuel. The boilers belonging to the plant were fitted with Körting nozzles for burning crude oil. The difference between the two plants was therefore this: for the working of the steam engine the whole boiler plant with its chimney, fuel supply apparatus, purification plant for feed water with feed pumps, extensive steam pipes, condensation plant with water pumps and an enormous water consumption, had to be provided, with the final result of consuming 2½ or more times the fuel per horse-power required by the Diesel engine standing beside it. The latter, being an entirely independent engine without any auxiliary plant, took up its crude fuel automatically and consumed it direct in its cylinders without any residue or smoke.

Thus the Diesel engine has doubled the resources of mankind as regards power production, and has made new and hitherto unutilised products of nature available for motor power. The Diesel engine has thereby exercised a far-reaching influence on the liquid-fuel industry, which is at the present time improving more rapidly than was previously conceivable. Owing to the interest which petroleum producers have taken in this important question, new petroleum sources are continually being developed, and new oil districts discovered. Moreover, it has been proved by recent geological researches not only that there is probably on the globe as much, or perhaps even more, liquid fuel than coal, but also that it is more conveniently distributed as regards its geographical position. These facts have gradually silenced those who objected to too great a development of the Diesel engine for fear of insufficient stores of liquid fuel. Any such anxiety may be relieved by the fact that the world's production of crude oil increases at present 3½ times more quickly than the production of coal, and that the ratio of increase itself is steadily getting higher. Further, that 40 per cent. of the present production of mineral oil is already sufficient to supply the whole of the naval and mercantile fleets of the world with power, if they were worked by Diesel engines. It may safely be asserted that, with the continual development of new oil districts, the production of mineral oil will increase much more quickly than the demand for newly-built engines.

As early as the year 1899 the author utilised in his engine the by-products of coal distillation and coke plants, such as tar and creosote oils, with the same satisfactory results as with natural liquid fuels, but at that time the quality of these oils was generally too inferior for their use in the Diesel engine, and it was, moreover, subject to continual variations. The difficulties were then chiefly the following:—

(1) Muddy deposits of solid hydrocarbons, especially naphthalenes, which made the working of the fuel pumps difficult, filled up the pipes and nozzles, and formed a hard crust at the nozzle mouths. These solid hydrocarbons also made higher ignition temperatures necessary.

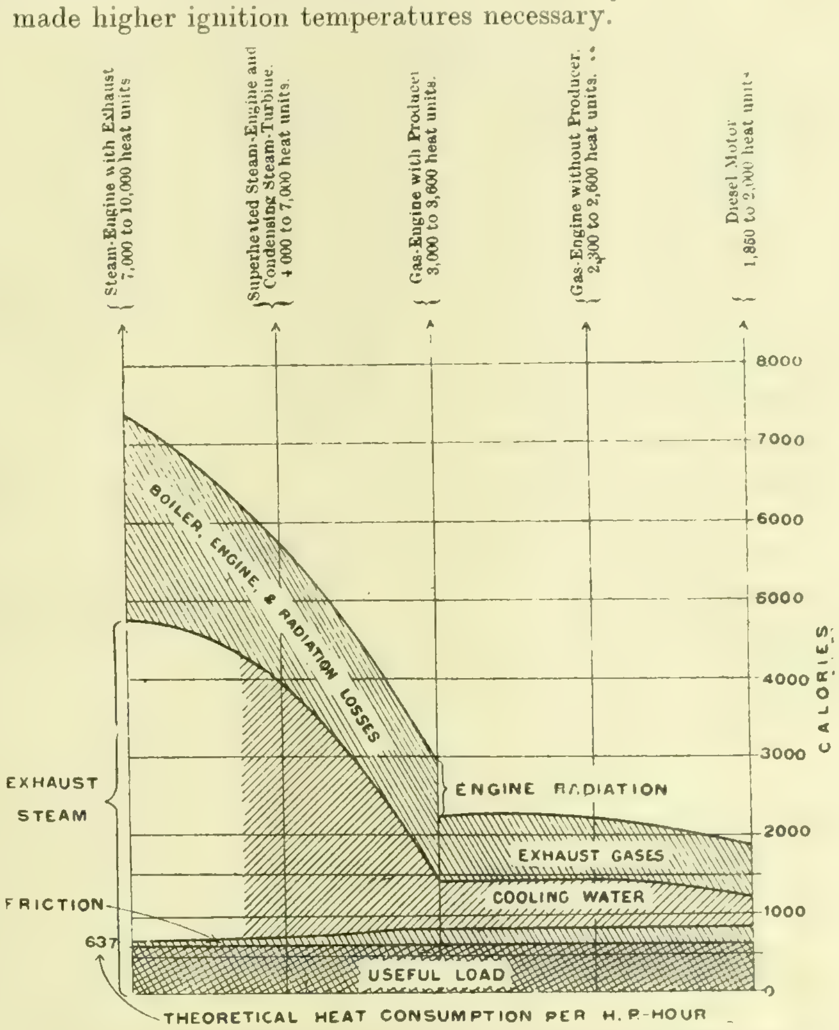


FIG. 1.—HEAT CONSUMPTION OF DIFFERENT HEAT ENGINES PER B.H.P. HOUR.

(2) Continuous change in quality and composition of the crude, uncleaned tar-oils; with each cask fresh variations appeared even in cases where the works guaranteed the use of the same coal, and the carrying out of the same distilling process, so that it was impossible to make scientific observations for drawing any definite conclusions, or making logical experimental arrangements. The characteristics of crude tar-oils were not then exactly known even to the producers; for instance, nobody imagined that differences in the distilling temperature and variations in the nature and position of the retorts gave entirely different tar products even when the same coal was used. It is only in recent years that the chemical industries interested in the matter have, by improved methods of fractioning and refining, combined with more careful selection of the material, succeeded in supplying fuel of a constant and regular quality, without the drawbacks of the crude tar-oils used previously. These products—the tar and tar-oils—are thus to-day definitely brought into the sphere of activity of the Diesel engine.

From what has been just stated, it will be seen that the Diesel engine is having an increasing influence on two other

* Abstract of paper read before the Institution of Mechanical Engineers, March 15th, 1912.

industries—the manufacture of gas and coke—the by-products of which have become so important for power production that an enormous business is at present connected with them. It is especially noteworthy that every town gasworks with a modern installation, and every cokeworks, can be completed with an electric power generating plant by using its tars. This will have an excellent effect on many municipal and national works. As tar and tar-oils are from three to five times better utilised in the Diesel engine than coal in the steam engine, a much better and more economical utilisation

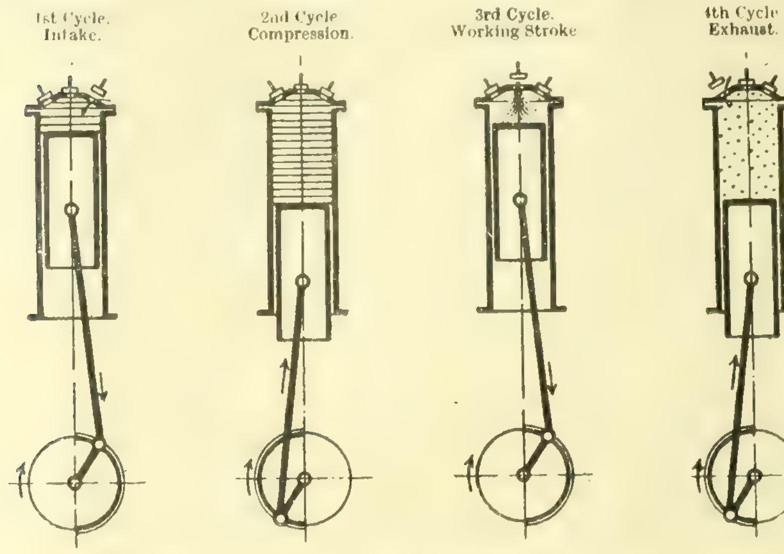


Fig. 2.—Working Diagrams of Single-acting Four-stroke Cycle Diesel Engine.

of coal is obtained if, instead of being burned under boilers on grates in a wasteful way, it is first transformed into coke and tar by distillation. Coke is used in metallurgical and other general heating purposes; from a part of the tar the valuable by-products are first extracted, and undergo further processes in the chemical industry, whilst the tar-oils and combustible by-products, and a great part of the tar itself, are burned in the Diesel engine under extraordinarily favourable conditions.

The proper development of the utilisation of fuel, which has already been started, and is now making rapid progress, is therefore the following: On the one hand liquid fuel in

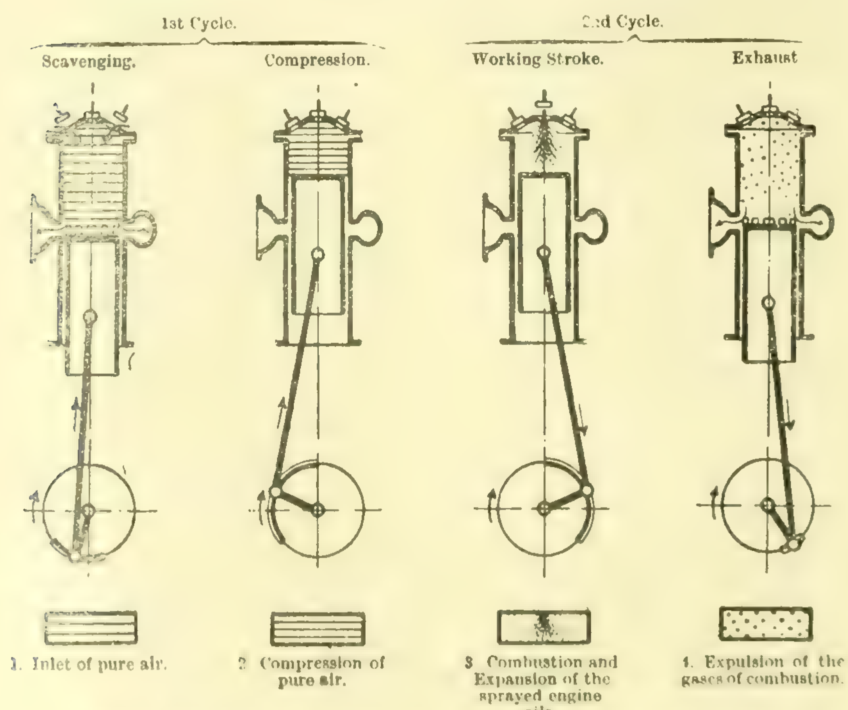


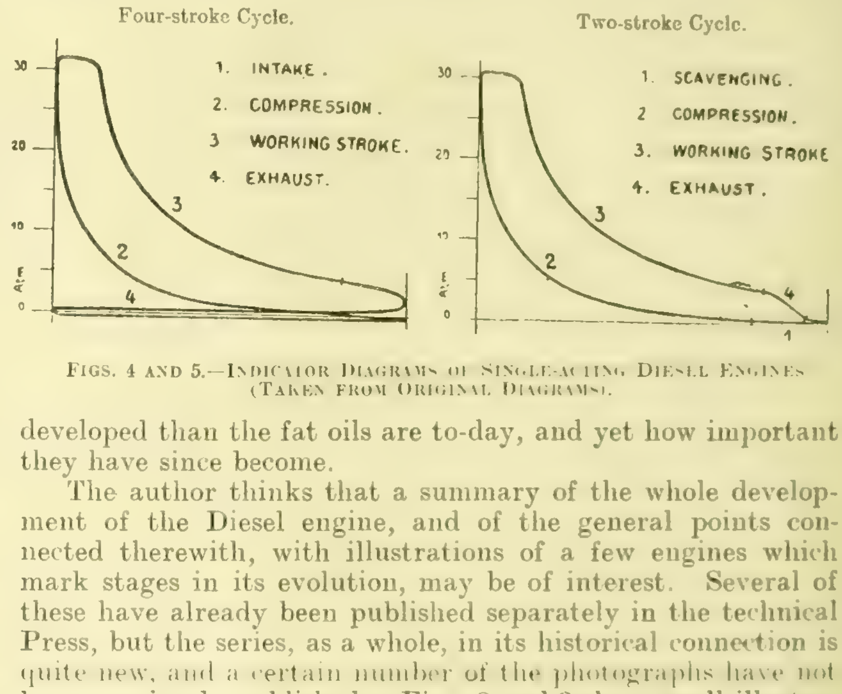
Fig. 3.—Working Diagrams of Single-acting Two-stroke Cycle Diesel Engine.

Diesel engines, and, on the other hand, gas fuel also in the form of gasified coke in the gas engines; solid fuel as little as possible for steam power generation, but only in the refined form of coke for all other heating and metallurgical purposes.

The list of fuels applicable to the Diesel engine is not, however, exhausted with these liquid fuels mentioned previously. It is known that brown coal or lignite, the production of which is about 10 per cent. of the pit coal production, also yields tars by distillation, and these tars when distilled, when worked up on paraffin, produce the so-called paraffin oils as by-products. Not all kinds of brown coal, however, are suitable for this process; but, in any case, these oils have been produced in such quantities that so far they have satisfied a good part of the German demand for liquid fuels for Diesel engines. To these must be added other products, such as shale and similar oils—produced not in great but in sufficient quantities to be of importance for power generation. Some countries—France and Scotland for instance—possess them in considerable quantities, and they are used in a good many Diesel engine plants. It is not generally known that it is also possible to burn fat vegetable oils and animal oils in the Diesel engine without any difficulty.

It has been proved that Diesel engines can be worked on earth-nut oil without any difficulty, and the author is in a position to publish, on this occasion for the first time, reliable figures obtained by tests: Consumption of earth-nut oil, 240 grammes (0·53lb.) per brake horse-power hour; calorific power of the oil, 8,600 calories (34,124 B.Th.U.) per kilogramme, thus fully equal to tar oils; hydrogen, 11·8 per cent. This oil is almost as effective as the natural mineral oils, and as it can also be used for lubricating oil, the whole work can be carried out with a single kind of oil produced directly on the spot. Thus this engine becomes a really independent engine for the tropics.

Similar successful experiments have also been made in St. Petersburg with castor-oil; and animal oils, such as train-oil, have been used with excellent results. The fact that fat oils from vegetable sources can be used may seem insignificant to-day, but such oils may perhaps become in course of time of the same importance as some natural mineral oils and the tar products are now. Twelve years ago the latter were not more



Figs. 4 and 5.—Indicator Diagrams of Single-acting Diesel Engines (Taken from Original Diagrams).

developed than the fat oils are to-day, and yet how important they have since become.

The author thinks that a summary of the whole development of the Diesel engine, and of the general points connected therewith, with illustrations of a few engines which mark stages in its evolution, may be of interest. Several of these have already been published separately in the technical Press, but the series, as a whole, in its historical connection is quite new, and a certain number of the photographs have not been previously published. Figs. 2 and 3 show small illustrations of the principal movements in the 4-stroke and 2-stroke cycle engines, with the corresponding indicator diagrams in Figs. 4 and 5, because these will constantly be referred to in the paper.[1]

Four-stroke Cycle Engine.

Vertical Stationary Engines.—The first experimental Diesel engine, Fig. 6, constructed in 1893, had the piston fitted with a piston rod and external crosshead, the cylinder having no water jacket, the cam shaft was arranged very low, and the valves were actuated by means of long rods. The starting storage chamber consisted of a wrought iron pipe with riveted flanges, and there was no air supply pump, the fuel being injected directly.

A later pattern, Fig. 7, built in 1895-96, had a similar base to that shown in Fig. 6, but it had a water-jacketed cylinder and the cam shaft was placed higher up. But the most important difference from the old pattern was in the air supply pump, the necessity for which was only recognised after several years experimenting, as without it a smokeless combustion could not be effected. This air pump is single acting, but the author previously used a special vertical compound air pump driven from a transmitting shaft. The first French and Belgian engines were nearly of the same type as

[1] [illegible] are taken from a publication by the Maschinenfabrik Augsburg und Maschinenbaugesellschaft Nürnberg A.G. (M.A.N.)

that shown in Fig. 7, but had no air pump; they were also of better and more compact construction.

The first reliable Diesel engine, Fig. 8, of 18 h.p., was finished in 1897 at Augsburg, after about four years' laborious experimenting. It was a vertical engine having the piston connected to an external crosshead and worked on the 4-stroke cycle. The illustration shows the engine with the testing brake attached, and with the other testing apparatus exactly in the state in which it was used by the numerous commissions of engineers and experts who came from different countries to examine the engine. This type was for about 10 years the exclusive and almost stereotyped pattern for all Diesel engines which were built in various countries.

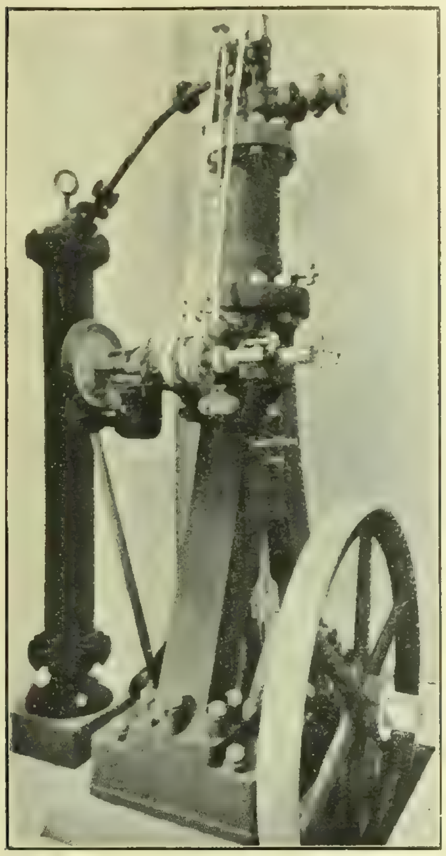


FIG. 6.—FIRST EXPERIMENTAL DIESEL ENGINE, 1893.

FIG. 7.—LATER EXPERIMENTAL PATTERN, 1895-6.

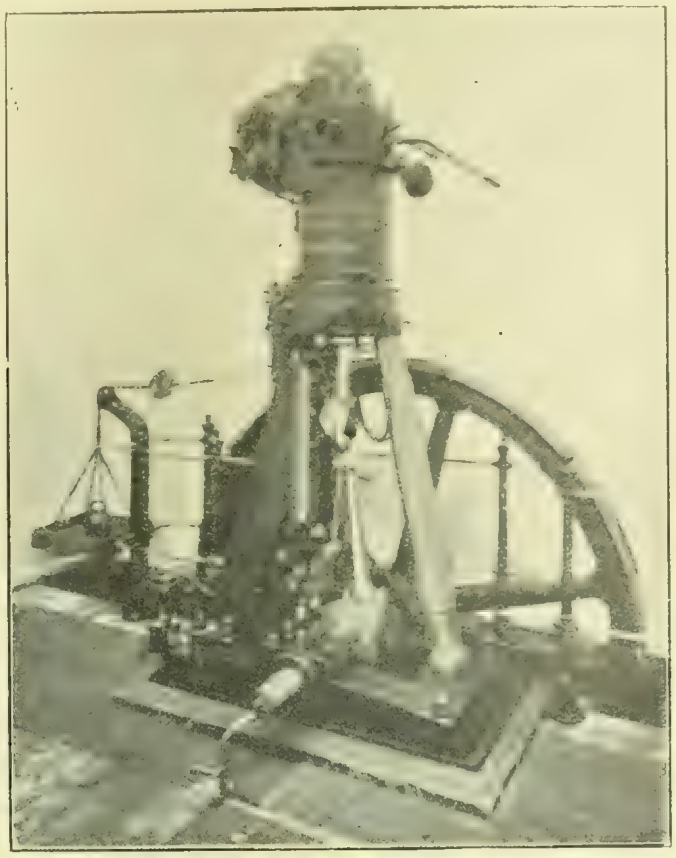


FIG. 8.—FIRST COMPLETE ENGINE, 18 H.P., 1897. SHOWING BRAKE AND OTHER TESTING APPARATUS.

In the following year, 1898, a single-cylinder engine of 20 h.p. to 25 h.p. was built at the Augsburg Works. This engine had almost all the characteristic details of the experimental engine just mentioned, the only difference being that the experimental engine had the cylinder connected to the base by an inclined column in front, whilst the later pattern had the well-known A-frame which the author employed on his first experimental engines. No further alterations have been made. The engine had still the external crosshead and guides, and the petroleum pump was actuated by the cam shaft in exactly the same way as in the experimental engine, Fig. 8. The air pump was cast on the base in exactly the same way, and was driven in both cases by rocking beams from the crosshead. The lubrication of the cylinders was effected by means of Mollerup appliances, and the valve rods, the regulator, and all the details were identical in both engines. Except for alterations in unimportant details of construction, the only changes since made were that the dimensions and the numbers of cylinders were enlarged.

A 2-cylinder engine of 60-76 h.p. was made in 1899, in which all the details of Fig. 8 are still to be recognised. The only alteration which was made in the year 1901 was the abandonment of the external crosshead and adoption of the trunk piston shown in Fig. 9. A comparison of this engine with that illustrated in Fig. 8 shows that, with the exception of the omission of the crosshead, no alterations of any importance have been made. Vertical 4-stroke cycle engines of from 10 h.p. to 250 h.p. per cylinder were constructed after this pattern, and units up to 1,000 h.p. were obtained by combining several cylinders. These engines ran at comparatively low speeds, from 160-200 revolutions, according to their size, and were of very heavy construction. Their weight was originally from 280 kg. to 350 kg. (617-771 lbs.) per horse-power, and later from 240-300 kg. (529-661 lbs.) per horse-power. This type of engine was used exclusively as a stationary plant for various industrial purposes. A 2-cylinder M.A.N. engine of this type of 250 h.p. or 125 h.p. per cylinder was built in 1902. Another 2-cylinder 160 h.p. engine of the same type, designed by the Diesel Engine Company, London, was built by Carels.

A 3-cylinder engine of the same type, Fig. 10, was made by Sulzer Bros. in 1906. The two latter engines show a slight alteration; the petroleum pump is driven from the vertical instead of from the horizontal cam shaft, as was the case in the previous engines. The engines built by Sulzer Bros. and by Carels have also a rotating stuffing box for the fuel needle. This arrangement was first built in Sweden on the author's instructions, and worked successfully. The well-

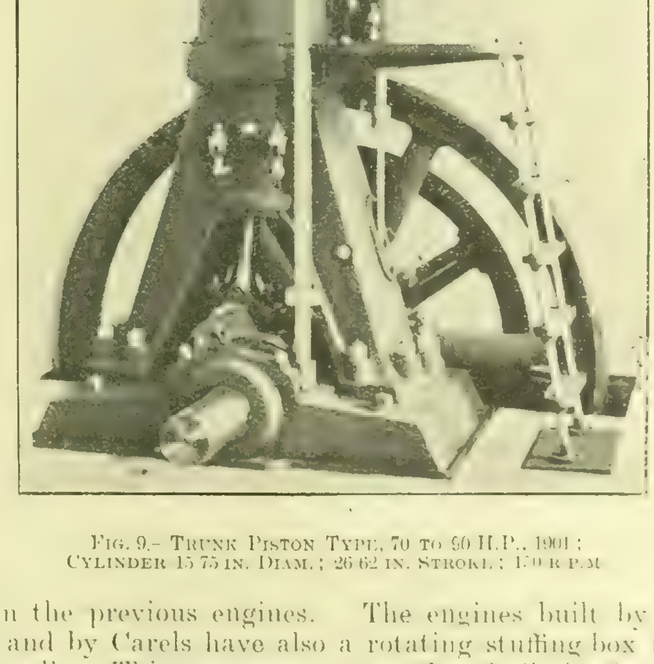


FIG. 9.—TRUNK PISTON TYPE, 70 TO 90 H.P., 1901; CYLINDER 15·75 IN. DIAM.; 26·62 IN. STROKE; 170 R.P.M.

known 500 h.p. 3-cylinder engine of Carels was exhibited at Liége in 1905.

The author has purposely referred to this type of engine to show that these engines, which have been built in various factories and in various countries, still remain almost an exact copy of the old experimental engine, Fig. 7. Only in America was the design simplified, or rather cheapened, from the commencement by the director of the American Diesel

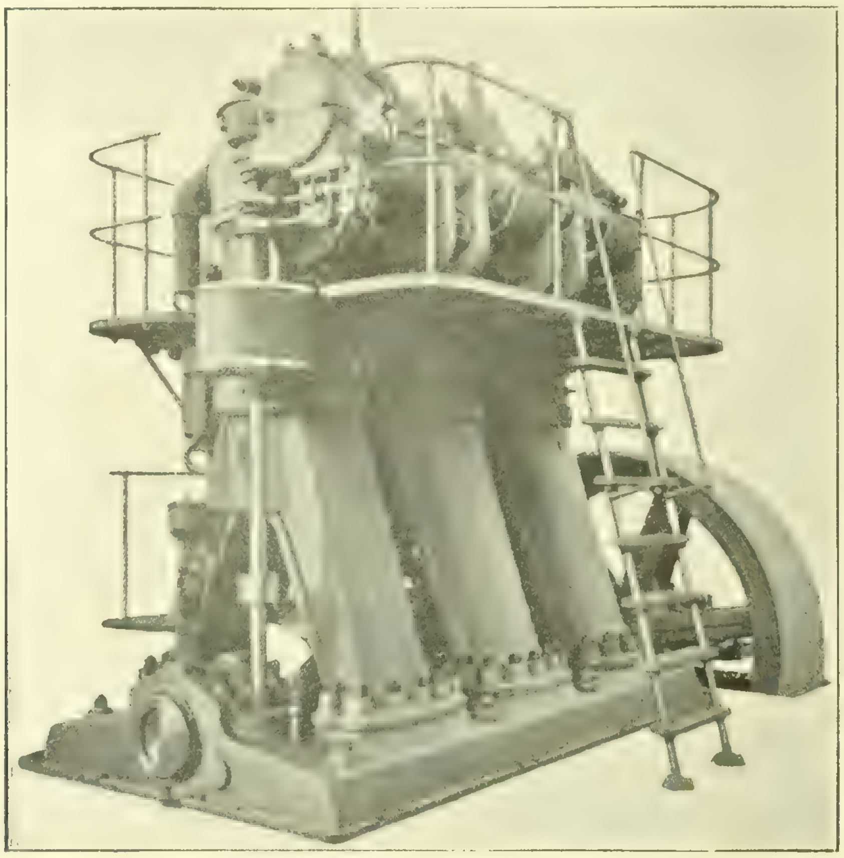


Fig. 10.—Three-cylinder 300 H.P. Engine, 1906.

Engine Company, Colonel E. D. Meier. In America the engines were built without crossheads from the beginning, an idea which, as already mentioned, was followed in the year 1901 by the European works after the American engines with trunk pistons had proved successful. The Americans also built from the commencement a closed base frame, and this construction, as will be seen later, has also been recently adopted in the European high-speed engines, but in a more refined and better form. Moreover, the American engines had no valves in the cylinder covers, but they were placed in a chamber cast at the side of the cylinder, which necessitated the fuel needle being placed horizontally between the suction and exhaust valves. Finally, the Americans, instead of driving the air-supply pump direct from the engine, always set it up independently and drove it either by a small extra engine, by a transmission shaft, or by an electric motor, in the manner in which air pumps are now set up in many Diesel engine plants on board ship. All these alterations were made with the object of cheapening the manufacture, which is the cardinal feature in American practice.

A remarkable fact is that the first Diesel engines, built in 1897-1898, are still working, without any change in their fuel consumption; also the first English engine built by the Mirrlees, Watson, & Yaryan Co. at Glasgow, according to the author's design of 14 years ago, is still working.

As the central electric stations took up the Diesel engine very early, the necessity for quicker-running engines arose. This need, and the improvement in methods of construction and utilisation of materials, caused the gradual introduction of the new quicker-running 4-stroke cycle engines, with speeds of from 300 up to 600 revolutions. These, however, were still exclusively vertical. The main difference in construction as compared with the first type was that the bearings of the crank shaft were connected with the cylinders by means of light steel columns instead of by heavy cast-iron A-shaped frames, so that the cast-iron pedestal of the machine became a light crank case, relieved from great strain; in addition, the thickness of all the castings was diminished. By this means the weight of the engines was reduced to about one-fourth to one-fifth of the weight of the old types, or to about 50 kg. (110lbs.) per horse-power. Engines of this kind are now built up to about 700 h.p. and are especially suitable for driving dynamos, blowers, and centrifugal pumps, and also as auxiliary engines on board large vessels, &c.

The first of these high-speed 4-stroke cycle engines made by the M.A.N. had no alterations in the valves, the needle, or the gearing, nor in the driving and the position of the petroleum and air-supply pumps, &c.

In a 4-stroke cycle high-speed engine, Fig. 11, made by Messrs. Sulzer Bros. in the year 1909 the only difference, except the box-pattern frame, between it and the arrangement of the old type consisted in the position of the air-supply pump, which was in this case fitted to one end of the engine and driven direct from the crank shaft. In a later 4-stroke cycle high-speed engine of 350 h.p. made by Messrs. Sulzer Bros. in 1911 the air-supply pump was also driven from the crank shaft, but was fitted between the cylinders on the box-pattern base in a neater way. In this case also no radical alteration has been made.

These latter kinds of engines may be regarded as the final and permanent type of the vertical 4-stroke cycle engine for stationary purposes, both for high and low speeds. With this and similar types the development of the 4-stroke cycle engine reached a definite state of development. When in the last decade, through rapid development of the French submarines, an urgent need for a reliable submarine engine was felt, these 4-stroke cycle engines were further reduced in weight by using steel and brass castings, with still thinner walls, and they have also recently been fitted with reversing gear. The author will return to this point later when discussing marine engines.

Small Engines.—This summary of the development of the vertical 4-stroke cycle engine would not be complete without a reference to the small engines which have recently been built in accordance with the author's designs. The officially recognised consumption for a 5 h.p. engine is 240 grammes (0·531b.) per brake horse-power, which is therefore not much more than with the old large engines of medium horse-power. At present the author is endeavouring to simplify and strengthen this small engine, which will then be suitable for small manufacturers and for farmers, who are not especially skilled in mechanical work.

Horizontal Stationary Engines.—After vertical engines had solely been used for about 12 years, horizontal 4-stroke cycle engines were built. The author is uncertain whether this type was a real necessity, or whether it was originally only

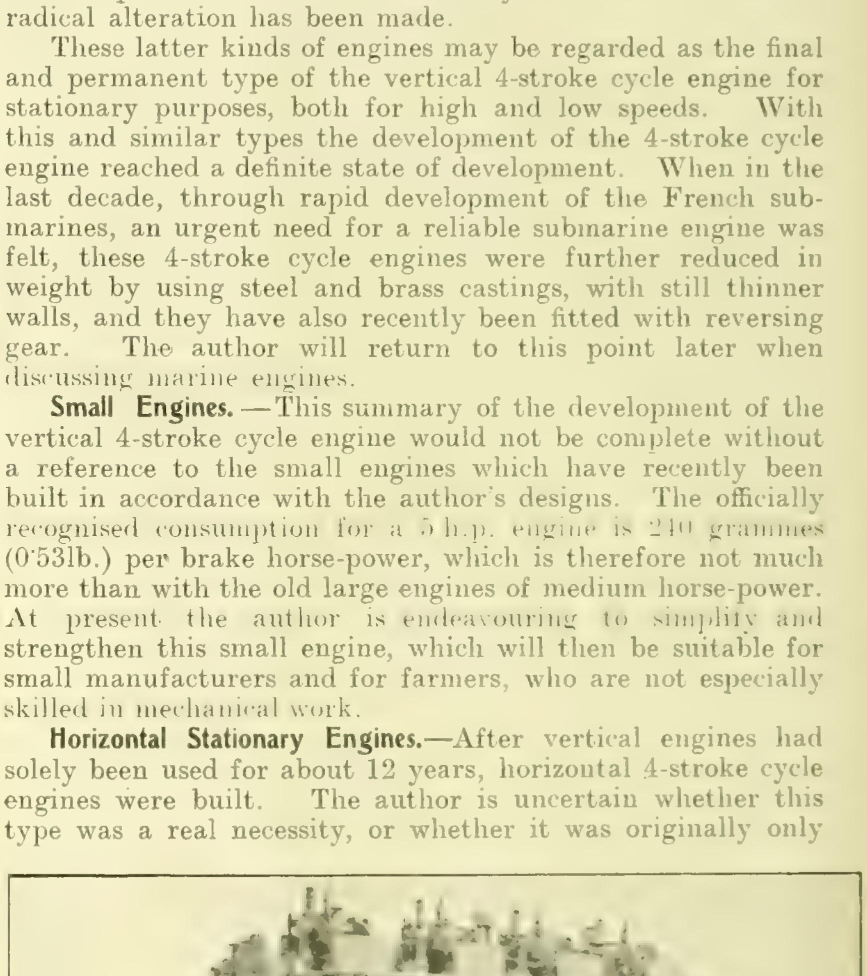


Fig. 11.—Four-stroke Cycle High-speed Engine, [illegible] Showing Box Frame and Air Pump.

constructed for purposes of competition to bring out something new; it is, however, not his intention to compare the merits of the two types. The first horizontal engines were practically only vertical engines laid on their sides without any independent structural innovations; all the valves were fitted in the cylinder cover, in exactly the same way as was done in the old vertical engine, shown in Fig. 8. The valves were actuated by a small cross shaft, which was itself driven

by means of gears from another shaft parallel to the cylinder axis. The air pump was fitted in exactly the same way as in the old vertical engine.

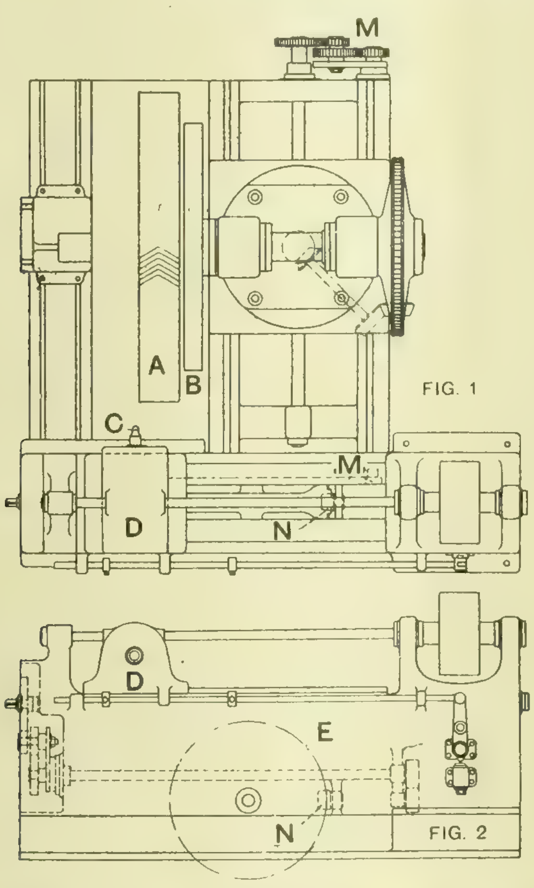
Gradually the designers freed themselves from the tradition of the vertical engine, and some details were altered in such a way that they were more suitable for the horizontal position, and a type of engine was thus obtained which is hardly distinguishable from the horizontal gas engines. In the engine made by the Swiss Locomotive Works, Winterthur, the inlet valves are no longer placed in the cover, but on the side of the cylinder as in gas engines, and are directly driven from the longitudinal cam shaft. A cross cam shaft is no longer used. Only the fuel and exhaust valves are left in the cover, while the air compressor is here arranged in another way.

These designs are to-day very often used for smaller plants of 20 h.p. and more, especially by gas engine manufacturers, who took up the construction of Diesel engines on their own account on the expiration of the patents, and who preferred to keep to the old types of horizontal gas engines. But the M.A.N. built such horizontal Diesel engines for very high horse-powers as double-acting 4-stroke cycle engines with two or four cylinders arranged tandem. The largest engine of this kind so far is a double-acting 4-stroke cycle tandem twin engine, of 1,600-2,000 h.p. or 400-500 h.p. per cylinder, with a speed of 150 revs. per minute; this engine is working in the corporation gasworks at Halle, using water-gas tar as fuel. It was constructed on the lines of the well-known Nürnberger large gas engine for blast-furnace gas.

(To be continued.)

REVERSING MOTION FOR MACHINES FOR MILLING DOUBLE HELICAL WHEELS.

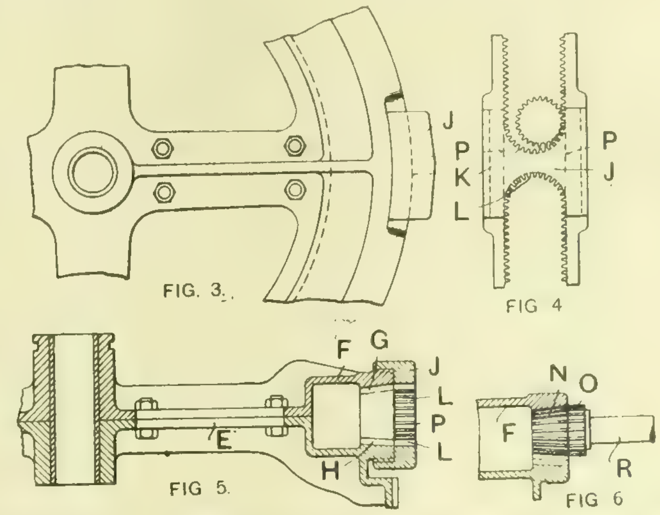
THE accompanying illustrations show a machine for milling double helical wheels, fitted with an improved positive reversing motion, the invention of D. Brown & Sons, Ltd., Park Gear Works, Lockwood, Huddersfield. Fig. 1 is a plan view,



REVERSING MOTION FOR MACHINES FOR MILLING DOUBLE HELICAL WHEELS.

and Fig. 2 a front view of the machine. Figs. 3 to 6 are details of the reversing motion.

Referring to the illustrations, the blank A to be cut is secured, in the ordinary way, to a face plate B. The cutter C is carried in a slide D which is traversed across the face of the blank A. This blank is rotated in one direction until the cutter has reached the centre of the blank, and in the opposite direction during the latter half of the travel of the cutter. For obtaining an accurate and positive reversal of motion of the blank when the cutter has reached the centre thereof, a wheel E is employed provided with a recessed peripheral portion F, the opposing interior faces G and H of which are toothed to form two opposing toothed wheels with a space between them. The wheel E has at one point in its periphery an opening P formed in each of its opposing toothed portions, and secured to this wheel over the opening F is a plate J having at its ends half-circular openings K and L each provided with teeth and forming semi-circular racks extending from the ends of the openings in the two toothed portions of the bifurcated wheel E to form as it were continuations of the toothed portions, the teeth in the recesses K L being, however, outside of or at a greater distance from the centre of the wheel E than the toothed portions G and H, as will be understood from Fig. 5. The wheel E is revolubly mounted, to be capable of endwise or sliding movement, on a shaft connected by gearing, portions of which are indicated at M, with the shaft carrying the face plate B, so that rotary motion of the wheel in either direction is communicated to the blank. Meshing with one or other of the toothed surfaces G or H of the wheel E is a pinion N fast on a shaft R driven by gearing from a part of the machine, and, as will be understood, the wheel E is driven in one direction or the other, according to which of the toothed portions G or H the pinion N is in mesh. The pinion N, as will be seen from Fig. 6, has its teeth continued out as O beyond the periphery of the wheel E, and when the latter wheel has been rotated in one direction nearly



REVERSING MOTION FOR MACHINES FOR MILLING DOUBLE HELICAL WHEELS.

to the extent of a revolution, the gap or opening P in the particular toothed surface with which the pinion has been meshing will come opposite to the pinion and the portion O of the pinion will run into mesh with the teeth in the recess K or L adjacent that end of the opening P.

The action of the pinion on the curved rack with which it engages causes the wheel E to move laterally on its shaft and the opposite toothed surface of the wheel to be brought into position to mesh with the pinion, so that when the portion O of the pinion leaves the curved rack K or L the pinion engages the opposite toothed surface and drives the wheel E and consequently the blank A in the opposite direction, in which the blank continues to rotate until the pinion arrives at the opposite end of the opening F and the portion O of the pinion runs into mesh with the other curved rack, whereupon the wheel E is again moved laterally on its shaft and the direction of rotation of the blank A is again changed. The wheel E and curved racks K and L and the gearing by which the wheel is driven and by which it transmits motion to the blank are all suitably proportioned, according to the shape of tooth to be cut and the speed at which the cutter C is traversed across the face of the blank. The reversing mechanism is also applicable to grinding and other machines in which a reversal of motion with extreme accuracy is required.

Northampton Institute Day Students' 10th Annual Dinner.—The 10th annual dinner of the Northampton Institute (Engineering) Day Students took place on Saturday last, Mr. E. L. M. Emtage in the chair. An excellent musical programme was gone through. Dr. Walmsley during the evening distributed the Engineering Society's premiums for papers read during the past session. The function was in every way a record success.

A DISASTROUS BOILER EXPLOSION IN AMERICA.

THE accompanying photographs, reproduced from our contemporary "Power," show the remains of the boiler which exploded at the quarry of the Royal Marble Company, near Knoxville, Tenn., on February 5th, killing the fireman and his brother, who happened to be present at the time. The boiler was of the locomotive type, carried on skids, and furnished steam to operate rock drills at the quarry.

On January 28th, 1912, the boiler had, it is stated, been inspected by a well-known American insurance company and pronounced safe for 100lbs. pressure.

Fig. 1 is a general view of the quarry and the adjoining field after the explosion, showing the location of the boiler-house and where the main portion of the boiler landed, 350ft. from its original location; the front part landed 150ft. in the opposite direction, near which also were found the bodies of the fireman and his brother. At one corner of the boiler-house there stood an electric-light pole carrying two transformers. Both of these were destroyed, one being hurled a distance of 120ft. A man passing the boiler-house at the time of the explosion was struck by a barrel used for supplying water to the boiler, and was hurled a distance of 75ft.

FIG. 1.—EXPLOSION OF A LOCOMOTIVE BOILER.
Location marked 1 shows where boiler originally stood; 2, where main part of boiler was hurled; 3, where front of boiler was found; and 4 where the bodies of the two firemen were found.

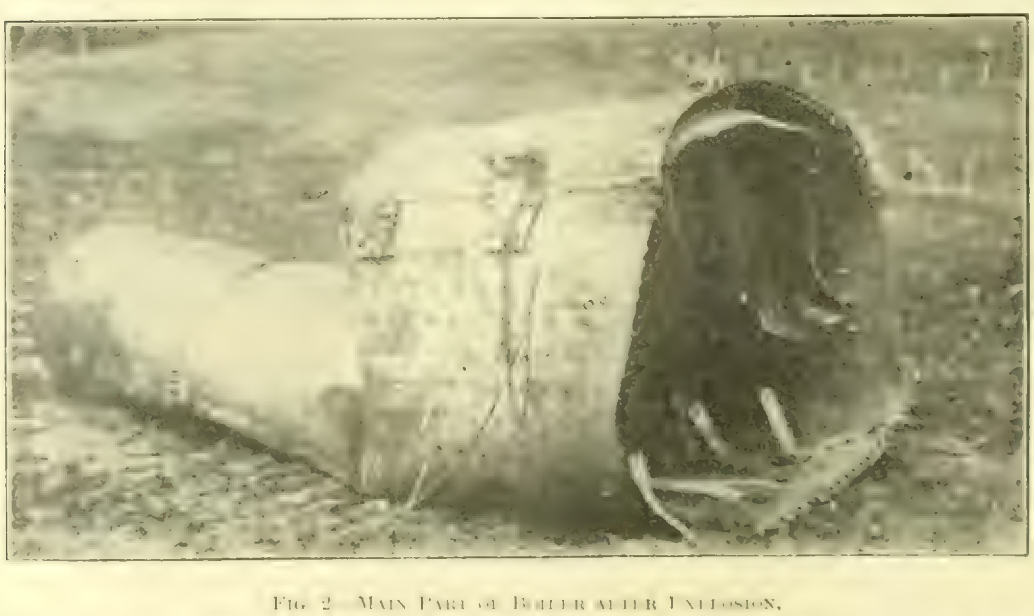


FIG. 2—MAIN PART OF BOILER AFTER EXPLOSION.

Fig. 2 shows the boiler in its final position, and Fig. 3 is a view of the front plate showing how the crown-sheet tore from the stay-bolts and braces. This piece landed on several men working in the pit and more or less injured all of them. Fig. 4 is another view of the same piece.

Fig. 5 shows the safety valve that was on the boiler. It will be observed that the valve had been screwed down until the coils of the spring were pressed one upon the other and the valve could not open under any pressure.

When the valve was tested with water at a pressure of 130lbs. per square inch after the explosion, not a drop came past the valve, which was supposed to be loaded to 100lbs.

A fusible plug had been put in the boiler about one month before the explosion, and upon examination the fusible metal in the plug showed that it had melted, but the face of the plug in the boiler, it is said, was scaled over and prevented it from dropping out.

THE PERIODICAL EXAMINATION OF BAKERS' STEAM OVENS.

AT the meeting of the National Association of Master Bakers held at Swansea during the past month, Mr. J. Hilditch, H.M. Inspector of Factories, at the invitation of the president of the association, made some observations on the working of bakers' steam pipe ovens. He said his Department had thought that the meeting of the Council at Swansea would provide a suitable opportunity of bringing to the notice of the trade the necessity for a periodical examination of steam ovens. He did not know what the practice was generally, but locally he believed nothing was done. A considerable number of explosions had occurred in different parts of the country during the last few years and in 1910 he thought the Board of Trade investigated 14. Some of these were attended with injuries to the workpeople, and in one or two cases to the occupiers themselves. According to the Board of Trade Returns, it was found that the cause of some of these explosions was overheating—he was simply giving the findings of the Board of Trade after investigation—and a limitation of the temperature at which these ovens were worked was recommended. Another thing recommended was that the care of these ovens should be entrusted to skilled and experienced men. The Board of Trade also recommended the use of coke fuel instead of coal, and that the banking up of fires at night should be prohibited. Of course, the latter point did not arise where there was continual working of the oven; some ovens were worked for confectionery by day and for bread by night, and there the question would not arise. He presumed in other cases the general practice was to bank up the fires at night. Another recommendation was that a close watch should be kept for any defect in the tubes or brickwork of the furnace chamber. Defective brickwork tended to increase the length of the tube exposed to the fire.

with resultant overheating of the tube and increased pressure therein. Clinkers, adherent to the firebricks, quickly destroyed the furnace chamber, hence the furnace should be cleaned out when baking was finished. Prompt repairs should be made when needed, and there should be frequent inspection and examinations by competent persons; which as a rule, could best be secured by insurance. All explosions of tubes should be reported to the Board of Trade, whether accompanied by personal injury or not. The Board of Trade had nothing to do with insurance; they were merely concerned with the question of having these steam ovens examined by a competent person, and it was for the occupier of the factory or workshop to decide as to the competency of

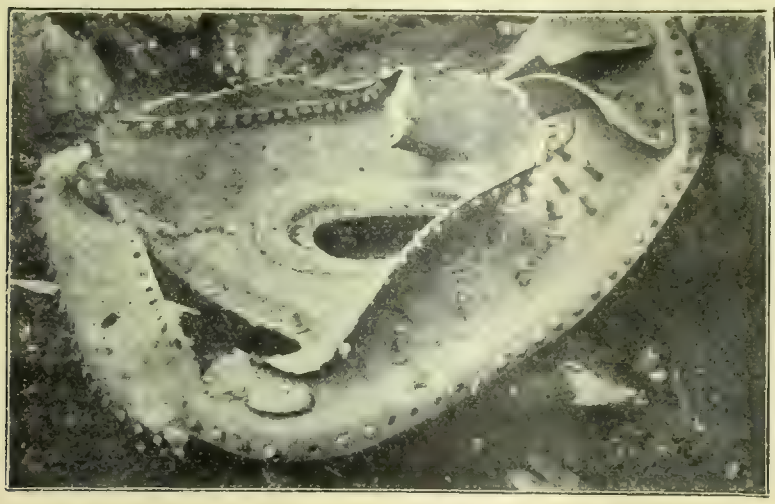


FIG. 3.—FRONT OF BOILER.

the workman. Taking Swansea as a district, it might be possible to appoint a competent engineer to undertake the whole work and agree with him to do it for a certain price instead of insuring. This was a matter for themselves entirely.

The President said he was sure all the members desired to welcome Mr. Hilditch, and looked upon his presence as a recognition of the National Association on the part of the Home Office. He wished to ask Mr. Hilditch what guarantee bakers had that the tubes put into their ovens had been tested to the extent guaranteed on the contract?

Mr. H. J. Matthews said most of the accidents that occurred were attributable to the fact that the tubes had been allowed to become covered with clinkers in some parts, with

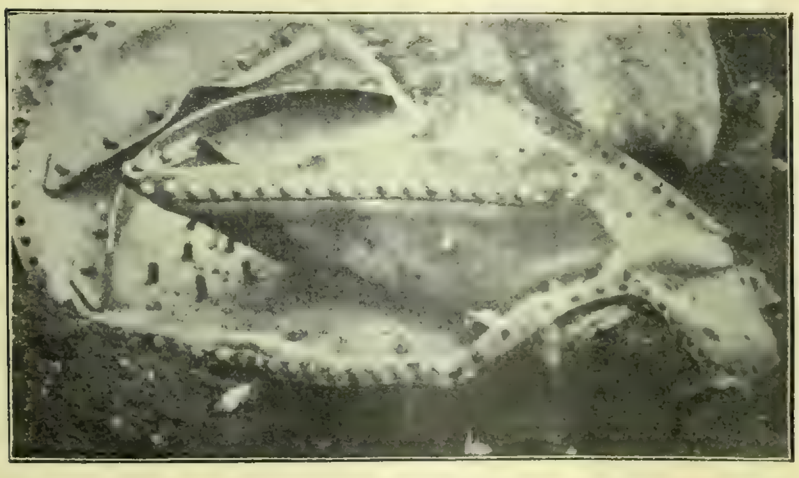


FIG. 4.—VIEW SHOWING RIPPED CROWN SHEET.

the result that the other parts got an excessive amount of heat, and consequently an excessive amount of pressure. If tubes were properly made and tested there would be little fear of any explosion.

Mr. J. Jordan (Manchester), relating his personal experience, said that after making enquiries about insurance he got into touch with the builders of the ovens and arranged for two inspections per annum of each oven for half a guinea. The report of the builders' inspectors was accepted by the Board of Trade. He tried banking the fires, and found it did not suit; he could keep the furnaces cleaner and get more regular heat by letting them go out, then cleaning them, and lighting them again about two hours before the men started baking. Cleanliness, in his opinion, played an important part in the success of a steam oven.

Mr. J. H. Merrett (Cardiff) said they were all agreed that the cause of explosions required looking into, but did not think all steam tubes should be condemned because there had been a few explosions. He thought the Government should insist upon tubes of a certain standard only being used in ovens. He had never heard of an explosion taking place where the best quality tubes had been in use; on the contrary, all the explosions in his own locality had occurred where cheap tubes had been used in the construction of the ovens.

Mr. G. C. Bell (Sheffield) asked whether it was not desirable to insist upon a definite number of tubes. Contractors frequently restricted the tubes to as few as possible, and the fewer the tubes the greater the amount of pressure, and, of course, the greater the risk. If it were possible to insist upon a sufficient number of tubes being put in, the risk of explosion would be considerably reduced.

Mr. J. T. Walker (Penarth) remarked that he formerly had an aversion to steam ovens until he became convinced that they were essential if the baker wished to be up to date. To obviate, as far as possible, the risk of explosion, he went to the expense of having his ovens built with double rows of tubes. At the present time they were working well, and the fire had to be pushed to only half the extent necessary where only a single row of tubes was used to carry the heat into the baking chamber. The cost of fuel was also considerably reduced. He wished to know how it was possible to inspect ovens from a furnace only 6in. wide? The only way, in his opinion, to properly inspect the tubes of steam ovens, was to pull the oven down from top to bottom, and this was an impossibility. His contention was that the Government ought to insist that all steam ovens should be built of a certain type of tube, and under Government inspection.

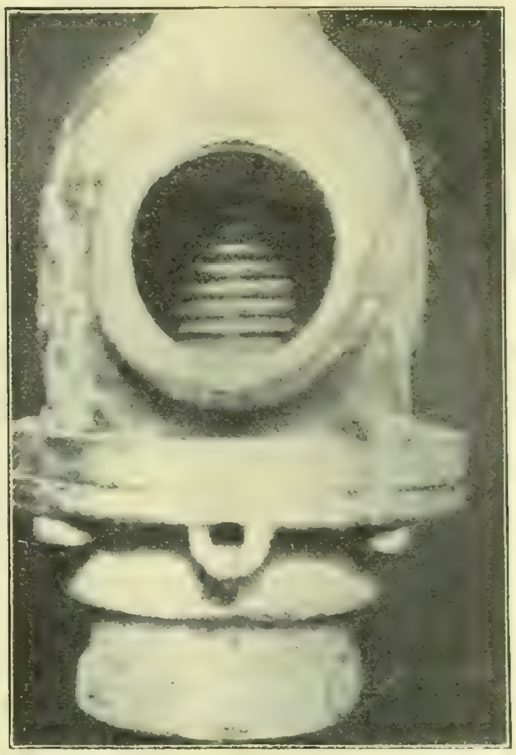


FIG. 5.—VIEW OF SPRING SAFETY VALVE, SHOWING SPRING COILS CLOSED AND INCAPABLE OF FURTHER COMPRESSION.

Mr. J. Leighton (London) thought the reason minor explosions were not always reported was that the Department insisted upon an inspection, followed by an enquiry, with the probability of a fine, and small bakers hesitated to report an explosion unless some injury was caused.

Mr. W. T. Callard (Leicester) said this was a matter to which he had given a considerable amount of attention, and a considerable amount of personal observation, and he had failed to find any man more qualified to test the average bakers' oven than the baker himself. He differed strongly from the view taken by Mr. Walker that the only way of inspecting a steam oven was by pulling it down. His experience was that steam ovens were always better if their upper rows of tubes were occasionally brushed off, and the dirt dislodged. The steam-heating principle had been demonstrated beyond all question as being the type best adaptable to modern requirements, but at the same time it was a slow-heating principle, and this drawback was overcome by the number of tubes put into the oven. The matter of the quality of tubes would be much better dealt with by the Department, but at the same time, it was true that explosions did not always depend upon defective tubes. Given an oven with excellent tubes, if a man tried to explode the tubes under certain conditions he could do so. He had adopted a plan for some considerable time, a rather rough and ready plan, but one worth the attention of the Department. It

was that all steam ovens should be about once a quarter heated to about 60° or 70° more than the average baking capacity. In other words, if a man heated his oven for ordinary work up to 500° or 520° he should heat them to 580° or 600°.* Of course, he would do that under careful conditions of firing, and he might rely upon it that there was nothing much the matter with ovens that would stand a test of that kind. He wished to point out, however, that under conditions of improper firing it was quite possible to explode the oven without going up to 580° or 600° He again warned the Department against trusting to any form of boiler inspector.

Councillor G. Cox (Hastings) asked whether an inspection of the tubes by the Government when the oven was in course of construction would be any safeguard? In his opinion, there was far more danger in the erection of a new oven than when it had been in operation for some years.

Replying to some of the points raised, Mr. Hilditch said that though clinkers on the bars were all right as a protection, when they became vitrified they adhered to the bar—that was when the tube was used as a bar—and in getting rid of them the tube was often damaged. Personally, he thought the bars should be kept as clean as possible. With regard to a penalty for not reporting failures raised by one of the speakers, this was a matter that did not concern his Department; it was a question for the Board of Trade. He did not invite bakers to subject themselves to penalties at all, and they need not be afraid of reporting explosions of all kinds. As they were aware, they were bound to report explosions if injury was caused, and it would assist the Home Office and the Board of Trade if all explosions were reported so that thorough investigation should be made with a view of finding out whether the lap-welded tubes or the solid-drawn tubes were the best. Some speakers seemed to be under the impression that it was the policy of the Department to condemn the steam ovens, which was absurd. The steam oven had undoubtedly come to stay, and it was for the Department, with the assistance of the trade, to see what could be done to obviate injury to life and limb. With regard to examination, he could quite see that bakers could not have their ovens torn to pieces once a year. The Act required that every steam boiler should be examined once in 14 months. He agreed it was a difficult matter to examine all the tubes without taking the oven to pieces in many instances, but he should like to point out that destruction naturally took place on the part of the tube exposed to furnace heat, and this was the part that should be tested first of all. He did not mean to say that tubes did not fail further on, but that was by excessive pressure generated at the back end; it was at the back end where the tube was exposed to the fire. The insurance companies had their experienced officers. He wanted to make it quite clear that the Department did not want the bakers to insure; they only suggested that this would probably be the most convenient course for them. If bakers insured with boiler companies they were insured against damage to property and against damage to life and limb. Their inspectors were all practical men, as far as he knew; at anyrate, all he had met, and he did not agree with those members who thought the inspection was done in a perfunctory way. With regard to statistics relating to explosions of the different types of oven, straight tube and curved tube, and their frequency on tubes used as firebars or otherwise, he was sorry he had none, but the Secretary could easily obtain the information by applying to the Board of Trade. As to the suggestion that the Government or the Board of Trade should give a guarantee that a certain oven was safe when it was put in, he could say straight away that the Government would not do anything of the sort. He had seen it suggested in a report of one of his colleagues that the tubes should be subjected to a water test of 4½ tons per square inch before being accepted, and bakers could insist when ordering tubes upon a certificate to the effect that the tubes had been tested up to that. With regard to the brushing of tubes, he thought it would be better if they were taken out, as it gave a chance of detecting any defective tube. If it were possible to get an oven designed from which it would be practicable to get out the tubes, it would be most useful in more respects than one. He wished it to be understood the Department did not insist upon these examinations; the Department only wished them to consider the best means to adopt to prevent, if possible, any likelihood of explosions.

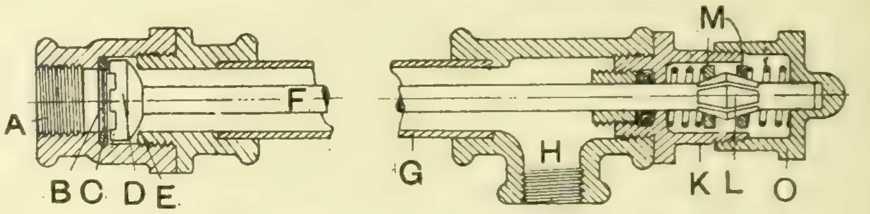
* This may be so, but to test a tube with steam pressure to see if it will burst is a dangerous way of ascertaining its strength.—Ed. M. E.

With the increasing use of steam ovens explosions were increasing. There were 14 reported in 1910, as compared with five in 1909.

The President, in thanking Mr. Hilditch, said he might rely upon the trade doing everything possible to ensure the safety of the workers, and the suggestions made during the course of the discussion would receive the attention of the Council at an early date.

CLELAND & STEWART'S STEAM TRAP.

A design of steam trap on the expansion principle that automatically adjusts itself when the steam pressure varies is shown in the accompanying illustrations. There is mounted on the valve spindle F a sliding sleeve L with each end conical or tapered, and this sleeve is cut or split longitudinally into a number of pieces in such a manner that when the pieces are pressed from the ends they move closer against one another and grip the spindle F. They are held in place by an open wire hoop at the middle. This sleeve L is enclosed in a grip box K through which the valve spindle passes. Rings M are provided to press against each end of the split sleeve. At the back of these rings are springs. These rings M and springs are all inside the grip box K and surround the valve spindle F. There is a screwed cap O on the end of the grip box which when screwed up causes the split sleeve L to close and grip the valve spindle F as it first compresses the springs which in turn push the rings M closer together, and these rings moving up the tapered ends of the split sleeve L force its parts closer together, and so reduce the diameter of the hole in the sleeve.



Cleland & Stewart's Steam Trap.

The action of the trap is as follows: The contraction of the trap shell G causes the split sleeve L to open the valve D against the stop C and when the steam pressure rises and the expanding casing G of the trap with its sleeve L can close the valve D no further than the seat E it draws the split sleeve or grip L up longitudinally on the valve spindle F, and when the steam pressure falls again the contracting casing G carries the split sleeve L back along the spindle F after it has opened the valve D. When the trap is cold its valve D is open to the limit stop C or fullest extent. When low-pressure steam is turned on, the air and water from the pipes is discharged through the trap, and when the water begins to get hot the expansion begins to close the valve D gradually until all water and air is discharged and the steam is then trapped. If the pressure of the steam rises the expansion is then more than sufficient to close the valve D, then the sleeve L has to move a little outwards along the valve spindle F until it eventually adjusts itself to the altered conditions. When steam is shut off after working at high pressure, the trap contracts more than sufficient to open the valve D back against its stop C, then the sleeve L has to slide inwards to its original position on the valve spindle F or on whatever it may be fixed to operate the valve D, and it is therefore ready again to deal with low or high-pressure steam So that whilst the sleeve L grips the valve spindle F tightly enough to open the valve D against any steam pressure in use it does not grip so tightly that the force of expansion or contraction of the metal trap G cannot slide it along the spindle to a new position after the valve has come against its abutments C or E at either end and leave the sleeve L at such a position as corresponds with the heat from the particular steam pressure that the trap may be dealing with at that particular time. The special feature of the design of trap illustrated, which is the joint invention of J. Clelland and J. C. Stewart, Short Strand Engineering Works, Belfast, is limiting the movement or travel of the valve to the amount of movement it has when draining ordinary low pressure steam, and this, working in conjunction with a sliding grip L on the valve spindle F operated by the trap shell movement causes the automatic adjustment of the trap under all steam pressures. A is the inlet and H the outlet. B is a strainer to prevent grit getting into the valve casing. Prongs are provided on the valve to abut against the stop C and still allow water to pass

ON THE WIDER ADOPTION AND STANDARDISATION OF WATER-TUBE BOILERS.*

BY E. M. SPEAKMAN.

TEN or fifteen years ago, no broad technical questions absorbed the attention of marine engineers to the extent which that of the water-tube boiler did, and probably few have been more keenly discussed. The subject grew in interest, and criticism of their adoption continued to become more intense from the time of the decision to instal Belleville boilers in H.M. cruisers "Powerful" and "Terrible," till the appointment by the Admiralty, in 1900, of a committee of independent engineers to investigate and report on the status and future of naval boilers. Partly, perhaps, owing to the final verdict of this committee being rather of the nature of a recommendation to wait and see what the results of experience with newer and modified designs should be, and partly to fresh interests

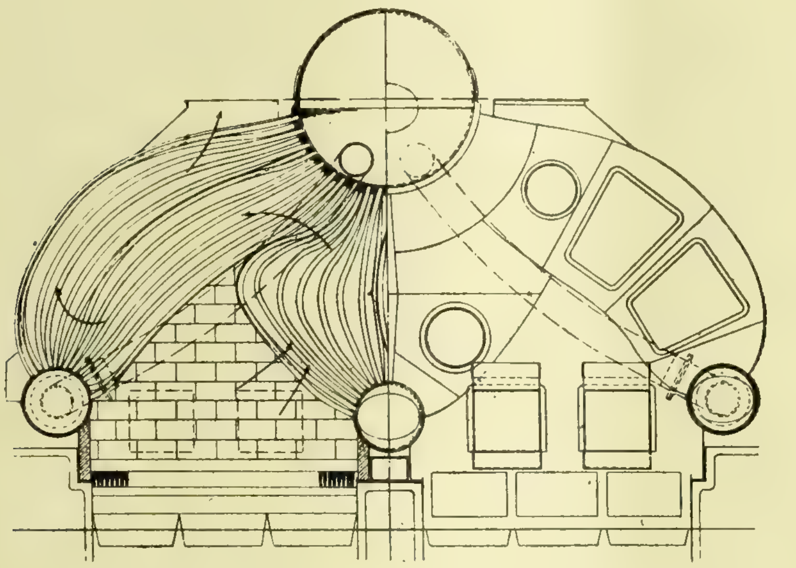


FIG. 1.

arising in other sections of propelling machinery, public interest in the water-tube boiler has recently somewhat flagged. This is probably, to a large extent, attributable to the greatly increased reliability and freedom from the troubles and breakdowns which characterised the boilers of earlier years, and which thereby attracted much attention from the technical Press. Except for cases of culpable misuse, nearly all the difficulties that originally arose with water-tube boilers were due—(1) To bad design arising from inexperience; (2) to inferior workmanship and the employment of unsuitable tubing; and (3) from a desire to press the advantages of reduced weight and capability to withstand forcing to an undue extent.

The efficiency of the water-tube boiler of 12 years ago, notwithstanding its defects, was distinctly good, and the improvements that have taken place in the last few years have been mostly in the direction of reliability and durability—that is, in better mechanical design, coupled with use of better material and improved proportions, which, although adding somewhat to the weight, have not appreciably increased the thermal efficiency in comparison to the extent to which the troubles have been removed.

Concurrently with, and as a result of, improvement in mechanical design, there has been a constant tendency for the various types of the last decade to become standardised into more reasonable shapes and proportions, the Thornycroft, Normand, Reed, and other designs being now largely merged into the prevailing Yarrow type, which alone has retained its original characteristics. Of the various large tube boilers, the Babcock & Wilcox, Belleville, and Niclausse still remain, but in an improved form. Practically all the above, with the exception of the Babcock & Wilcox, are, at the present time, naval boilers only, and their general adoption, both in the large and small vessels of the various navies of to-day, is shown in Table I.

Throughout the merchant service the cylindrical boiler is, of course, still generally adopted, and for all ships in which the weight of boilers is a relatively small fraction of the total displacement, no other type seems likely to displace it. There are, however, distinct signs that, for certain special services, the wider adoption of water-tube boilers would be a welcome innovation.

TABLE I.

Nation.	Type of boiler adopted.		
	Large war vessels.	Small war vessels.	Torpedo craft.
England	Yarrow.	Yarrow.	Yarrow.
	Babcock and Wilcox	—	White-Forster.
France*	Belleville.	Lagrafel-D'Allest	Normand.
	Niclausse.	Du Temple.	White-Forster.
Germany........	Schulz—Thornycroft.	Schulz—Thornycroft.	Schulz—Thornycroft.
Italy*†	Babcock and Wilcox.	Cylindrical.	Thornycroft.
	Belleville.	—	—
	Niclausse.	—	—
Japan	Belleville.	Miyabara, &c.	Yarrow.
	Miyabara.	—	
United States* ..	Babcock and Wilcox.	Babcock and Wilcox.	Normand and other express types.

* Very few small cruisers have been built by these Powers in the last 10 years.

† Italy is adopting Yarrow boilers in the latest battle-ships, as are also Russia and Spain.

Referring to Table I., it is significant that only one Power has so far adopted a standard type of boiler; the German Admiralty apparently rightly regards a boiler as a steam producer of a certain efficiency in relation to its weight, and as such it is independent of size or type of ship.

The reasons for and against the wider adoption of water-tube boilers in vessels, to which, while appearing applicable at first sight, they have not yet been applied, are much the same as those quoted 15 years ago in making comparisons with cylindrical boilers, but it should be remembered that the

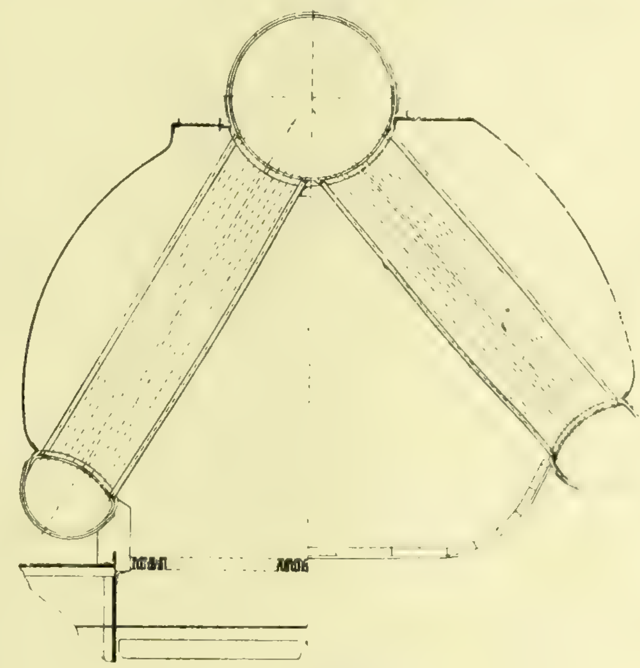


FIG. 2.

conditions now met with are very different. As a steam producer the water-tube boiler is now of proved reliability, durability, and efficiency, instead of being a doubtful quantity, and its light weight and great capacity for steam production in relation thereto strongly recommend it in many cases besides those of naval work. Compared with their dimensions 15 years ago, the size of ships on many services is now approaching a commercial maximum—even if that be only temporary—either in length or draught of water, and, again, on limited dimensions, *i.e.*, weight, there is a constantly increasing demand for speed. For the bulk of mercantile tonnage, much of which is in relatively slow vessels, the water-tube boiler, unless more efficient than the cylindrical type, and no more costly either originally or in maintenance, cannot be considered commercially, and even if it complied with these

* Paper read before the Institution of Engineers and Shipbuilders in Scotland, February 20th, 1912.

TABLE II.

Type of Ship.	Speed.	Displacement	Number of boilers	Type (cylindrical).	Pressure.	Weight of boilers × 100 / Displacement
Channel steamer -	knots.	tons.			lbs.	
Turbine	23	2,700	8	S.E.	185	19·45
Reciprocating	22	2,200	4	D.E.	175	17·7
Turbine*	20	2,000	2	,,	160	15·4
Paddle	20	1,500	6	S.E.	120	18·0
Reciprocating	16	1,600	2	D.E.	180	10·9
River steamer						
Turbine............	21	750	1	,,	150	18·65
Reciprocating	12	1,000	2	,,	160	9·0
Merchant steamer	10	9,000	2	S.E.	180	2·15
,, ,, .. †	12	9,000	4	..	180	3·31
,, ,, .. †	12	9,000	4	..	215	3·62
,, ,, ...	13	12,000	3	,,	180	3·45
,, ,, ...	14	10,500	6	,,	190	4·67
,, ,, ...	15	10,700	6	..	180	4·8
Combined cargo and passenger	17 (at sea)	20,000	6	D.E.	215	7·2
Combined cargo and passenger	18 (trial)	17,000	6	S.E.	215	8·5
,, ,,	17·5(trial)	15,200	4 2	D.E. S.E.	215	5·8
Passenger steamer, turbine	20	10,500	6	D.E.	175	11·0
Atlantic liner, turbine	25·5	36,000	23 2	D.E. S.E.	215	11·0
,, ,, ,,	23	60,000	18	D.E.	215	5·4
Battle-ship	22	22,000	18	Yarrow	220	2·1
Cruiser	24	3,000	10	,,	220	6·5
Destroyer	36	2,000	10	,,	220	18·0
,, ...	33	900	5	,,	220	21·0
,, ...	30	450	4	,,	220	16·0

* In a similar vessel to this, now under construction, but fitted with five Babcock boilers, the proportion of weight of boilers has been reduced to 8·5 per cent.

† Note influence on percentage weight due to higher pressure used for quadruple in place of triple-expansion machinery.

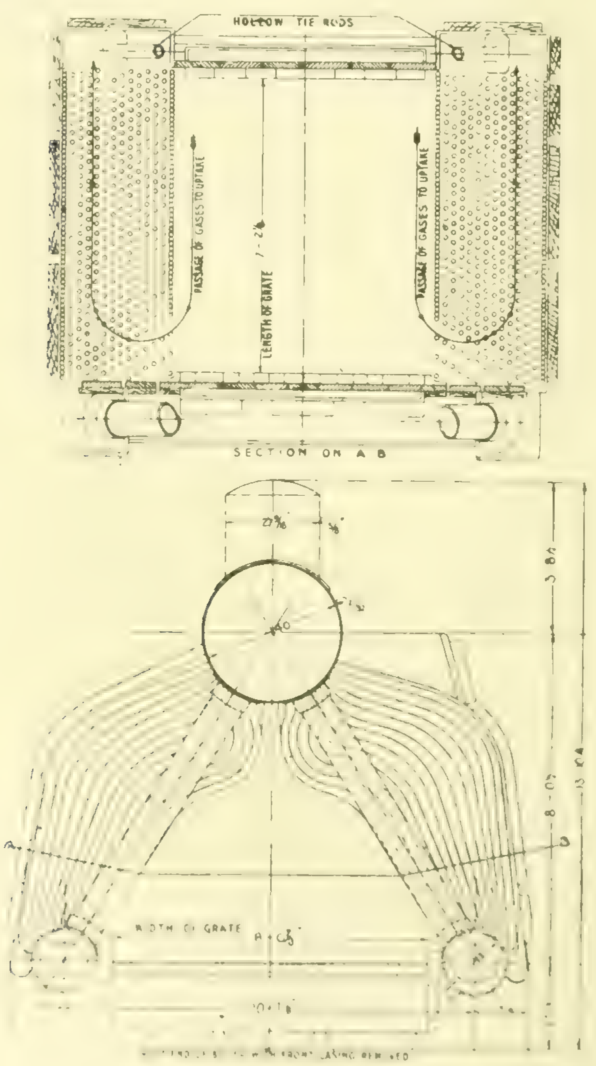


FIG. 3.

conditions, other practical circumstances arise, peculiar only to the nature of the service on which such vessels are employed, that would tend to limit, if not to exclude, its adoption. For all vessels comprised in the cargo-carrying and low-speed types, the weight of machinery is very small in relation to the displacement. It is only when this ratio becomes high that the introduction of water-tube boilers should be carefully studied, and it is just in these cases that limitations affecting the ship

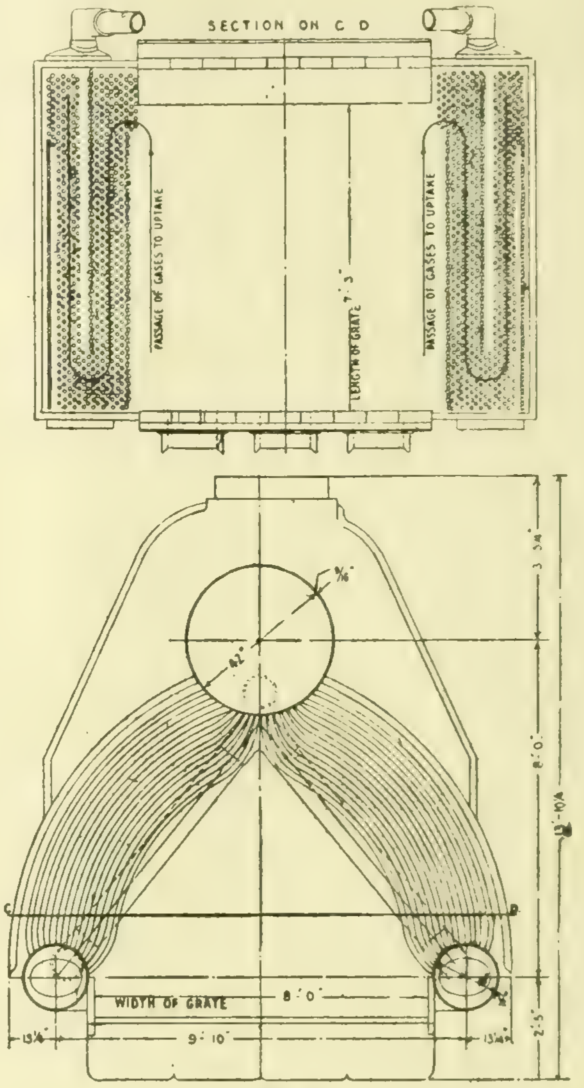


FIG. 4.

as a whole—length or draught of water, for instance—are seriously beginning to be felt. Their scope for wider adoption consequently is still somewhat circumscribed.

In Table II. is given a list showing the percentage of boiler weights to normal displacement for a number of typical vessels. The weight referred to, in order to exclude all variables except the generator portion only, consists of the boiler complete with water to normal working level, lagging, and firebars, but no uptakes or mountings. It will be seen at a glance that it is only in the cases in which the percentage forms a large proportion of the displacement, the saving in weight due to installing water-tube boilers would be justified. A few examples of naval vessels, all of which are fitted with Yarrow boilers, are added for comparison. From the same table will be seen the types of vessels in which the percentage weight is exceptional, the maximum condition being, of course, obtained in vessels of the destroyer type, when the horse-power per ton of displacement may be as much as 27. In small cruisers it may be as much as 8, but the figure rarely exceeds 4, even for merchant vessels of high speed and small size. In the fastest Atlantic liners this falls to about 2; in slow carrying vessels it may be only one-tenth of this. With the exception of river steamers, in which shallow draught is essential, these figures indicate that only in very high-speed Atlantic liners and fast Channel steamers would the light weight of water-tube boilers tend to counterbalance certain practical objections to them. In the former case the enormous growth of length and breadth has only been accompanied by a relatively small increase in draught of water, and at the present day there are a large number of vessels on the Europe to New York service which are unable to take full advantage of the draught to which they might safely be loaded, on account of the depth of water at their ports of departure.

For the time being the practical limit is about 34ft. By the substitution of Yarrow boilers for Scotch, a fast ship 800ft. by 90ft. might carry nearly 1,500 tons more cargo, or have her draught reduced by 12in. In Channel steamers the same considerations apply: length is limited on the French routes, draught on the Ostend route, and high speeds are essential on all. In fact, on the limited maximum dimensions permissible in each case the attainment of a higher power on less weight

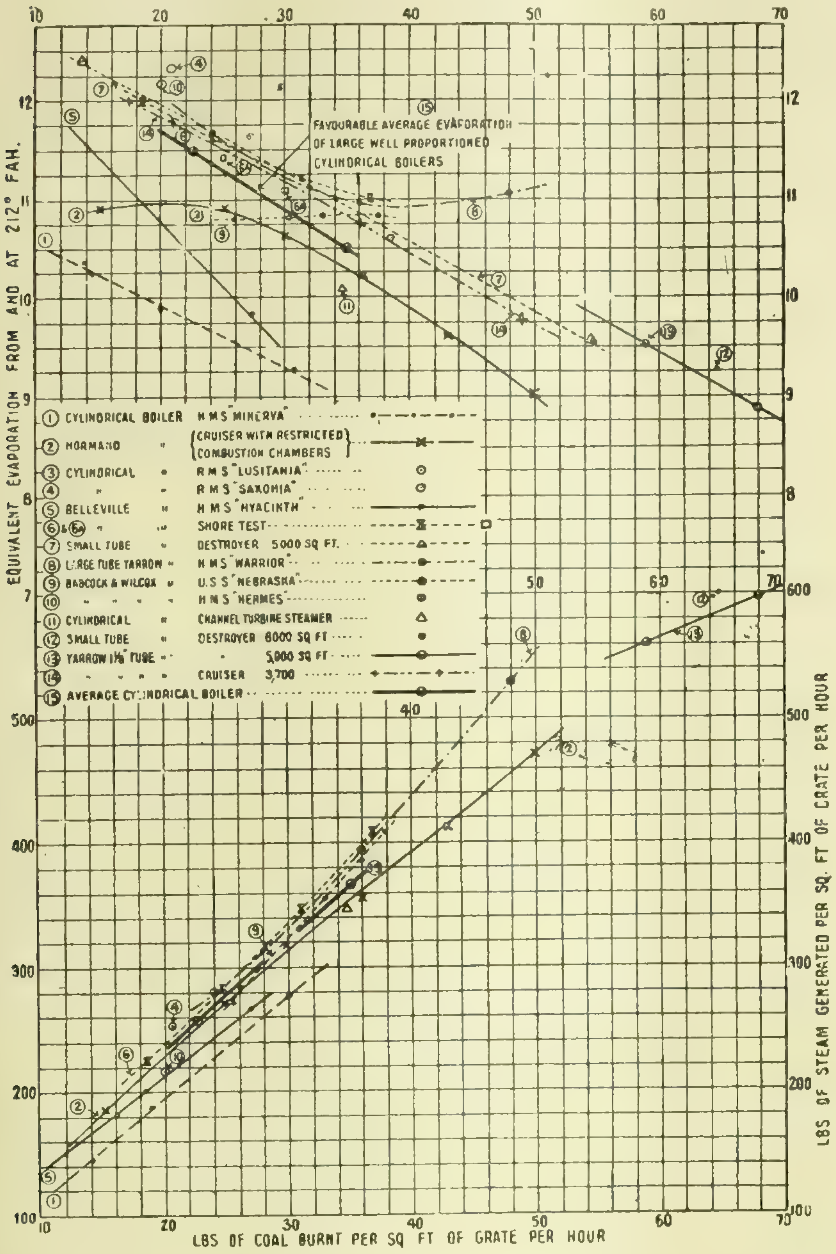


FIG. 5.

and in less space is the only means of obtaining a much faster ship.

Now, although the water tube boiler might appear to offer the solution, there are various practical difficulties still confronting its adoption. The greater initial cost might alone be considered sufficient objection if it were not for the advantages its light weight confers. But its liability to prime in the event of condensers leaking, the tendency of the tubes to become choked externally more rapidly than those of the cylindrical type, and the difficulty of the necessarily frequent tube cleaning, together with the distinctly and rather unnecessarily drastic survey requirements demanded, are also features, as far as continuous merchant service work is concerned, that do not commend it to shipowners and their marine superintendents. Further, there is the possible slightly lower efficiency, compared with the large cylindrical boiler.

Against all this there is the fact that, for the same hourly steam production, which, other things being equal, is the true criterion of merit, the 3-drum type of water-tube boiler weighs less than half what the cylindrical boiler does. When this proportion of saved weight forms 5 to 10 per cent. of the complete displacement of the ship, it becomes an important question as to whether the alleged disadvantages are not more than counterbalanced in view of the saving in the ship as a whole. It is not suggested that an average naval boiler should be installed without change into merchant vessels, but there are features connected with the design thereof that strengthen the idea that water-tube boilers as used in warships may be installed in fast mercantile ships if, as seems easily possible, they can be so modified in minor ways as to render them thoroughly serviceable for the practical and economical requirements involved, while simultaneously considerably reducing the above-mentioned objections. These points may be considered in detail.

Type of Boiler.—The Boiler Committee, appointed by the Admiralty in 1900, investigated no less than 36 different types of water-tube boilers, only three of which now find a place in modern British practice. These types are: (1) Yarrow, applied to large and small vessels; (2) Babcock and Wilcox, applied to large vessels only; (3) White-Forster, applied to small vessels only. With the possible exception of the German Navy, where the Schulz boiler, as illustrated* in Fig. 1, is now universally adopted in battle-ships and destroyers, the British Navy has attained a degree of standardisation in boiler practice not found elsewhere. The United States Navy Department, while adhering to Babcock and Wilcox boilers for big ships, adopts several types for destroyers, as does also the French Admiralty, which retains both Belleville and Niclausse boilers for battle-ships. This divergence in practice is not easy to understand. The inconsistency displayed in the case of the four principal navies enforces the idea that the separate authorities are willing to accept pros and cons entirely at variance with those of the others, the reliance on individual views and corresponding policies being based presumably on the developed service opinion of many years' growth. For wider adoption this hardly facilitates the choice of prospective users, and it is, in the author's view, somewhat surprising that, after so many years of use, a closer consensus of opinion has not been more generally achieved.

Obvious disadvantages would seem to be involved in those types wherein excessively curved tubes or forms of tube baffling are adopted, on account of difficulties of manufacture, of cleaning internally and externally, and also of rapid repair. There is the further great objection that any considerable curving towards the firebars, Figs. 1 and 3, tends to reduce the combustion space. On this basis straight, or nearly straight, tubes would seem to be necessary, and in spite of apparent success in other types, practical experience of both strongly emphasizes the objection to sharp bends.

Fig. 2 shows two half-sections of typical Yarrow boilers, one of the 1¾in. tube type as used on large vessels with coal fuel, the other with 1⅛in. tubes designed for oil burning. The simplicity of this design for manufacture and cleaning compared with Figs. 1, 3, and 4 is undeniable. In Fig. 3 is shown the Normand boiler, as used in the United States cruiser "Chester"; Fig. 4 shows a variation of the Du Temple type, as fitted to her sister ships "Salem" and "Birmingham." The extreme curvature of the tubes and the tube baffling adopted not only lessen the combustion space for given overall dimensions, but also prevent the best use being made for the heating surface installed.

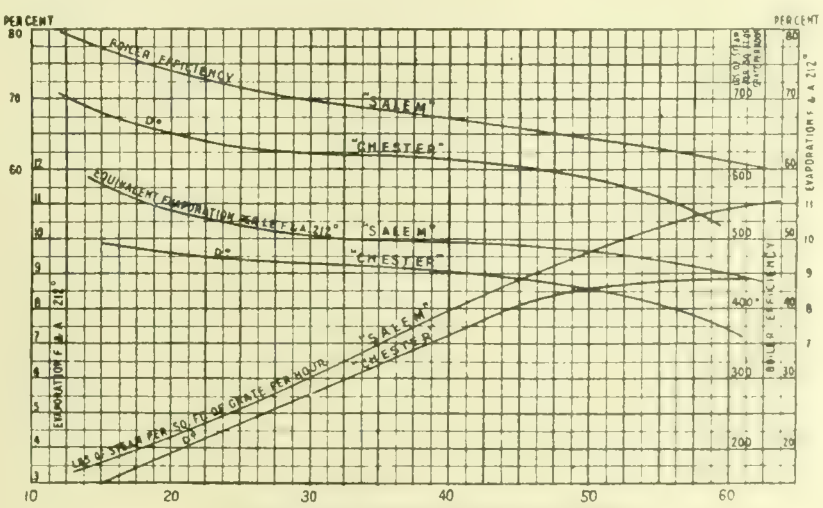


FIG. 6.

Capacity for Steam Production.—Generally speaking, a large boiler is proportionally more economical than a small one, and a double-ended boiler more so than a single ended one. Experience has shown that for Atlantic and long-distance work an equivalent evaporation of 11 times from and at 212° Fah.

* The German Admiralty oil fuel boiler is of the ordinary three-drum type.

can be attained when burning from 23lbs. to 26lbs. of coal per square foot of grate per hour. A figure as high as 12 has been reached when burning 20lbs. In Channel steamers, where economy is of less importance, in order to reduce their size, boilers are forced so as to burn from 32lbs. to 38lbs. per square foot, when the evaporative value falls to about 10. These figures represent steam productions of 240lbs., 270lbs., and 350lbs. per square foot respectively. Unfortunately, elaborate evaporation trials of large cylindrical boilers are seldom carried out at varying rates of combustion, so that in Fig. 5 a favourable average mean line has been drawn through a series of spots to show the tendency of cylindrical boiler evaporation. The conditions under which they are designed to work are such that much additional combustion reduces their efficiency, owing to the high proportion that even a little more bears to the designed amount.

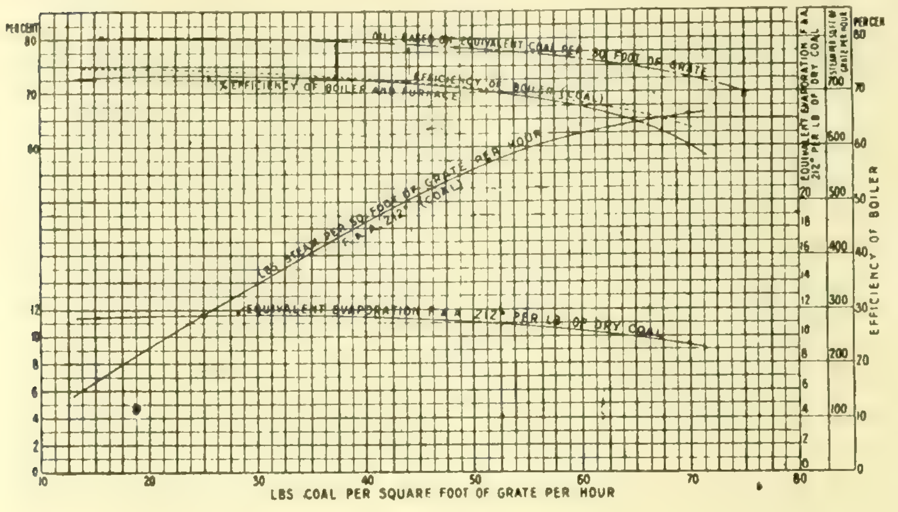


FIG. 7.

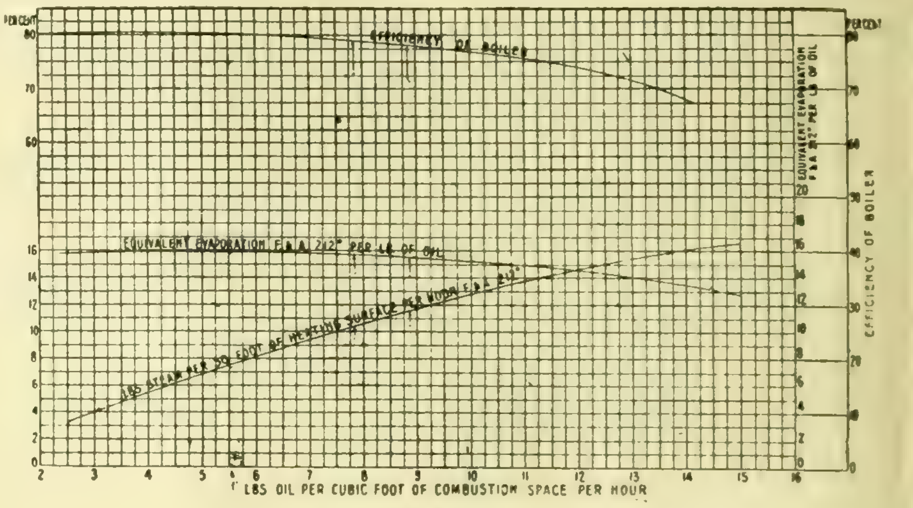


FIG. 8.

TABLE III.

Number	Type.	Pressure lbs. per square inch.	H.S. sq. ft.	G.S. sq. ft.	Weight of generator complete, with water, tons.	Lbs. of steam per hour, from and at 212° Fah.	Lbs. of steam per hour. per sq. ft. H.S.	Lbs. of steam per hour. per ton of boiler.	Remarks. L × B
	Cylindrical.								ft. in. ft. in.
1	D.E.	215*	6,600	169	170	45,000	6·82	267	17 6 × 22 0
2	S.E.	215*	3,500	85	90	20,000	5·71	222	17 6 × 10 7½
3	D.E.	160†	6,500	168	148	58,000	8·93	392	16 4 × 23 0
4	S.E.	160†	3,320	73	80	28,000	8·4	350	16 4 × 11 6
5	D.E.	175†	4,620	130	95	36,000	7·79	380	14 0 × 19 0
6	S.E.	185*	2,230	58	66	20,000	8·95	303	14 3 × 11 6
7	D.E.	180*	3,000	75	76	24,000	8·0	316	12 0 × 20 0
8	S.E.	175*	1,500	50	40	14,500	9·65	290	12 6 × 9 3
	Water-tube.						9·33	1,600	Coal fuel.
9	Normand	240	3,000	50	17·5	28,000	9·8	1,890	
10	Mosher	260	4,500	92	23·3	44,000	9·25	1,840	
11	Yarrow	230	5,000	85	25·5	47,000	11·6	2,130	
12	White-Forster	230	5,100	110	28·2	60,000			
				Combustion chamber, cubic feet.					
13	Thornycroft	250	4,500	423	24·5	51,300	11·4	2,090	Oil fuel.
14	Normand	260	4,830	336	26·75	54,600	11·29	2,035	
15	Yarrow	230	6,000	600	29·5	78,000	13·0	2,620	
16	White-Forster	230	8,500	915	40·0	120,000	14·1	3,000	

NOTE.—The above are service or trial results and not test-house figures. The data have been corrected to the designed pressure of the boilers, and, where necessary, for local conditions of working. A considerable difference in evaporative value, of course, exists between boilers working under Howden's draught,* closed stokehold† conditions, or under natural draught. All the data given of torpedo-boat destroyer boilers, of course, are under forced-draught conditions.

In Fig. 5 are also given a series of evaporation curves of typical water-tube boilers, together with their rate of steam production per square foot of grate. Although, as might be expected, the evaporation falls off at the higher rates of combustion, especially in cases of contracted combustion chambers, the average intermediate values at, say, from 30lbs. to 40lbs. per square foot, range about 11, and that for a properly proportioned boiler at 60lbs. per square foot should not fall below 10 times. In Fig. 6 are given the curves of steam production corresponding to the boilers in Figs. 3 and 4. In Figs. 7 and 8 are given the evaporation curves of a half section of a Babcock & Wilcox boiler for the United States battleship "Utah"; the former refers to a series of coal fired tests, after which the firebars were removed, the ashpans bricked over, and the boiler front modified to allow the oil fuel apparatus to be installed, with the result shown in Fig. 8. These trials are specially interesting in view of the efficiencies obtained at high rates of combustion. With coal an equivalent evaporation exceeding 11 times was obtained when burning 50lbs. per square foot, 10·5 times at 60lbs., and 9·45 times at 70lbs., the latter being double the average full power amount of United States naval practice. With oil fuel the same boiler exceeded an evaporative value of 15 times when burning up to 10·5lbs. of oil per cubic foot of combustion space; when burning 15lbs. the evaporation was 13 times, which is equal to 16·45lbs. of steam per square foot of heating surface per hour. The relative efficiencies, Fig. 7, when burning coal at 70lbs. per square foot, and the equivalent amount in oil, are 60 per cent. and 72·6 per cent. respectively Fig. 9 gives the evaporation curves of a Mosher type of boiler built to replace the cylindrical boilers of the United States battleship "Kearsarge." No little difficulty and cost are involved in conducting large series of evaporative trials, and local conditions frequently affect the readings to a considerable extent. By massing a varying series of curves together, and by deducing evaporative values for comparative estimating from a general mean value rather than from isolated instances, is probably the best means of obtaining a fair average value. From the curves in Figs. 5 to 9 it might reasonably be felt that for trial purposes an evaporation of 11 times when burning between 30lbs. and 40lbs. of coal per square foot of grate per hour, rising to 11·5 times at 20lbs., could be obtained from a well designed water-tube boiler. For general service at this rate a value of 10lbs. should certainly be obtained.

The Weight of Boilers.—In Table III. will be found the dimensions of a few typical boilers and their corresponding weights and steam production. Even if the inevitable discrepancies that must occur in practice due to various well-known conditions be found therein, the general deductions from this list will be found accurate. Approximately the pounds of steam produced per ton of boiler per hour from and at 212° Fah. by the various types are as follows:

Double-ended—360lbs. per hour.—For relatively highly forced cylindrical boilers, such as in Channel steamers.

Single-ended—320lbs. per hour.—For relatively highly forced cylindrical boilers, such as in Channel steamers.

Double-ended—270lbs. per hour.—For long-voyage, large-size vessels with lower rates of combustion.

Single-ended—230lbs. per hour.—For long-voyage, large-size vessels with lower rates of combustion.

For coal-fired torpedo-boat destroyer boilers -1,800lbs. per hour.—At full power.

In oil-fired torpedo-boat destroyer boilers -2,400lbs. per hour.—At full power.

No one would suggest the torpedo-boat destroyer type of boiler for a merchant vessel. Suppose the steam production in relation to weight be halved, in order to make proper allowance for the modifications to design, and permissible com-

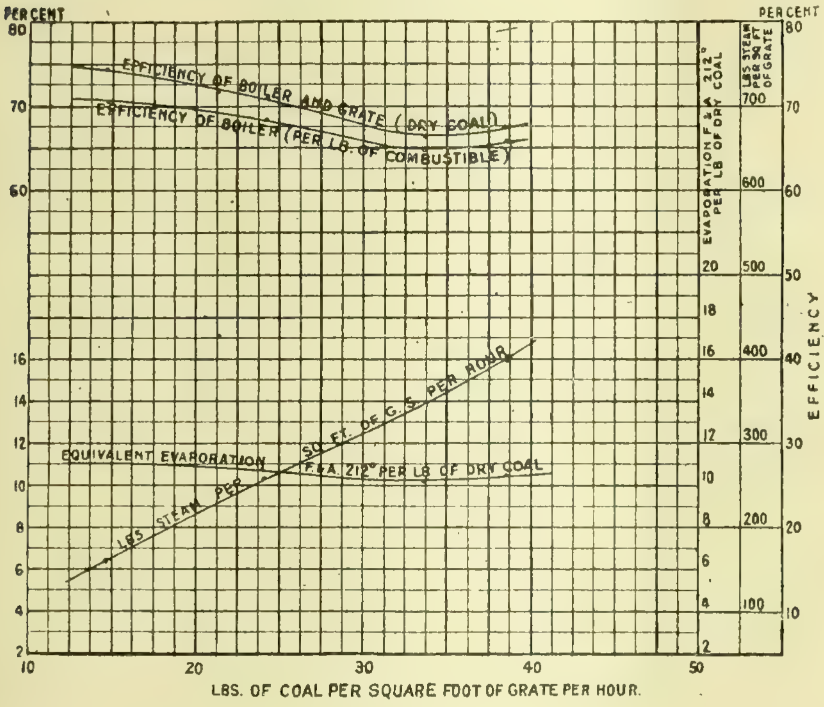


FIG. 9

bustion as discussed below, the water-tube boilers of the 3-drum type would still weigh less than half that of the cylindrical. As given in Table II., this applies to the generator portion complete and does not include uptakes and funnels, or, if fitted, a Howden heating system, which can, of course, also be applied. Roughly speaking, a large double-ended boiler weighs ·9 tons per square foot of grate surface, a single-ended boiler 1·02 tons per square foot, and a coal-fired water-tube boiler ·35 tons per square foot. That is, if increased in proportions and scantlings by 50 per cent., to suit merchant practice, the latter would only weigh one-half of the cylindrical unit for equal grate area and steam production.

The approximate weight of an entire boiler-room installation with piping, pumps, and all accessories might be put down as:—

—	Tons per square foot of G.S.	Lbs. of steam per hour per ton of boiler-room from and at 212° Fah.
For cylindrical boilers	1·4 to 1·7	150 to 200
For Babcock boilers	·65	450
For Yarrow boilers	·9	490

It is difficult to give in the space available fuller information than that tending to prove the point at issue; but in the case of two vessels each of 2,000 tons—virtually sister ships and fitted with the same turbines and shafting—the cylindrical boilers of the one weigh 320 tons, against 180 tons of the water-tube boilers in the other, the remaining stokehold weights being practically identical. In this case 140 tons represent 7 per cent. of the displacement, and about 100 tons of which has gone into additional deadweight capacity.

(To be continued.)

THE TROLLEY VEHICLE SYSTEM OF RAILLESS TRACTION.

At a meeting of the Society of Engineers, held on the 4th inst., a paper on this subject was read by Mr. Henry C. Adams. The trolley vehicle system of railless traction, which was a comparatively recent development so far as this country was concerned, might, the author observed, be described as consisting of mechanically propelled vehicles adapted for use upon roads, and moved by electrical power transmitted thereto from an external source. The power was obtained from bare overhead conductors erected and fixed in a manner somewhat similar to that in use for tramways, except that, as there were no steel rails for the return current, a second overhead wire was necessary for the purpose. The connection between the overhead wires and the vehicles was by means of rigid trolley poles or flexible cables. Installations had been working abroad for some years in Vienna, Dresden, Bremen, Drammen, Spezia, California, and about 30 other places, there being 50 miles in Italy alone. It was first definitely suggested in this country in 1902, was now in operation at Leeds and Bradford, and would shortly be working at Dundee and Rotherham. In November, 1910, there were 15 Bills deposited in Parliament, and 11 in November, 1911. It was understood that the Board of Trade was considering the question of simplifying and cheapening the procedure by means of Provisional Orders instead of having to proceed by Bill, as at present, so that it was possible before next session the last hindrance to the adoption of the system would be removed.

There were many localities where additional means of transport were urgently required, but the probable traffic was not sufficient to warrant the outlay necessary to construct an electric tramway. Success had not been obtained in the smaller towns with motor omnibuses; it was cheaper to generate power in bulk at a central station for trolley vehicles than to do so separately for each individual motor omnibus and the wear of tyres and roads with the lighter trolley vehicles would be less than with motor omnibuses. The trolley vehicle and motor omnibus could be steered with equal facility in crowded narrow streets. The railless system of traction was specially fitted to form extensions beyond the termini of an existing tramway system, to act as a feeder and create a traffic, then, when the time was ripe for a track to be laid, the overhead work could be adapted for use by tramcars. A detailed description of the various systems in operation was given in the paper.

The total capital cost of the schemes was approximately £3,000 per mile of route, compared with about £10,000 per mile for electric tramways. The cost of overhead work depended upon the standard desired and the length of cables required, but for good work might be taken at from £1,250 to £1,500 per mile. The vehicles cost £700 each. The cost of obtaining Parliamentary powers might vary from £400 to £5,000, dependent upon the amount of opposition. Reasonable periods to allow for repayment of the cost of installation would be: For the Bill, 5 years; vehicles, 10 to 15 years; overhead equipment, 20 to 30 years; cables, 40 years. The cost of working was about 5½d. per car mile. The receipts depended entirely upon local conditions; they varied abroad from 5·6d. to 10·75d. per car mile, at Leeds they had been 10·75d., and at Bradford 8·25d. per car mile, all of which figures showed a handsome profit.

Trailer cars were run attached to the omnibuses abroad, but it is doubtful whether they would be permitted in this country. No double-deck cars had been used at present. Tyre companies were willing to maintain the tyres on trolley omnibuses at from 1d. per car mile, dependent to some extent upon the condition of the roads. Tyres had been run for 28,000 and 24,000 miles respectively on trolley omnibuses abroad. Any road which now carried ordinary motor car traffic without detriment could also carry trolley omnibuses without further addition to the cost of maintenance. Attempts had been made to obtain payment for the use of the roads, but in the Aberdare Bill both Houses of Parliament declined to insert a clause requiring payment.

CHINESE ENGINEERING.*

BY W. D. B. DODSON.

CHINA has brought from the past no effective engineering ability. In their day, there can be no doubt of pre-eminent capacity among the builders of the old China. It was a narrow, egotistic Occident that enumerated the Seven Wonders of the world, and omitted the work of the Chinese engineers of antiquity. Everyone now knows of the Great Wall, which is found to-day extending from the sea out a distance of 1,500 miles, up mountain and down, in good condition, and there are remnants beyond, which disappear in the shifting sand dunes. The Grand Canal, an engineering audacity for the age of its construction, is an industrial marvel incomparably beyond any ancient achievement of the Occident. A system of highways was once constructed in China, radiating from Pekin, miles upon miles paved with broad flagstones, splendid grades established, rock cuts made around hills, and even an occasional tunnel driven, and this system, comprising seven great trunks, connected every part of the empire with the capital. Out in Western China will be found to-day an occasional suspension bridge, with chain cables. One great Wu, sung for centuries in Chinese traditions, irrigated the Chengtu plain in the heart of Szechuan province, the home of 67,000,000 people, and any man who will go for days over the canals and ditches placed by the engineer of the hoary past must feel that the Occident has overlooked a leader among Nature's noblemen. Arches found at intervals over canals and streams suggest forgotten builders of note. China's Sorrow, the terrible Hwang Ho, or Yellow River, has matched itself against engineering ability of the greatest order, and often lost. A stream that can switch its debouch into the sea two or three hundred miles within as many years, and which is marked by the worst types of floods, is a worthy foe for any engineer the world has ever produced, Occidental or Oriental.

I hastily suggest these achievements to prove that China has had engineering ability. She will have again. But for all the years of modern times, while the Western world was forging ahead, the Chinese mind has been repressed. Whatever it was that worked the backset is seemingly passing away. Keenest interest is aroused in the minds of Chinese students over engineering problems. Those who have taken the American and European engineering courses have developed into enthusiastic and tireless workers upon returning home. In the period since Caucasians have come in contact with the Chinese, there has been no academic engineering instruction until within very recent times. The Great Examinations, the most impressive educational tests ever known in any land, were calculated to inspire knowledge of the literary classics only, and never suggested material sciences. The Chinese Civil Service, which stood upon the educational system culminating in the Great Examinations, and which made the ruling class below the Imperial Clan a strict literary democracy, had no place for the worker in material things.

For a few years, since Chinese leaders conceded the supremacy of Western science, students were sent to America and Europe, and later a polytechnic school was established in Shanghai, and certain phases of engineering were taught at some of the larger universities. Chinese graduates through the American and British polytechnic schools have made most progress. There is a universal demand in China for Western education. If finances permitted, the new political order soon to be established would find every man with average intellect eagerly absorbing Western knowledge. Everything in a modern state affecting the material world will have to be acquired. Transportation, on land and water, will be Western. The steamboat is displacing the stately junk at sea and on the river. The launch beats the junk and sampan on canal and small stream. The railway is often a pioneer for overland transportation for long distances, as there are large areas where wheeled vehicles have disappeared for many decades, except wheelbarrows. Electricity, chemistry, mechanics, and even organisation of aggressive business will have to be taught by the West. China awaits it all eagerly. When the Great Examination system disappeared, in 1907, the old China surrendered. That was the real opening of the door. Given opportunity to put the political system in accord with these new aspirations, China will become a superb field for development.

A brief survey of natural resources is opportune. These are varied and abundant. Mineral resources are almost unbelievable. Much has been published upon hasty surveys and estimates which is no doubt exaggerated. But the uncontrovertible evidence of production, with range of occurrence, favouring formations and superficial workings leave no doubt of China's immense stores of minerals. Baron Richtofen, the famous German geologist, placed estimates upon the coal deposits that made the world sit up and take notice. He said that Hunan Province alone had an anthracite field equal to that of Pennsylvania. After spending a long time studying the formations of Shansi Province, he concluded that the cropping and slightly developed coal measures there were without an equal anywhere. In the Western Hills, near Pekin, Pumpelly found coal mines which had been operated for perhaps two thousand years, where an extreme width of one seam was found to reach 30ft. In Chili for a considerable distance about Chin Wang Tao, coal has been mined for ages, and there the big Chinese Engineering and Mining Company is now operating one of the great coal mines of the world, with expensive modern machinery. In Shantung an excellent soft coal has been mined by the natives for an unknown period, and there the Germans are developing several great coal mines on modern lines. In Manchuria the Japanese are making the Fushun collieries steady producers, with the avowed purpose of raising the yield to five thousand tons daily. In Kiangsi, Kiangsu, Honan, Szechuan, Hupe, Yunnan, Kwangtung, and Kwangsi provinces good coal deposits have been worked.

Transportation for coal between mine and world market is exceptionally favourable. The Yangtze-kiang has a minimum low-water depth of 9ft. to Hankow, 650 miles from Shanghai, and for nearly half the year is ascended by average coast and light ocean-going craft to that point. This transportation line intersects the great coal zone of China. For ages coal from Hunan has been taken by junk down the Siang River to the Yangtze, and thence conveyed on the Asiatic Father of Waters to the sea or consumers near seaboard. Before the steamboat came, solid strings of junks lined the Yangtze for hundreds of miles, one side passing upstream and the other scurrying down.

Other rivers entering the Yangtze and the Grand Canal were the old coal distributing lines. The Grand Canal, built primarily for movement of tribute grain, or tax grain, from coast provinces to the capital, became a great coal highway. But coal mining had no hope until the railway came. Early travellers in China found coal not moving more than 100 li, or 30 miles, from the pit where mined, except by water. Railways are now connecting the important coal-producing centres. The Ping Hsiang colliery, the greatest developed by Chinese capital alone, has a costly 30-mile railway connecting it with the Siang River. Extensive railway work will within a few years open all. There can be no question but what this fuel will soon be in the channels of trade; and in placing it there the modern engineer has a wonderful opportunity. Many informed men I met believe China can and will in due time duplicate the coal yield of the United States.

Iron occurrence is almost as general as coal. Hunan and Shansi were the scenes of ancient Chinese production, especially Shansi. In that province I inspected the old, old furnace type for reducing iron, and saw others for the Hunan product being used at and near Hankow. I made a special trip to the Tayeh iron mine, 80 miles below Hankow, and 15 miles from the Yangtze River bank. Here a great cropping of magnetic and hematite ores was being mined, by the Hanyang Iron and Steel interests, for consumption in the Hanyang furnaces and for sale to the Japanese under a big loan contract. Terrace cuts were worked on the sidehill by coolie hand labour, ore was dumped on to mere platforms and discharged on to ore trains of a small railway that conveyed it to the river bank, where it was dumped on to the ground. Coolie labour drawn from the surrounding agricultural district was employed.

Development of China's iron ores has not even begun. Tayeh was really the only place where modern methods were

* [illegible]

being met while I was in China. Innumerable districts where Richtofen and other learned travellers through China found superficial workings of an extensive character are yet to be opened. At Tayeh the Japanese had made a loan of four to six million taels, and were taking pay in iron ore, at the rate of 150,000 to 200,000 tons a year at a phenomenally low figure. The Japanese were using this ore at the Imperial Steel plant at Wakamatsu, in Japan. A shrewd provision in the contract penalising heavily where the iron content went below given percentages was working to Chinese loss, as the contract apparently had been based upon early shipments when magnetite was handled, and the main volume of shipments later was hematite. The Hanyang Iron and Steel Company, since reorganised under another name, owned the Tayeh iron mine, the Pinghsiang collieries, and the iron furnaces and rolling mills at Hanyang. Good progress was being made in producing commercial pig, railway rails, and several rolling mill products.

Coke production was being attempted on a large scale at but two points, the Pinghsiang collieries, in the Yangtze basin, and the Tongshan mines, in Chili, the first being the work of the Hanyang Company, and the latter of the Chinese Engineering and Mining Company.

Copper was probably mined in Yunnan and Kweichau provinces of China before the Romans ever thought of working the Rio Tinto copper mines of Spain. This metal was used for the very ancient Chinese cash mintage in periods antedating the Christian era. Recently a French syndicate, operating from Tonkin, or French China, has constructed a railway to the heart of the ancient copper zone of Yunnan, and there is prospect of important development work when the Chinese Government permits modern operations. Copper abounds in many parts of China, two or three of the foreign concessions having been for such ores.

About one-fifth of the tin of the world is mined in southern China, largely Yunnan Province. Crude mining methods, followed by cruder reduction and refining, gives the industry little opportunity to grow. Mercury has been packed out of Kweichau Province and shipped to the world for many centuries. Important cinnabar deposits are still found there, which are also promising of material development when properly opened. Antimony ores are being taken from Hunan Province to-day by the Germans, a concentrating plant being operated at Hankow to facilitate the trade. Manganese is being mined in connection with the iron industry. Szechuan has deep brine wells, from a few of which natural gas is procured to evaporate the brine. A salt marsh in the southern end of Shansi Province is reputed to have been used by the Chinese for five thousand years, being the salvation of the inland nation before it got a footing on the sea. Every mineral that we know is found there. Gold is barely mined at all, but this seems due to absence of proper encouragement, for there are many streams where panning methods are ancient custom. One quartz mill was erected in Shantung, by means of a foreign promotion, and dismally failed, for the mill preceded ore development. L. S. J. Hunt, the American, got a concession from the old Korean Emperor and built up a great Oriental Consolidated Mining Company property, having 220 stamps, which is one of the large gold mining enterprises of the world. Mineral formations are very favourable, the area of China immense, and there is no reason why it should not become a great gold-producing country in the coming years.

Foreign engineers direct all modern mining and reduction operations that I observed, but were training astute, observant Chinese staffs for the work. Germans directed the Pinghsiang collieries. Under Mr. Lee, a German staff was in charge of the Hanyang reduction plant and rolling mills. A German-American engineer was in charge of the Tayeh iron mine. The great plant of the Chinese Engineering and Mining Company had British and German engineers in charge, this being nearly entirely owned by British capital, following a struggle with the original Chinese interests. In Shantung, German capital and engineers direct all the modern coal operations of that district. No people of the world are giving foreign engineers a more cordial welcome than the Chinese.

Electric plants grow rapidly of late. Light and power plants were going up in the more prominent cities, the latest under Chinese ownership and management, with a foreign engineer in charge. No hydro-electric installations are practical in the central or northern region, so all plants generate with coal fuel. As a rule the company getting the equipment contract has a contract about furnishing an engineer for a given period. Germans and British, with occasional Dutch and French, have most of this work in hand.

Railway construction in China has been fast for seven or eight years, and will be at a far swifter pace when the reorganised country permits industrial development to keep pace. The Imperial Railways of North China, a Government enterprise, built by means of a British loan, covers the territory from Pekin to Mukden, viâ Tientsin and Chinwangtao. The main line mileage is about five hundred miles. A British engineer-in-chief directs the operating department, construction and maintenance included. Most of his staff are Chinese. A railway school is maintained to train mechanics and operatives. Chinese engineers, firemen, conductors, and other members of the crew man all trains. Repair and new construction work is carried on in the large, well-appointed shops at Tongshan, where the Chinese make coaches and freight cars and will even reconstruct an engine. An official prominent in the company told me that the year preceding operating costs were but 28 per cent. of revenues, which astounding statement he maintained was based upon fair bookkeeping methods. Both freight charges and passenger fares are low, there being three classes of passengers.

The Pekin-Hankow line was built under a Belgian concession, with joint Belgian and French engineering, and all equipment was drawn from those countries. The Shanghai-Nankin line was a British concession, where British engineers, materials, and equipment were used exclusively. Americans were granted the Canton-Hankow concession, and opened work, but not being financed, hawked the franchise until Chinese wrath was aroused. The syndicate was trying to sell to a Belgian and French concern when the Chinese redeemed the grant and have prosecuted slow construction since by means of Chinese and British funds, with a proviso giving British engineering preference. In Manchuria everything in connection with the great South Manchuria Railways is Japanese, except the American rolling stock and rails, which were bought in this country, but these would have gone to Japanese factories had the country been able to provide them. A joint German and British concession was granted for the Tientsin-Pukow line of nearly seven hundred miles, German engineers and materials prevailing at the northern end, and British at the southern. In Shantung two hundred and fifty miles of main line railway has been built under German concession, everything being German in the work. At the time I left, the Chinese were building, with their own finances, engineers, and workmen, the Pekin-Calgan line, and were making remarkable records in the charges for cutting and filling roadbeds, in some instances running about half the charges for same work on the Shanghai-Nankin line. The most insistent demand being made by the Chinese of foreigners at that time was for permission to have a freer hand in railway construction, with the privilege of purchasing materials and equipment in the market offering the best for the least money.

Many lines of industry beyond the possible scope of this paper were observed, wherein the foreign engineer and business manager were being given free rein. Cement manufacture and sugar refining are great industries, being conducted mostly under foreign guidance, and sometimes exclusive foreign control. Silk filiatures, flour mills, paper factories, cotton spinning plants, and arsenals were being erected and operated under foreign guidance.

I have emphasized how engineering is largely determined. Most of the loans made there fix the nationality of the engineers and the purchasing place for material and equipment. Nearly all engineers pull for the products of their own nations, even when not obligated to do so, and especially will they do this where prices are nearly the same and relative merits are subject of debate.

In enumerating a few resources of the country, I have omitted one of overshadowing moment—China's reserve of labour. There is nothing approaching this elsewhere in the world. Chinese estimates of their own population give 410,000,000 to 420,000,000 people in the 18 provinces. Multitudes of the coolies are as fine specimens of physical strength as any race produces. Coolie bearers of the interior have been pronounced by experts the third strongest class of the world, certain Chilean miners being placed first, and

Turkish porters second. For feats of fortitude and prolonged endurance, these Chinese coolies have no superiors. Ways of life and traditional customs seem to limit range of initiative, but any man who has worked among them, and adapted himself to certain Oriental principles, gains a very favourable impression of their future. I spent two years travelling over China with a demonstration telephone plant, of the automatic type. After my expert mechanic furnished by the factory was taken ill and had to return home, I operated the plant with a Chinese crew without serious difficulty, and found their minds remarkably keen to master mechanical intricacies. Foreigners who have lived among them for years declare them marvellous mechanics. All the machinery going to the Orient is operated by the Chinese, with only loose supervision in most instances. For courage and daring, where a cool head and steady nerve are required, I believe the Chinese are in the foremost rank when given the proper discipline. In handling machinery which requires keen eyes and alert minds they are ready to sail on the margin of danger to gain speed, and seem to enjoy the hazard involved. Certainly a race that can man the crazy junks which for centuries have tempted the typhoon-whipped seas bordering China will become great navigators some day. I found that amazing fund of labour willing, able, alert, and inclined toward progress. Unless my chart of human nature is wholly in error, Chinese labour, properly directed in the midst of Chinese resources, will bring forth results to gladden the world. I can see nothing to prevent those people soon becoming a mighty nation of modern times.

STEEL CASTINGS.

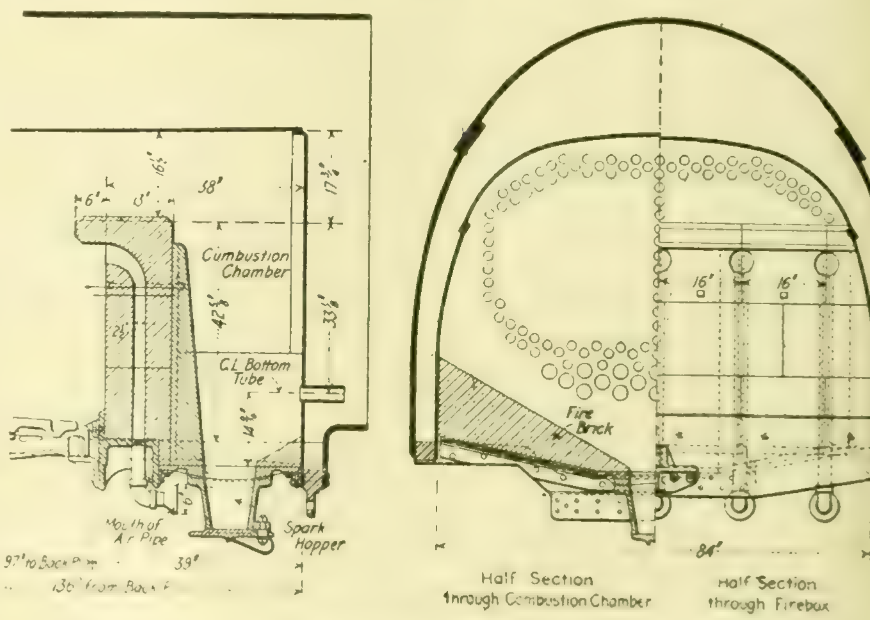
A LECTURE on "Steel Castings" was delivered by Mr. Brearley, of Sheffield, to members of the British Foundrymen's Association, in London, on the 8th inst. Mr. Brearley pointed out that the coarse crystalline appearance which the fracture of a steel casting was supposed to have was not now a sufficient distinction between castings and forgings. Examples of the coarse crystalline fractures of steel cast in sand moulds and slowly cooled were exhibited, and also illustrated by lantern slides, side by side with portions of the same casting after heat treatment. The exposed fractures of the latter were in all respects undistinguishable from well-wrought forgings. The lecturer spoke highly of the workshop value of careful observation of fractured and prepared surfaces with a hand-lens or any other available magnifying outfit, and then showed by a series of low-power photographs the wonderfully perfect structure of the interior of separate crystalline grains of mild steel. By the same means the defects arising in and about the crystalline grains were demonstrated, and a clear impression conveyed of the objects to be attained by annealing. He thought it highly undesirable that unannealed castings should be brought into any kind of service where a reliable object was called for, and showed, quite apart from the question of cooling stresses, how they might be expected to fail, and how the important question as to whether or not a casting had been successfully annealed could be determined by a simple means. The main object to be accomplished by annealing was, he said, the elimination of the coarse crystalline structure due to cooling from the liquid state, and the substitution of a much finer structure by methods which varied with the composition of the steel. Some slides were exhibited illustrating the hindrances which occurred in uncontrollable ways to the attainment of this object, and led also to that kind of rupture between the crystals known to the foundryman as pulling. The pulling of metal as it passed from the fluid to the solid state was illustrated by a few instances occurring in simple shapes usually cast in chill moulds. The difficulties he indicated were, however, such as could be overcome by intelligent care and close observation.

Disastrous Locomotive Boiler Explosion in the States.—A Reuter message from New York says that 14 persons have been killed through the explosion of a locomotive boiler in the Southern Pacific Railway's round house at San Antonio (Texas). Many others were injured.

LOCOMOTIVE FIREBOX WITH BRIDGE WALL AND COMBUSTION CHAMBER.

The desirability of effecting complete combustion of fuel and gases in the firebox of a locomotive boiler is generally recognised, but difficulties are encountered in effecting this under the conditions of locomotive construction and operation. The firebrick arch and the combustion chamber are important auxiliaries in ensuring this complete combustion, but while they are used extensively their use is by no means general. The admission of air to the fire is necessary for good combustion, but on probably a large majority of locomotives a considerable proportion of the trouble from leaky tube ends, cracked tube sheets, &c., is due to the entrance of large volumes of cold air when the fire-doors are opened, thus air chilling the hot plates and tubes, and (if in excess) lowering the efficiency of the combustion.

An interesting modification in firebox construction which has been designed to facilitate complete combustion, and which incidentally reduces boiler repair work, consists of placing a firebrick bridge-wall just in front of the tube sheet. The products of combustion have to pass over the narrow space above this wall, and the space behind it forms a combustion chamber and spark trap, while the wall protects the tube sheet from the attack of currents of cold air entering the fire door. The wall is perforated and air is supplied to the firebox through these openings, so as to give an ample air supply and to deliver it (highly heated) at a point where it will act upon the fire without striking the plates or tubes. The construction



LOCOMOTIVE FIREBOX WITH BRIDGE WALL AND COMBUSTION CHAMBER.

referred to has been applied to a number of engines with satisfactory results, as noted below. It has been invented and patented by F. F. Gaines, superintendent of motive power of the Central of Georgia Railway, Savannah, Ga. To him we are indebted for particulars and plans of the firebox, and for a record of tests made with one of the engines thus equipped.

The general construction is clearly shown in the accompanying cut, which shows its application to a wide firebox having a total interior length of 11ft. 4in. from back plate to tube plate. A cross frame carries the bridge wall, which gives a clear length of 8ft. 1in. for the firebox proper (as before its modification and lengthening) and a combustion chamber 24in. wide between the wall and the tube plate. The bottom of this chamber is sloped to a spark hopper or chute fitted with a gate, as shown. The wall has five 2½in. tubes which end at enlarged openings just below the overhanging top of the wall, so that the air entering is thrown into the hottest part of the fire. These tubes extend below the firebox, where they are turned to a horizontal position and fitted with trumpet-shaped mouths. The open space between the bridge wall and the crown of the firebox has a maximum height of 16½in.

This firebrick bridge-wall construction has been applied to a number of engines in both freight and passenger service on the Chicago Great Western Railway. J. G. Neuffer, superintendent of motive power, states that it materially improves the steaming capacity (where there is ample grate surface) and

reduces the repair work on the tubes, but the device has not been in service for a sufficient length of time to allow of an opinion as to what effect it may have on the firebox plates. These engines have narrow fireboxes, 42¼in. wide inside at the grate, with the usual mushroom section of the upper portion. The inside length from back plate to tube plate is 9ft. 4in., while the wall divides this into a firebox proper 6ft. 6in. long and a combustion chamber 20in. long. No information is available as to the fuel economy on this road.

In regard to the question of fuel economy, however, we have been furnished by Mr. Gaines with a record of tests made on the Central of Georgia Railway, in January, 1911. The tests were made in freight service between Mason and Columbus, 100 miles, but a train of 18 steel cars loaded with company coal was used for all runs, so as to avoid complications due to changes in load and composition of the train. The weight of train was 1,286·25 tons. All the engines were of the consolidation (2 : 8 : 0) class. No. 1,014, with cylinders 21in by 32in., had the construction shown, and a total heating surface of 2,987·33 sq. ft. No. 1,012 was identical with No. 1,014, except that it had the original boiler unchanged and a brick arch; its heating surface was 3,022·29 sq. ft. No. 1,716 had cylinders 22in. by 30in., and its firebox had a brick arch; the toal heating surface was 3,230 sq. ft.

The same kind of coal was used on all engines and on all runs. It contained 1·55 per cent. sulphur, and the analysis was as follows: Fixed carbon, 55·11 per cent.; volatile combustible matter, 30·56 per cent.; ash, 12·94 per cent.; moisture, 1·39 per cent. The heat value (by the Mahler-Atwater calorimeter) was 13,179 B.T.U. per pound of dry coal, or 12,996 B.T.U. per pound of coal actually used. The relative efficiency, based on coal consumption per mile and taking the equipped engine No 1,014 as 100 per cent., was 61·96 per cent. and 85·88 per cent., respectively, for the non-equipped engines Nos. 1,012 and 1,716. The excess in coal consumption as compared with the equipped engine No. 1,014 was 15·94 tons for No. 1,012 and 4·45 tons for No. 1,716. A summary of the tests is given in the accompanying table.—"Engineering News."

Tests of Locomotives with Different Types of Fireboxes. Central of Georgia Railway.

Actual time, h.m.	Stops. No.	Stops. Time, h.m.	Coal Consumed. Total, lbs.	Coal Consumed. Per 1,000 ton-miles, lbs.	Coal Consumed. Per hour, lbs.	Water Evaporated. Total, lbs.	Water Evaporated. Per lb. of coal, lbs.	Run per ton of coal, miles.
			Engine No. 1,014. With Gaines Firebox.					
6-34	6	1-04	11,950	93	1,820	96,800	8·10	16·74
6-42	8	1-33	13,350	104	1,991	109,000	8·16	14·98
6-12	7	0-49	12,450	97	2,008	105,750	8·49	16·08
6-39	7	1-12	14,250	111	2,143	109,800	7·71	14·04
26-07	—	4-38	52,000	101	1,991	421,350	8·10	15·38
			Engine No. 1,012. With Ordinary Firebox and Brick Arch.					
7-12	5	0-57	20,400	159	2,833	121,458	5·95	9·80
8-04	5	1-16	21,900	170	2,715	124,887	5·70	9·13
6-43	5	0-45	19,087	148	2,841	113,095	5·93	10·48
7-20	8	1-43	22,500	176	3,068	121,883	5·42	8·89
29-17	—	4-41	83,887	163	2,865	481,323	5·74	9·54
			Engine No. 1,716. Newer engine, with Ordinary Firebox and Brick Arch.					
8-00	9	2-33	15,000	117	1,875	110,400	7·36	13·33
7-24	10	1-41	16,500	128	2,230	120,000	7·27	11·43
6-50	9	1-20	13,800	107	2,080	102,801	7·45	14·49
7-28	12	1-42	15,600	121	2,089	117,166	7·51	12·82
29-42	—	7-16	60,900	118	2,050	450,367	7·39	13·14

Efficiency based on coal consumption per mile: No. 1,014, 100 per cent.; No. 1,012, 61·96 per cent.; No. 1,716, 85·58 per cent.

SOME TESTS ON CARBURETTERS.*

BY GEORGE W. MUNRO.

THE carburetter used on vehicle motors is a machine for mixing liquid gasolene with air in such proportions that the motor will always be supplied with combustible mixture suitable for explosive burning behind the engine piston. For satisfactory service it must respond automatically to the engine demand, whether light or heavy; and must be so well designed and built as to function under the most trying conditions of vibration and jar, and in any position less than complete overturn. Its action must not be seriously affected by weather conditions and provision must be made for meeting readily wide variation in character of fuel supply.

Increase in demand may result either from additional load or increase in piston speed. The heavy load at low speed results in an intermittent carburetter action, while at the higher speeds the flow of mixture to a multiple-cylinder motor is nearly continuous. So in addition to responding to a quantity change, the carburetter must also meet a variation in the character of the demand.

Until recently, effort was centred in meeting these operative conditions, and but little consideration was given to cost of operation. With the growing popularity of the automobile and motor boat, however, and the advent of a number of carburetters giving satisfactory service, questions of fuel

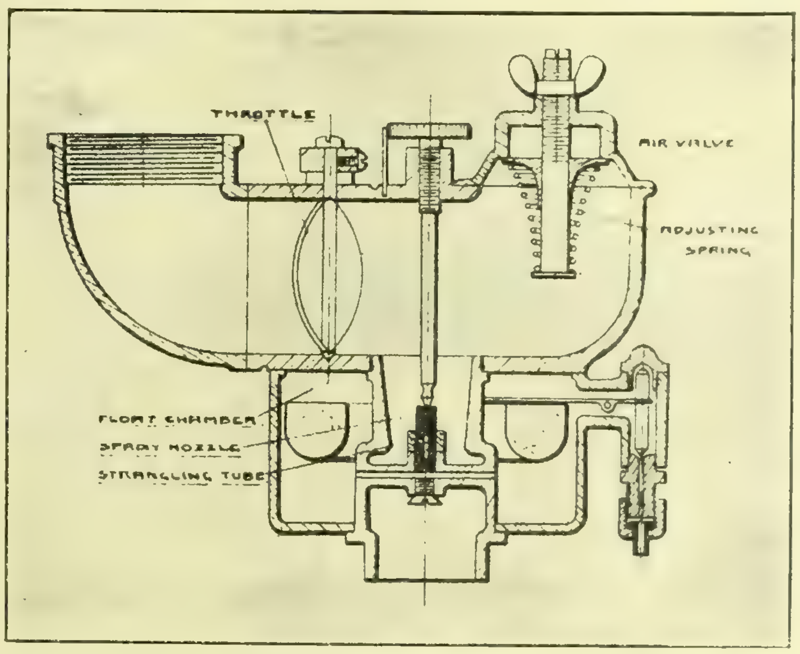


FIG. 1.—CARBURETTER A.

economy arose, demanding comparative tests and performance. Here the lack of established methods of testing, the absence of standards of comparison, and even a too limited nomenclature, prove troublesome.

The Problem of Carburetter Testing.—The peculiar features of the problem are that a carburetter is used only in connection with an engine and so should properly be tested in use upon it, thus introducing engine characteristics into all results.

* Paper read before the American Society of Mechanical Engineers.

Again, the engine requires a carburetter for operation, and so its performance cannot be determined free from carburetter factors. From this it appears that the two must be tested together, and the securing of a proper standard for comparison of results is most important.

As the best possible performance of the engine marks also the best possible carburetter action, the complete determination of the engine characteristics would establish a basis for comparing the behaviour of any carburetter which might be used. Owing, however, to the fact that the characteristics of some carburetters are always superimposed on those of the

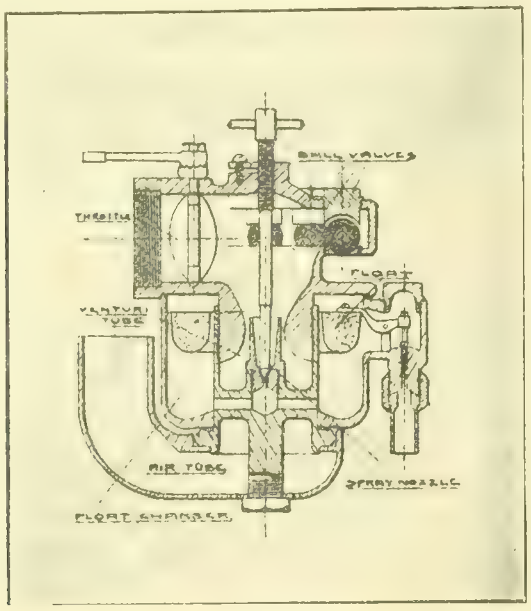


FIG. 2.—CARBURETTER B.

engine, the limitations due to such purely engine factors as compression, shape of the clearance space, and friction, cannot be readily determined. However, if an engine were tested under the same running conditions with a large number of carburetters, some one of them might furnish a perfect mixture and the best possible performance of the engine would be realised. The repetition of this process with a large number of running conditions would ultimately result in defining completely the engine performance. It is too much to expect that this result could be accomplished by testing only six carburetters, but lacking any other standard the best result obtained under each running condition has been plotted on each sheet of results for comparison.

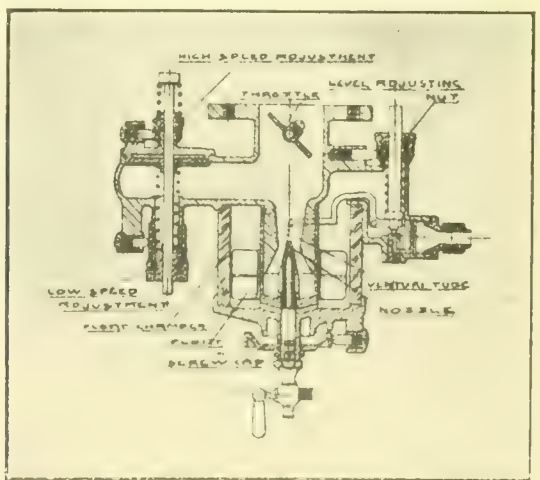


FIG. 3.—CARBURETTER C.

Scope of the Work.—The six carburetters were tested under identical engine conditions through a range of 10 speeds from 300 to 1,200 revs. per minute. At each speed, tests were run with 10lbs., 20lbs., 30lbs., &c., net load on the brake up to the maximum which could be carried, making 80 tests with each carburetter. The impossibility of maintaining all the conditions and lack of time made it impossible to complete all of the series, but a total of 401 tests was secured, with results so consistent as to indicate the essential accuracy of the work. In addition, the experimental work involved the repetition of one entire carburetter series, due to a broken crank shaft and consequent change of engines after the work with the first carburetter had been completed. A seventh carburetter was also tested, the results of which are omitted for reasons discussed elsewhere.

The Carburetters.—The carburetters, selected to represent as widely different types as possible, covered the standard construction of the different manufacturers at the time they were loaned or donated for the purpose of the investigation. The details of carburetter construction have changed so rapidly, however, in the two years since, that the results should now be interpreted as applying to the type of instrument rather than to the particular output of any manufacturer.

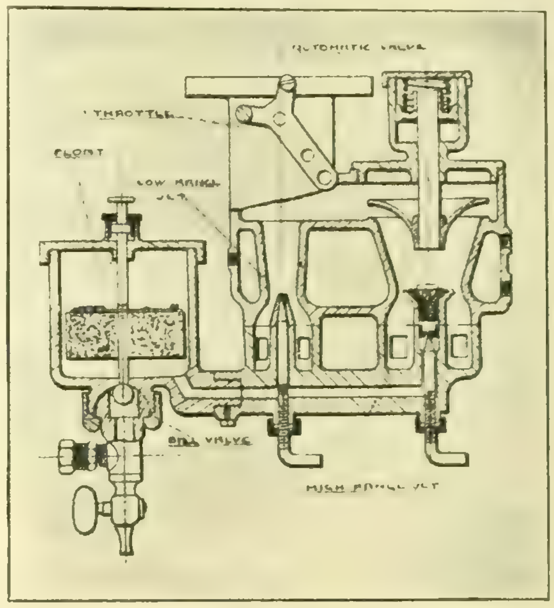


FIG. 4.—CARBURETTER D.

Carburetter A (Fig. 1) is a concentric float-feed, single-jet, auxiliary air-valve carburetter in which the auxiliary air supply is regulated by an adjustable spring controlling a light flat-seat metal valve.

Carburetter B (Fig. 2) is a concentric float-feed, single-jet type with floating ball auxiliary air valves, in which the auxiliary air enters by raising the ball valves in their cages

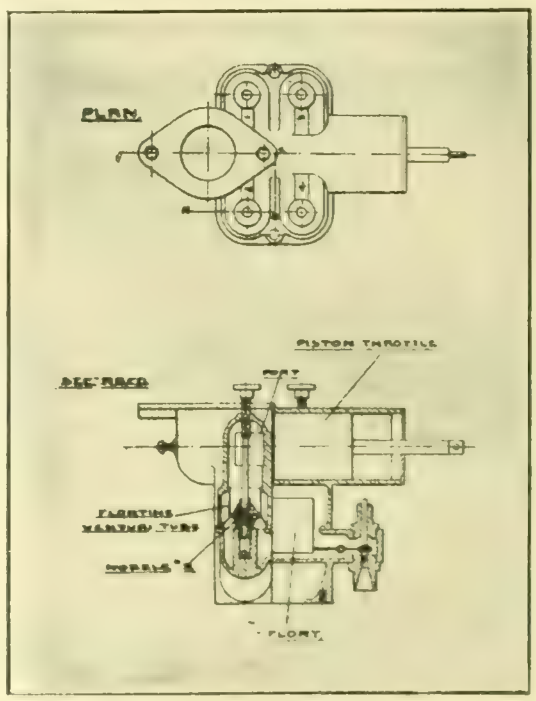


FIG. 5.—CARBURETTER E.

in response to the suction caused by increase of engine demand. Both these carburetters have many points of resemblance, and were chosen because of the difference in auxiliary air control.

Carburetter C (Fig. 3) is of the concentric float-feed type, but has no needle valve, the adjustment for fuel characteristics being made by changing gasolene nozzles. The auxiliary air valve is controlled by two springs, one of which comes into action only under conditions of high demands. Carburetters A, B, and C have in common the same general design features a gasolene nozzle with constant level fuel supply around which passes an unregulated air current, the air velocity being increased at the nozzle tip by a constric-

tion of the air passage at that point. As this device gives a mixture too rich to be explosive at all except under the conditions of lightest demand, provision is made for the admission under automatic control of additional air to dilute the mixture to required proportions. The notable differences consist of various automatic air controls, fuel controls to the nozzles, and forms of the constant air supply passages. Of these the automatic air control was considered the most important, and was the controlling factor in the selection of these carburetters for this work.

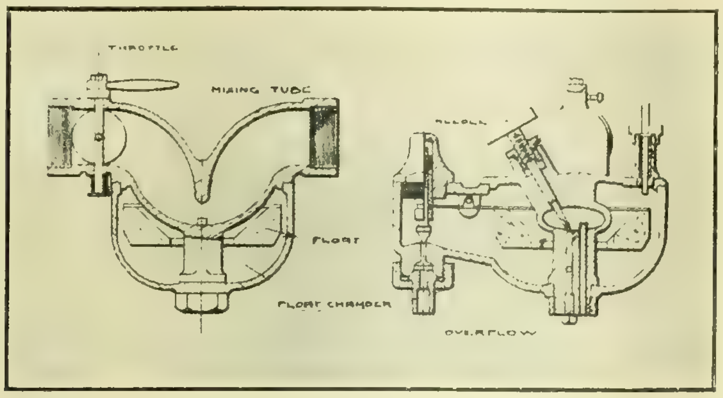


FIG. 6.—CARBURETTER F.

Carburetter D (Fig. 4) is a float-feed, two-jet, automatic-valve type, the automatic valve operating to keep one jet from service except under conditions of high demand. When the demand increases beyond the capacity of the first nozzle, the increased suction opens the valve above the second jet, which is of the cone multiple spray type, additional mixture being thus secured.

Carburetter E (Fig. 5) is a float-feed, multiple-jet type with floating venturi air tubes surrounding the nozzles. The jets, four in number, are successively brought into action as the piston throttle is operated to uncover their ports, the floating of the air tube being intended to maintain constant quality of mixture throughout the range of each jet.

Carburetter F (Fig. 6) is of the concentric, float-feed, puddling type, a gasolene puddle being formed in the bottom of the U-shaped air passage under conditions of light demand. With increased demand the puddle disappears by evaporation, the fuel supply being restricted by the needle valve. No auxiliary air supply is provided in this carburetter, the puddle furnishing mixture sufficiently rich for starting with air supply wide open.

Carburetter G is one of the very early machines equipped with a lifting needle under control of the throttle. Its behaviour on test leads to the belief that it is not representative of the type and so no interest attaches to the results, which are not given. It is mentioned here only because it gave maximum economy under a number of conditions, which results have been plotted for comparative purposes.

Testing Plant.—The tests were made on a new Rutenber 4-cylinder, 4-cycle, automobile engine. The cylinders, 4½in. diam. by 5in. stroke, were equipped with a single spark plug, and the timer controlling the ignition system was provided with a pointer and scale, showing the ignition point with reference to the inner dead centre in degrees of crank-shaft position. The power was measured and absorbed by a prony brake having an arm of a 2·1875ft. radius, bearing on platform scales. An oil drip on the brake-wheel rendered the brake very sensitive and eliminated all tendency of the engine to "hunt." Speed was determined by an indicating tachometer carefully calibrated for the speeds to be maintained. The fuel, ordinary stove gasolene, had a specific gravity of 0·723, and was supplied from a vertical cylindrical tank having a gauge glass and scale properly calibrated. The cooling water for the motor was stored in a large tank out of doors, and after use was discharged to the sewer. The operation of the plant was in every way satisfactory, and conditions of speed and load, once established, could be maintained constant as long as desired.

Adjustment.—In preparing for the tests the engine was "tuned up" by adjusting the carburetter for range and economy as follows: To maintain the maximum load at 1,200 revs. per minute; to give least possible fuel consumption under maximum conditions; to run light at 300 revs. per minute or slower; to accelerate properly when the throttle was opened quickly; and to attain all intermediate conditions under throttle and spark control without misfires, backfires, or noticeable smoke at the exhaust. This "tuning up" with each carburetter in turn was done by a man of experience and skill, and it is believed that the adjustments were uniformly good.

The Tests.—After adjustment the speed was brought to 300 revs. per minute, the brake load adjusted to 10lbs., the cooling water regulated to give desired conditions, and a 6-min. test made, readings of fuel consumption and temperature of out-going cooling water being taken at 1 min.

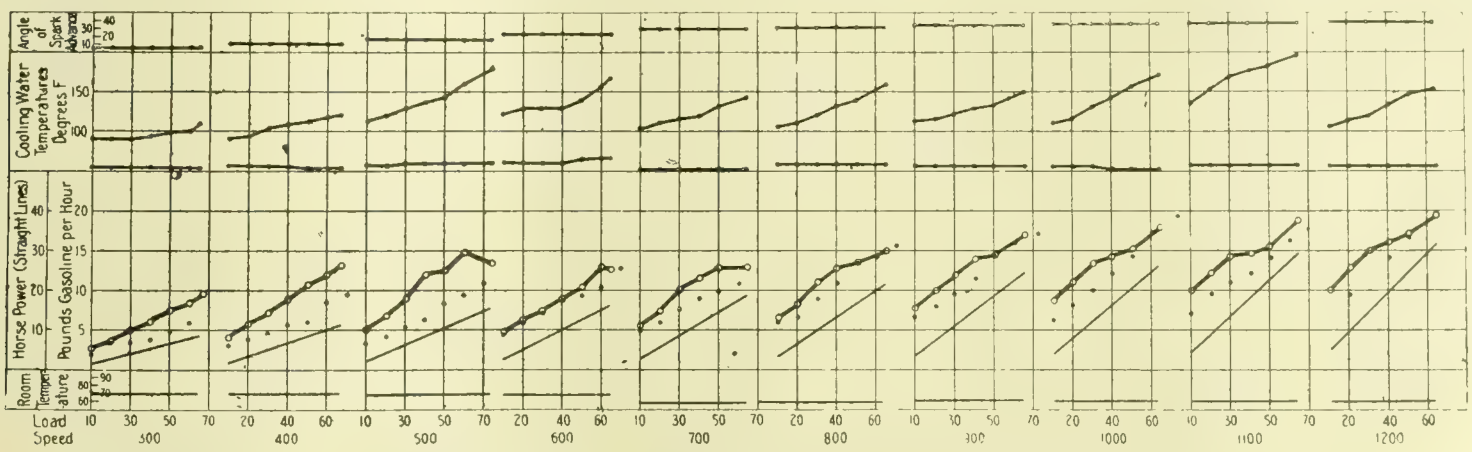


FIG. 7.—RESULTS OF TESTS WITH CARBURETTER A. BEST PERFORMANCE OBTAINED FROM ANY TEST INDICATED BY SOLID DOT.

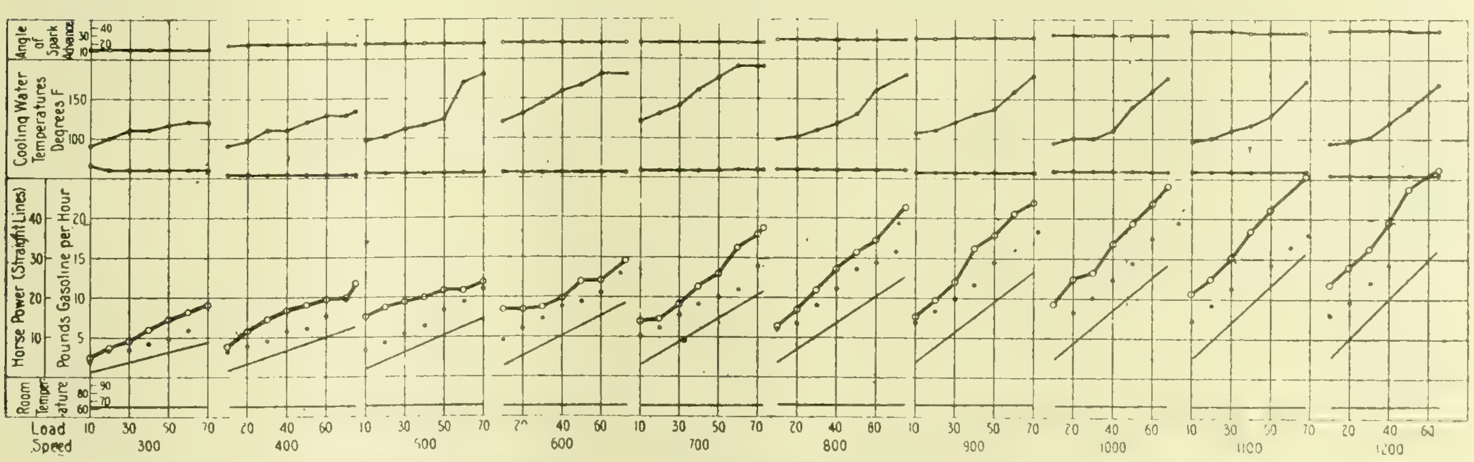


FIG. 8.—RESULTS OF TESTS WITH CARBURETTER B. BEST PERFORMANCE OBTAINED FROM ANY TEST INDICATED BY SOLID DOT.

intervals. The temperatures of the room and incoming cooling water remained nearly constant, and were taken only at the beginning and end of each test.

The tests were made in the order of increasing loads and speeds, that is, the load was increased at constant speed to the engine capacity when the speed was increased by 100 revs. per minute and the load series repeated. At all times the engine was given the most advantageous spark setting, ignition adjustment being made before each test. No adjustment of cooling water supply was made during a load series unless there seemed danger that the boiling point would be reached before the series was concluded. This shows in a gradually increasing temperature of outgoing cooling water through each load series.

After the 10 load series were completed, a "range test" was made, the carburetter adjustment remaining the same as throughout the economy tests. Maintaining the maximum load which the engine would carry at 1,200 revs. per minute, the speed was gradually decreased by throttle and spark to the lowest point at which the load could be carried. The results are given graphically in Fig. 14.

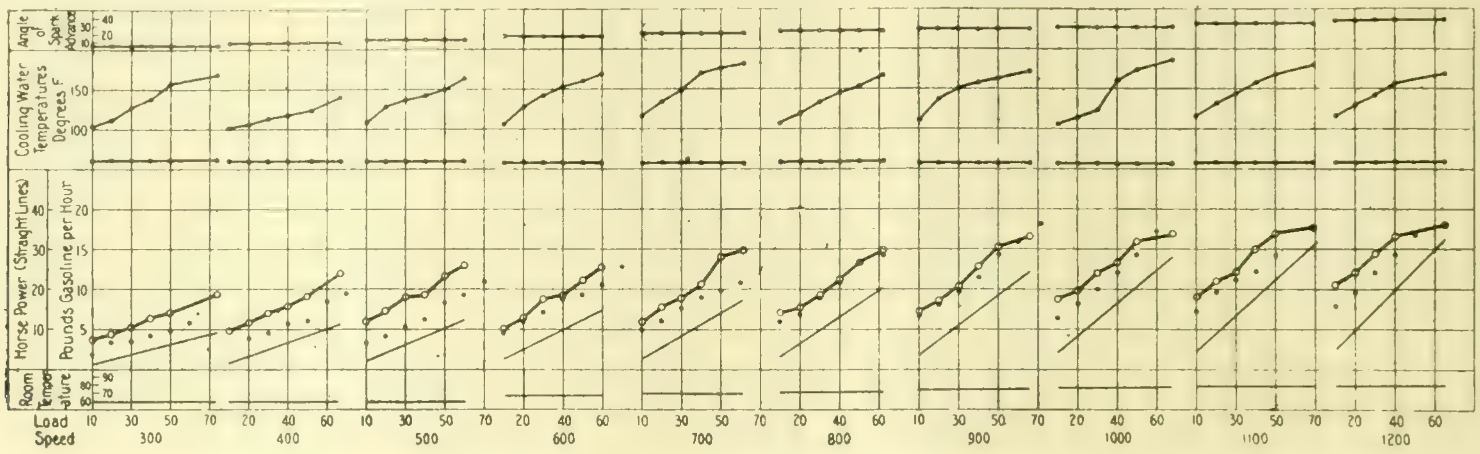


FIG. 9.—RESULTS OF TESTS WITH CARBURETTER C. BEST PERFORMANCE OBTAINED FROM ANY TEST INDICATED BY SOLID DOT.

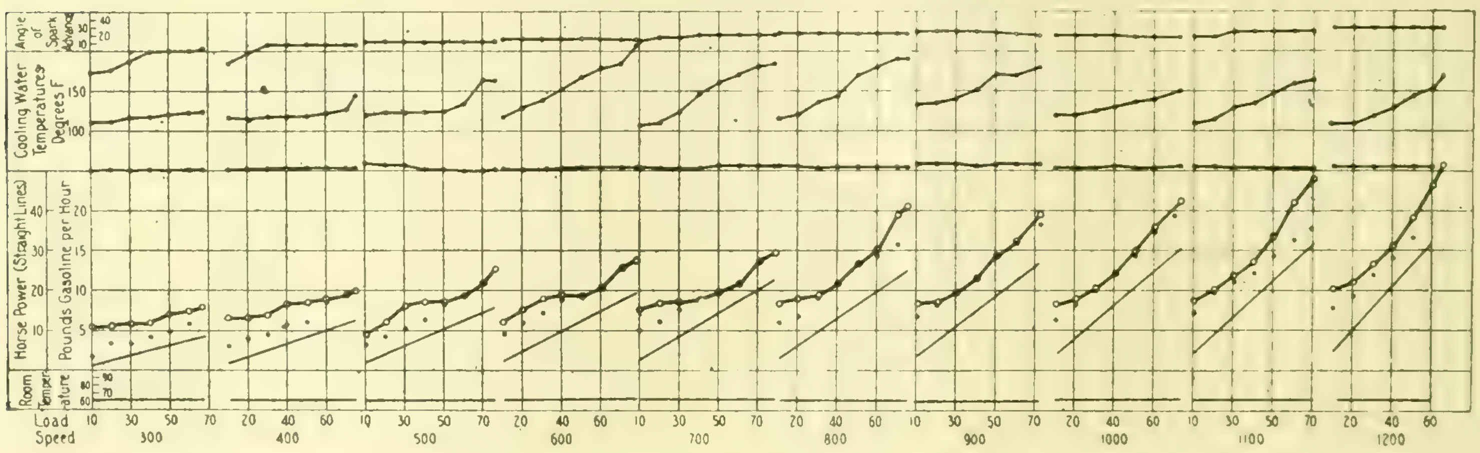


FIG. 10.—RESULTS OF TESTS WITH CARBURETTER D. BEST PERFORMANCE OBTAINED FROM ANY TEST INDICATED BY SOLID DOT.

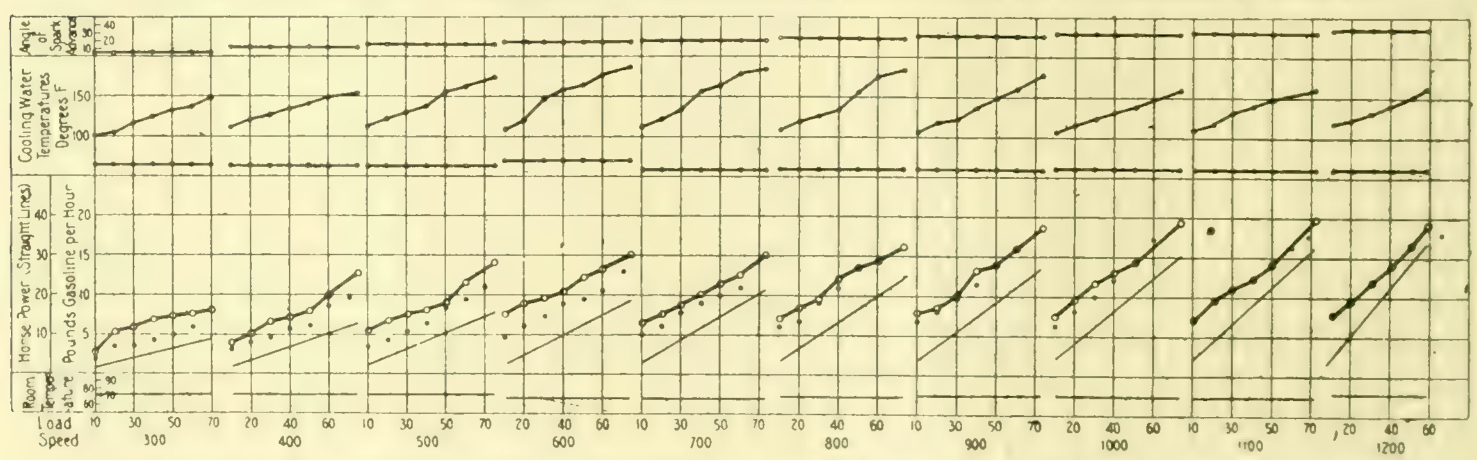


FIG. 11.—RESULTS OF TESTS WITH CARBURETTER E. BEST PERFORMANCE OBTAINED FROM ANY TEST INDICATED BY SOLID DOT.

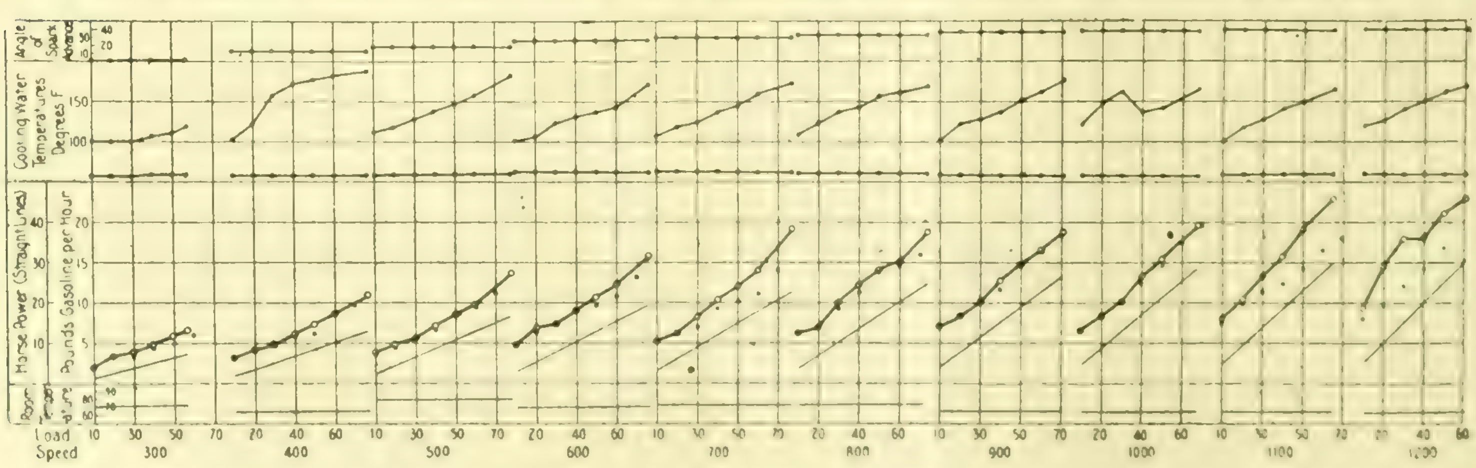


FIG. 12.—RESULTS OF TESTS WITH CARBURETTER F. BEST PERFORMANCE OBTAINED FROM ANY TEST INDICATED BY SOLID DOT.

The Results.—The results of all tests are given in graphical form in Figs. 7 to 12 inclusive. The graphical method followed in presenting results has the advantage of being concise and of furnishing certain comparisons in the process of presentation, whereas tabulation of the same data requires a quite bewildering mass of figures, from which comparisons are drawn only with difficulty. In the matter of accuracy

there is some advantage in tabulation, yet here the gain is not so great as might appear. Take, for example, the fuel consumption per hour which has been plotted to tenths of a pound, while the fuel reading was originally made to hundredths of a pound for a one-tenth hour test, making the plotting of the same accuracy as the original observation.

An inspection of the result sheets shows that for each load series there might be drawn a smooth curve which would show the performance characteristic of the carburetter for that speed. These curves were not drawn in, as it did not seem wise to confuse the presentation of data with its interpretation, but to illustrate the characteristics of the various carburetters Fig. 13 has been drawn, giving the results obtained from all carburetters at 1,100 revs. per minute. Comparison of these curves with the results obtained from the same carburetters at near-by speeds shows that they are typical forms.

Engine Performance.—As previously indicated, the best performance of the engine has a special interest in a series of carburetter tests, as it forms the only available basis for comparison of carburetter action. For this reason, as well as because of the interest that naturally attaches to records of engine performance, the best engine results at each speed have been shown graphically in Fig. 14, both in terms of gasolene per brake horse-power hour and in per cent. thermal efficiency, based on an assumed calorific value of 20,700 B.Th.U. per pound of gasolene. Also the best results obtained with each load at 800 revs. per minute have been shown in Fig. 15 in the same way. Smooth curves have been drawn to assist the eye in following the points and to indicate the general trend of results. The best performance with any one carburetter has been indicated by black dots in each case for comparison.

Table I. shows the maximum horse-power developed at each speed with each carburetter, together with the corresponding fuel consumption and engine efficiency. The best performance, 22·2 per cent., corresponds to a fuel consumption of 0·736 pints of gasolene per horse-power hour. The highest brake load, 78lbs., demands a mean effective pressure of 8lbs. to the square inch for the brake load alone. Assuming a mechanical efficiency of 85 per cent. for the engine, the mean pressure on the piston would be 95lbs., which corresponds closely with the best that is obtained with the same fuel in stationary practice, and shows that conditions in the cylinder are not materially changed up to seven or eight cycles per second. Indeed, the steady increase of efficiency with speed indicates that speed does not interfere with cylinder performance within the limits of the experiments.

TABLE 1.—*Maximum Power and Engine Performance at each Speed with each Carburetter.*

R.P.M.	300			400			500			600			700			800			900			1000			1100			1200		
Carbureter	Horsepower	Lb. Gasolene per hr.	Efficiency per cent	Horsepower	Lb. Gasolene per hr.	Efficiency per cent	Horsepower	Lb. Gasolene per hr.	Efficiency per cent	Horsepower	Lb. Gasolene per hr.	Efficiency per cent	Horsepower	Lb. Gasolene per hr.	Efficiency per cent	Horsepower	Lb. Gasolene per hr.	Efficiency per cent	Horsepower	Lb. Gasolene per hr.	Efficiency per cent	Horsepower	Lb. Gasolene per hr.	Efficiency per cent	Horsepower	Lb. Gasolene per hr.	Efficiency per cent	Horsepower	Lb. Gasolene per hr.	Efficiency per cent
A	8.138	9.6	10.4	11.122	13.2	10.3	15.429	13.4	14.1	16.276	12.7	15.8	18.688	13.0	17.7	21.678	15.0	17.8	24.602	17.0	17.8	26.688	18.0	18.2	29.357	18.9	19.0	31.80	19.5	20.1
B	8.764	9.0	12.0	12.450	11.7	13.1	14.595	11.8	15.2	18.380	14.5	15.5	21.316	18.6	14.1	25.010	21.3	14.4	26.292	21.9	14.7	28.356	24.0	14.5	31.192	25.2	15.2	32.552	26.1	15.3
C	9.265	9.4	12.1	11.122	12.0	10.4	12.510	13.0	11.8	14.898	12.8	14.3	17.958	15.0	14.7	20.677	15.0	16.9	24.789	16.6	19.3	28.356	17.0	20.5	31.651	17.7	22.0	32.552	18.0	22.2
D	8.380	8.0	12.9	12.450	9.9	15.5	15.870	11.7	16.7	19.530	13.8	17.4	22.776	14.8	18.8	25.010	20.6	15.0	27.012	19.5	17.0	30.441	21.2	17.5	32.109	24.0	16.4	32.552	25.8	15.5
E	8.764	8.0	13.4	12.450	12.6	12.1	15.640	14.0	13.8	18.530	15.0	15.2	21.316	15.0	17.5	24.345	16.1	18.6	27.600	18.6	18.2	30.441	19.4	19.3	32.797	19.8	20.3	34.050	19.2	21.8
F	7.136	6.5	13.5	12.782	10.8	14.5	16.263	13.5	14.8	19.030	15.6	15.0	22.484	18.0	15.4	24.679	18.6	16.3	26.667	18.6	17.6	28.356	19.5	17.9	29.815	22.8	16.0	30.548	22.9	16.4

EFFICIENCY BASED ON ASSUMED FUEL VALUE OF 20,700 B.Th.U. per lb.

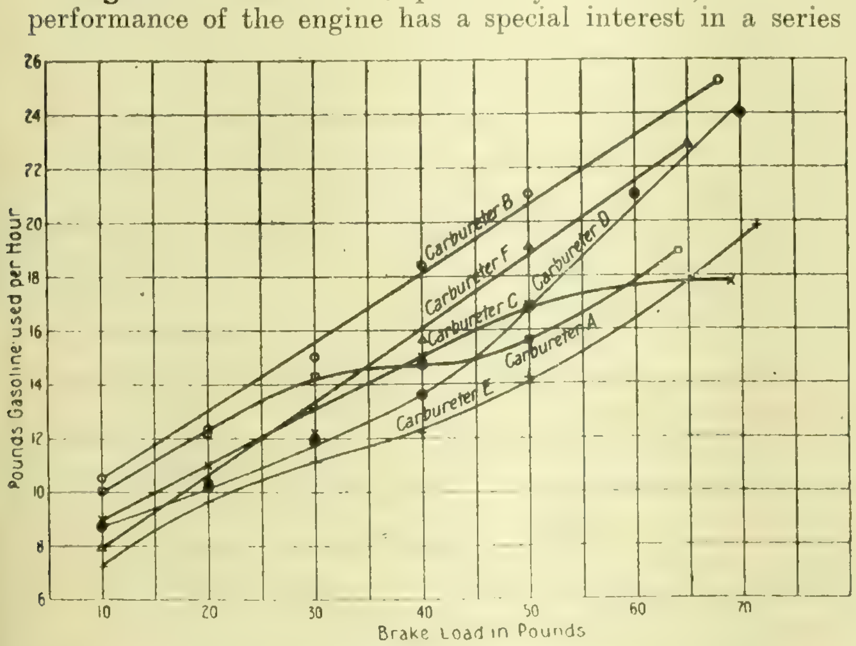


FIG. 13.—CURVES SHOWING CARBURETTER CHARACTERISTICS AT 1,100 R.P.M.

Conclusions.—A consideration of the results obtained leads to the following conclusions:—

(*a*) Under identical conditions of speed and load an engine gives materially different fuel economy when served by different carburetters.

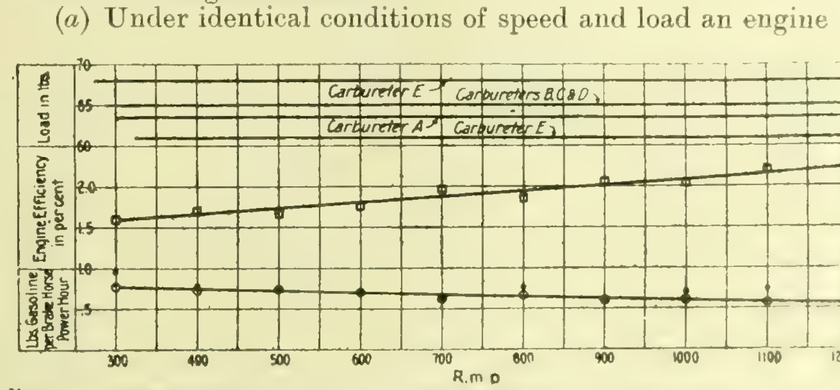


FIG. 14.—CURVES SHOWING RESULTS OF ENGINE TESTS AND BEST PERFORMANCE OF ENGINE AT EACH SPEED. BEST PERFORMANCE WITH SINGLE CARBURETTER (CARBURETTER D) INDICATED BY SOLID DOTS.

(*b*) Carburetter action is the limiting factor in engine capacity as well as in economy.

(*c*) Wide range and perfect operation give no indication of fuel economy.

(*d*) Each carburetter has distinctive performance characteristics which may be determined and plotted.

(*e*) The characteristic may be such that a carburetter giving excellent results under some conditions may give very poor economy over a large part of its range.

Being the limiting element of engine capacity and economy, the carburetter is a machine of great engineering and economic importance, and as such demands more scientific methods in its development than have yet been applied. This would necessitate systematic testing and comparison, not only of widely different types, but of the same carburetter after minor changes in design. A method of testing car-

buretters which would be independent of engine characteristics is much to be desired, as then results obtained by different experimenters in different places could be directly compared. Lacking such a method, it seems desirable that an engine be properly equipped and placed in some laboratory

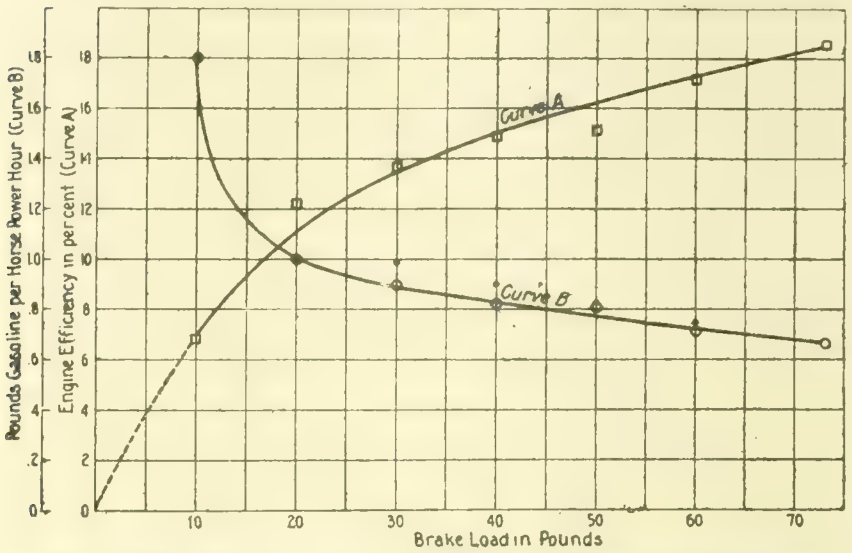


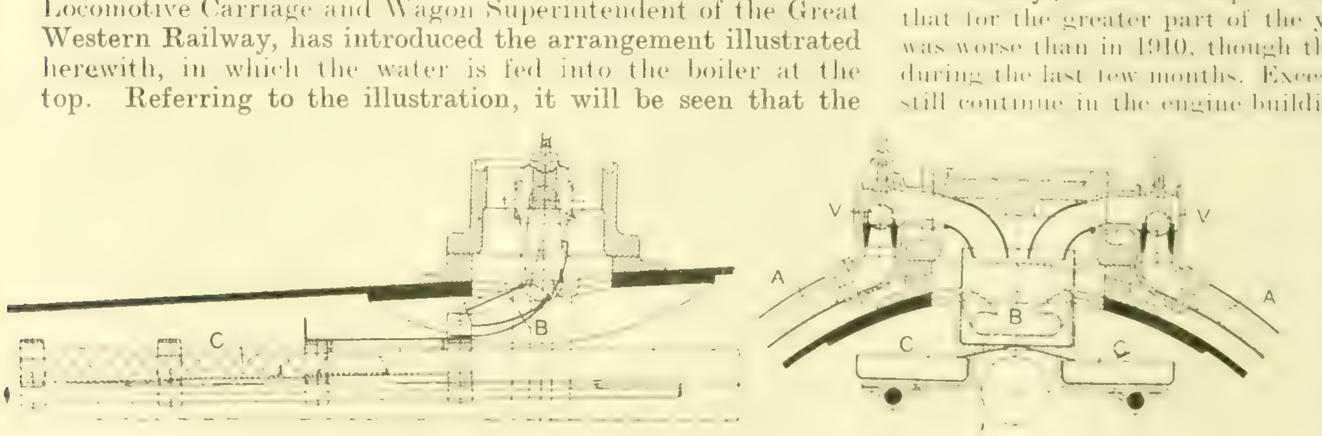
FIG. 15.—CURVES SHOWING BEST PERFORMANCE OF ENGINE AT EACH LOAD, SPEED CONSTANT AT 800 R.P.M. BEST PERFORMANCE WITH SINGLE CARBURETTER (CARBURETTER F) INDICATED BY SOLID DOT.

for the testing of carburetters, thus establishing, after the engine characteristics became thoroughly known, a definite standard available for reference. Such a standard would be valuable only in case carburetters retain their relative characteristics when transferred to different engines, which seems probable but has not yet been established experimentally.

This would require a large expenditure, both for plant and for operation, and, undertaken as a commercial venture, would probably be attended with financial loss. Engine builders, however, spend vast sums each year in developing and perfecting their output, and when the dependence of the engine on the carburetter is considered, it would seem that several engine manufacturers might profitably unite in the systematic improvement of the carburetter.

"TOP FEED" FOR LOCOMOTIVE BOILERS.

IN locomotives in which the feed water is introduced at the lower part of the boiler, troubles are sometimes experienced in the shape of grooving at the junction of the front tube plate and the barrel, as well as the breaking of stays in the region of the throat plate. With a view to overcome these disadvantages, Mr. C. J. Churchward, M.Inst.C.E., Chief Locomotive Carriage and Wagon Superintendent of the Great Western Railway, has introduced the arrangement illustrated herewith, in which the water is fed into the boiler at the top. Referring to the illustration, it will be seen that the feed pipes A are carried up round the outside of the boiler barrel to the clack boxes, which are fixed on to the seat for the safety valves. Ball valves V are arranged as shown in the feed pipes. The feed water is discharged into the shoot B, thence into the two trays C, and finally flows through the holes in the sides of the trays to the water below. The device has been fitted to several hundred engines on the Great Western with such successful results that the company have decided to adopt it on all their engines. By its use it is claimed that the troubles which arise from the strains set up when the feed water is introduced into the boiler at the lower part are obviated. The trays are so arranged that they can easily be withdrawn for cleaning purposes.



TOP FEED FOR LOCOMOTIVE BOILERS.

INDUSTRIAL AND TRADE NOTES.

Electric Iron Smelting in Norway.—According to the British Acting Consul at Christiania, work will be commenced at the electric iron smelting works at Tinfos, in Telemarken, in May next, with three blastfurnaces and a reserve furnace, provided that a concession is obtained for laying wires for conducting electricity at high tension to the works.

Canadian Pig Iron Production.—The "Bulletin" of the American Iron and Steel Association of March 1st states that, according to statistics which the Association have received direct from the manufacturers, the production of pig iron in Canada in 1911 amounted to 824,345 tons, as against 740,210 tons in 1910, an increase of 84,135 tons, or over 11·3 per cent.

Motor Omnibuses for Canada.—The municipal authorities of Toronto contemplate the establishment of motor omnibus services. It is estimated that an initial outlay of about £411,000 will be required, and will include the purchase of 200 motor omnibuses. Communications from British firms interested should be addressed to Mr. C. H. Rust, City Engineer, City Hall, Toronto.

Barrow Steelworks to be Restarted.—The directors of the Barrow Steel Company have decided to restart the plate mills at Barrow Steel Works which have stood idle for the past three years, immediately after the settlement of the coal strike. Alterations to the big mill are being made which will enable it to turn out much wider plates, and thereby meet the requirements of shipbuilders more completely than formerly. Local requirements have never been so large as at the present time, and the whole of these wants have for a few years been fulfilled from outside the district.

State of the Skilled Labour Market.—The monthly memorandum prepared by the Labour Department of the Board of Trade states that employment in February continued good. Towards the end of the month, it began to be affected in certain industries by the coal dispute, which has since had a very serious effect, especially on those trades using large quantities of coal. In the coal mining industry employment was exceptionally good until the beginning of the great dispute; it was also good in the engineering and shipbuilding trades. The pig iron industry was early affected by the coal dispute, and showed a marked falling off compared with the previous months. There was also a decline in the tinplate industry. As compared with a year ago there was a decline in the pig-iron trade. In all the other principal industries there was an improvement, which was especially marked in the iron and steel, tinplate, engineering and shipbuilding trades. In the 394 trade unions, with a net membership of 829,695, making returns, 23,611 (or 2·8 per cent.) were returned as unemployed at the end of February, 1912, compared with 2·7 per cent. at the end of January, 1912, and 3·3 per cent. at the end of February, 1911.

Galloways, Ltd. The report of this company for 1911 states that for the greater part of the year the Lancashire boiler trade was worse than in 1910, though there was a distinct improvement during the last few months. Excessive competition and low prices still continue in the engine building trade. The first gas engine, 1,350 b.h.p., has been completed. The price obtained showed a loss, but it is hoped the engine will be a means of obtaining further orders. Arrangements have been made for the manufacture of patent gas producers. The directors say the present condition of business is much better than shown by the balance-sheet. The orders booked during the last four months are sufficient to keep both engine and boiler works well occupied for some months on a profit earning basis. The directors have again decided not to accept any remuneration for their services for the year. After charging £5,182 to depreciation there was a profit on trading account for the year of £1,606, and sundry credits £558, making £2,164. Against this, however, must be placed debenture interest £6,000 and the special loss named above of £2,234, increasing the deficiency by £6,070, to £26,138. In 1910 the debit balance was increased by £9,403, and the interest on the preference shares is in arrear since June, 1908.

Amalgamated Society of Engineers.—The March report of the Amalgamated Society of Engineers states that the membership of the organisation is now 123,057, as compared with 122,200 a month ago and 117,217 a year ago. It is intimated that the negotiation of a demarcation agreement was not completed at the recent con

ference owing to a proposal of the employers to substitute for Clause 3, as they had originally drafted it, a new "form of words which, in the opinion of the joint trades, would have practically nullified the concession made." The question was left as a subject for further correspondence, it being distinctly understood that if this point was not satisfactorily settled no joint recommendation would be signed. The text of an important resolution on the subject of the premium bonus system passed unanimously by the Premium Bonus Joint Committee is given in the report. This is as follows: "That this meeting considers the recent vote taken and the expressions of conformity by those who have not taken a vote be taken as a guarantee of unanimity, and that the secretary be instructed to communicate with the various employers' associations concerned intimating our objection to the premium bonus system and requesting a conference to discuss the question of its abolition." The A.S.E. delegates agreed to this resolution, although during the discussion they made it clear that their society was not going to lead. They had done so before (in the 48 hours movement), they said, and had been "left in the lurch by their quondam allies." They were willing to move provided there was a definite and explicit pledge, backed by a vote of the members of each society, to co operate.

Trade Union Membership and Funds. The Board of Trade 17th report on trade unions in the United Kingdom was issued on Saturday last. The report last issued dealt with 1905 7, and the present report covers the three subsequent years, thus bringing the statistics of trade unions, federations of trade unions, and trade councils up to the end of 1910, the latest year for which returns are available. The present report states the first two years—1908 9—of the triennial period covered by this report were years of bad employment and falling wages, and these facts appear to have had a considerable effect on the membership of the trade unions, which declined by 57,000. This falling off in 1908-9 was, however, more than counterbalanced by an increase of 73,000 in 1910, a year of improving employment, the net increase in the three years being thus 16,000, which left the total membership at 2,430,000, or less than 1 per cent. above that of 1907, a rate of increase which compares with a rise of 7 per cent. in the previous three years. Seventy seven per cent. of the total membership of trade unions at the end of 1910 was included in 538 unions registered under the Trade Union Acts, while the remaining 23 per cent. was distributed among 615 unions not so registered. During the 19 years for which particulars are available (1892-1910) the total expenditure of the 100 principal unions was £35,300,000, of which £5,100,000 was spent on dispute benefit, £8,900,000 on unemployed benefits, and £14,100,000 on other benefits (sick, superannuation, &c.). The total funds of the 100 unions, which at the end of 1893 were only 28s. per member, gradually increased until at the end of 1906 they amounted to 80s. per member. At the end of 1910 they stood at 70s.

The Boilermakers' Society.—The General Secretary of the Boilermakers' Society (Mr. John Hill) in his March report states that trade in February was booming, and for output of shipbuilding put all previous records in the shade. Orders were still coming in to yards already filled with vessels, new shipyards were being opened, and additional capital was being invested in the industry. Mr. Hill, in referring to the abolition of the premium bonus system in the Royal Dockyards, says: "This action on the part of the Admiralty is most opportune, as we have just succeeded in obtaining unanimity among the leaders of the chief trades concerned, and a joint note has been sent to engineering and shipbuilding employers on the question. We have persistently opposed the premium bonus system from its inception. Premium bonus is the most pernicious system ever introduced for the unjust exploitation of workmen, and our members have already spoken and voted on the question with no uncertain meaning." Referring to the negotiations regarding a demarcation agreement, Mr. Hill says: "Of all questions we have to deal with that of demarcation of work between ourselves and other trade unions is the most disagreeable. For nearly three years we have been trying, along with some other 30 trades, to come to some arrangement with the two big federations of employers. We have been giving away point after point until everything of any value to us as a society has been given up. We met the employers again in February, and found them, like Oliver Twist, still wanting more. This broke the patience of the most long-suffering trades amongst us, and we unanimously decided to tell the employers we had reached the limit, and we separated without an agreement. Our members can rest assured that no agreement on this question will be accepted by their officials until the scheme has been submitted to them and their votes asked thereon."

Qualifications of Mine Surveyors. In a statement issued a few days ago the Home Secretary gives notice that he has made an order under the Coal Mines Act, 1911, prescribing the qualifications for a surveyor of mines, to which that Act applies. Under the order a surveyor must hold either (a) a certificate from the new Board for Mining Examinations to be appointed under the Act, or from an institution approved by the Secretary of State as to his experience, competence, and character; or (b) a first class certificate of competency as manager with an endorsement by a divisional inspector of mines or by the Board that the holder has had at least two years' practical experience in the surveying of mines. Any person, however, employed as a surveyor at the time of the passing of the Act (December 16th, 1911) will be entitled to obtain a certificate without examination from the Inspector of Mines of the district in which he was so employed on satisfying the inspector as to his experience competence, and character. Application for such certificates must be made to the inspectors before December 31st next. They should be accompanied (1) by a certificate from the manager of the mine in which the applicant was employed on December 16th, 1911, stating that he was employed as a surveyor at that mine at that date, and testifying as to his sobriety and general good conduct, (2) by a certificate from that manager (and if necessary from managers under whom the applicant was previously employed) showing that he has had at least two years' practical experience in the surveying of mines, and (3) by a statement signed by the applicant as to the nature of his training and experience in mine surveying. Holders of a first class certificate as manager who desire their certificates endorsed by the divisional inspector of mines must forward a certificate from a manager or managers as to their experience, and must also forward their manager's certificate. Institutions desirous of being approved by the Secretary of State for the purposes of granting certificates to surveyors should address an application to the Under Secretary of State Home Office, London, S.W.

Barrow Hematite Steel Company.—The report for the year states that the profit, before deducting debenture interest and depreciation, was £64,711, and £10,168 brought forward. The directors recommend payment of the cumulative dividend on the first preference shares for the year 1911, and the cumulative dividend on the second preference shares for 1909. For the greater portion of the year 1911, the iron and steel trades were in a very unsettled condition. Prices of pig iron were low, and certain branches of the steel trade were quite unremunerative. Fortunately, a certain amount of benefit was derived from the remodelled blastfurnace during the latter part of the year, the furnace having been completed in May. Up to the present time it has worked satisfactorily, and the directors have decided that another furnace of similar design should be built. This is now in course of erection, and it is hoped will be completed in June next. The directors have entered into a contract with the Simon Carves Company for the erection of 40 new by product ovens at the colliery, together with a tar distillery plant, and in addition, upon the advice of their colliery manager, have undertaken the remodelling of a part of the plant with a view to maintaining the output and minimising cost of production. Shipments of ore from the Beni Felkai Mines, in which the company is interested, were continued during the year, and 71,000 tons of the company's supply were received from this source. The results for the last three years have been as under:

	1911.	1910.	1909.
	£	£	£
Profit	64,711	54,594	46,310
Brought forward	10,168	9,060	8,384
Available	74,879	63,654	54,694
Debenture interest	15,789	15,724	15,703
Depreciation	20,500	20,500	11,637
Extensions	11,000	...	16,032
First preference dividend	2,262	2,262	2,262
Second preference dividend	15,000	15,000	
Carried forward	10,328	10,168	9,060

The second preference dividend is two years in arrear. The last dividend payment on the ordinary share capital was 2 per cent for 1907.

140,000-volt Transformers. Twelve 140,000 volt transformers are being built by the General Electric Company, of Schenectady, N.Y., for the Eastern Michigan Power Company. These are for 60-cycle operation and each has a capacity of 3,000 kv.-a. They will stand about 19ft. high on a floor space 11ft. by 5ft. Each transformer will contain about 4,000 gals. of oil, and oil-filled high-tension leads will be used, each lead itself containing about 30 gals. of oil. These terminal casings have cast iron bases which are fitted to the cover and extend down into the tank well under the oil. Each terminal is tipped with a brass ball and the whole lead is designed to reduce the possibility of corona discharge. The transformers are designed to withstand a test of [illegible] volts between the high-tension winding and all other parts. These are the highest voltage transformers yet developed for commercial service.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1910.

Process for compressing air or gas. Lieblich. 27848.
Engine valves. Shuman. 27883 and 27884.
Steam engines. Shuman. 27885.
Apparatus for purifying the feed water for locomotive boilers. Mouchin. 30206.

1911.

Propulsion and steering of aerial and marine vessels. Parsons. 1691.
Propellers and fans. Beadon. 4506.
Pumps, compressors, and turbines. Philbrow. 4793.
Valves and valve operating mechanisms for direct acting steam driven reciprocating pumps. Mackay. 4831.
Compressed air hammer drilling machine for rock or coal. Ovenden. 4955.
Internal combustion engines. Kirke. 5178.
Zinc distillation. Moulden, Webster, and Central Zinc Company 5196.
Railway signalling. Brice & Brice. 5206.
Locomotives. Ivatt. 5390.
Automatic car couplings for railway trains. Yamamoto. 5567.
Boiler furnaces. Thomson. 5860.
Power producing machine. Tamellier. 5987.
Bench vices. Aston. 6412.
Two speed gears. Bucknall. 6612.
Gas producers. Holzapfel. 6625.
Bogies for railway carriages. Stephenson. 7123.
Means for locking nuts on bolts. Hill. 7166.
Variable speed driving mechanism for vehicles. Scarborough. 7172.
Means for removing incrustation or scale from the interior of tubes. Crockatt. 7250.
Preventing the over winding of friction driven cranes. Ashworth and Wood. 7331.
Diamond drills. Bade. 7538.
Boiler furnaces. Thompson. 8561.
Pneumatic drilling machines. Smith, and Smith's Dock Company. 8916.
Lubrication of engines. Draper and Wartnaby. 9020.
Carburetters for internal combustion engines. Mackay. 9235.
Manufacture of woven belting. Mack. 10591.
Driving belts. Lycett. 10619.
Gas producers. Royston. 10911.
Metal punching, shearing, and wire cutting machines. Bostwick and Bennet. 11089.
Filter and feed water heater. Cumming. 11261.
Apparatus for the production of gas. Scott & Scott. 11311.
Centrifugal machines for separating tar and dust from gases. Hutchins. 11653.
Reversing valves for regenerative gas furnaces. Floyd & Rigby. 12687.
Apparatus for use in testing toothed gearing. Parkinson. 13465.
Controlling devices for use with winding machinery. Sandycroft Foundry Company, and Gott. 13531.
Coupling devices for railway wagons. Robinson. 13710.
Blow pipe and charging apparatus for ore treating furnaces. Banes. 13989.
Raising and lowering of pit cages. Barclay & Barclay. 14790.
Appliances for cleaning the tubes of water tube boilers. Witzenmann. 15184.
Carburetters for internal combustion engines. Weiss. 15419.
Cross head joints. Schmidt'sche Heissdampf Ges. 15483.
Reversible rotary motor or pump. Brun. 15579.
Self locking gearing. Clark. 15830.
Discharge valves. Barclay, Curle, & Co., and Bell. 15926.
Retorts for annealing furnaces. Kugel. 16918.
Propellers. Lake. 16961.
Starting cranks for hydro carbon engines. Bergeron & McGaffey 18884.
Fluid actuated reciprocating engine. Martens. 19259.
Roller bearings. Ericsson. 19515.
Safety appliances for mine cages and lifts. Sumner & Powell 19995.
Gas turbine. Brown. 20142.
Exhaust valves of internal combustion engines. Cloudsley. 20391.
Sectional boilers. Toruack. 20655.
Governing and controlling internal combustion engines. Crossley and Webb. 21013.
Ball grinding machines. Norma Compagnie Ges. 22324.
Guards for milling machines. Brayshaw & Brayshaw. 23552.
Air gas plant. Weiss. 25297.
Bearings for vertical shafts. Degn & Krafft. 25194.
Damper for the flues of steam boilers. Gordon. 25602.
Elastic fluid turbines. Curtis. 25664.
Lubricating devices. Turner. 26159.
Fluid pressure braking apparatus. Turner. 26762.
Stationary water tube boilers. Fried. Krupp Akt. Ges. Germaniawerft. 27221.
Starting device for the engines of power driven vehicles. Markmann. 27715.
Propeller chambers or tunnels for shallow draught vessels. Yarrow. 28726.
Junctions for flexible metallic pipes. Rudolph. 29215.

ELECTRICAL, 1910.

Systems of electrical transmission. Leitner. 27395.

1911.

Electric circuit controlling apparatus for train lighting. Electric and Ordnance Accessories Company, Loveley, and Price. 5005 and 5012.
Electrical transformers. Berry. 5190.
Automatic regulating devices for electric supply systems. Lake. 7530.
Controllers for electric motors. British Thomson Houston Company, and Wise. 8238.
Control of alternating current electric motors. Barbour. 8489.
Carbon electrode for electric furnaces. Bussey. 9652.
Electric current limiting apparatus. Compagnie pour la Fabrication des Compteurs et Materiel d'Usines a Gaz. 13315.
Electro static valves for protecting electric circuits and apparatus. Steels. 18997.
Interrupter for electric circuits. Robert Bosch. 25880.
Electric ignition devices for internal combustion engines. Bloxam. 28518.

METAL QUOTATIONS.

TUESDAY, MARCH 19TH.

Aluminium ingot	67/-	per cwt.
,, wire, according to sizes, &c. ......from	102/-	,,
,, sheets ,, ,, ... ,,	120/-	,,
Antimony £27 - to	£27/10	per ton
Brass, rolled	7⅞d. per lb.	
,, tubes (brazed)	10⅛d.	,,
,, ,, (solid drawn)	8¼d.	,,
,, ,, wire	7⅞d.	,,
Copper, Standard	£65/ /-	per ton.
Iron, Cleveland	51/6	,,
,, Scotch	57/6	,,
Lead, English	£16/10/-	,,
,, Foreign (soft)	£16/2/6	,,
Mica (in original cases), small	6d. to 2/-	per lb.
,, ,, ,, medium	2/6 to 4/-	,,
,, ,, ,, large	4/6 to 8/6	,,
Quicksilver	£8/12/6	per bottle.
Silver	26 $\frac{11}{16}$ d.	per oz.
Spelter	£26/2/6	per ton.
Tin, block	£191/-/-	,,
Tin plate	13/9	,,
Zinc sheet (Silesian)	£29/ -	,,
,, Stettin; Vieille Montagne)	£29/5/-	,,

International Smoke Abatement Exhibition.—The following is the programme of conferences and lectures to be held during the run of the Exhibition at the Royal Agricultural Hall: Section A.—March 26th, 1912, at 11 a.m. and 2.30 p.m. Chairman, Sir William B. Richmond, K.C.B., R.A. (President, Coal Smoke Abatement Society). "Smoke Pollution": (1) Its economical and artistic effects; (2) Effects on animal and plant life. Section B.—March 27th, 1912, at 11 a.m. and 2.30 p.m. Chairman, Sir William Ramsay, K.C.B., F.R.S. "Smoke Abatement": (1) Work done and to be done in organising preventive action; (2) The Physics of Smoke Abatement Apparatus and practical expedients for the abolition of smoke, both industrial and domestic. Section C.—March 28th, 1912, at 11 a.m. and 3 p.m. Chairman, Lord Justice Fletcher Moulton. "Law and Legislation": (1) The existing law and its administration, both at home and abroad. Comparative legislation; (2) Proposed new legislation.

The Mechanical Engineer

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Co-partnership in Industry.

THE Labour Co-partnership Association has published in pamphlet form a chronological summary of the various British profit-sharing schemes that have been tried since 1829, with some remarks delivered by Mr. Charles Carpenter, the Chairman of the South Metropolitan Gas Company, at a conference at Oxford in November last year, by way of preface. As befitted the occasion, and as might be expected from a chairman of a profit-sharing concern, he has a sanguine belief in this principle as a remedy for labour troubles, but his views are very partial, and a broader survey discloses many difficulties that are not visible in the case for industrial co-partnership as presented by its advocates. Co-partnership is a word the attractiveness of which to workmen depends largely on interpretation. In its ordinary legal and business sense it usually implies that the parties in an undertaking participate in risks and losses as well as profits, but such a view is not likely to arouse much enthusiasm in the breasts of workers whose interest in such arrangements is confined entirely to their profit-dividing aspects, while its enthusiastic advocates are generally associated with some concern possessing a monopoly working with an assured profit, free from the risks and losses which beset most industries to begin with and, unfortunately, follow many of them to the end. How co-partnership schemes are to be established when risks and losses, as well as profits, are to be taken into account, and they have to be in most manufacturing enterprises, is a question they pass over with delightful insouciance. Even the South Metropolitan Gas Company's scheme, we are told, was received by the workmen with "bitter opposition," and only "its undisputable advantage"—another word, we presume, for assured profit secured its final acceptance. "The principle upon which it is based," we are informed, is that "after capital has been fairly remunerated for the risks it takes by its investment in an undertaking it gives its employés a fair share of the

further profits." But if the concern is not more or less a monopoly, how can profits be assured? and if profits are uncertain what temptation, the worker may well ask, does such a proposal offer him? A reference to any share list, we regret to say, shows only too plainly that a very large number of engineering firms, at all events, would be unable to offer at the present time anything beyond the vaguest hopes of "a fair share of further profits," and future uncertainty, in many cases, is a cause of grave anxiety to both managers and shareholders, while a glance at the list of profit-sharing and co-partnership schemes in this pamphlet is not stimulating. It is prefaced with the observation that "most of the schemes have come to an end." Of those that survive, several of the engineering concerns which figure therein are, we know, in a moribund condition. The passing of businesses "into the hands of men who lack knowledge of, or sympathy with, the ideals of their predecessors" is put forward as some excuse for the "failures" and though it may be consoling to social enthusiasts to know they have contributed to "make a secure foundation for enduring success," they offer little solace to shareholders who have lost their money, and with it, we fear, in most instances their faith in "well-intentioned systems" that have "quietly ceased to be," however much they may serve as "aggregates in the mass of concrete to support the great co-partnership structure" and "enshrine our social and industrial hopes and ideals." There is too much maudlin sentiment just now respecting capital and labour. Too much talk about the "poor working man" and too little about the "thrifty, hard-working man," too much abuse of the "bloated capitalist," too little sympathy for the "small shareholder." The fact is overlooked that in these days of limited liability the number of individual capitalists who run manufacturing enterprises, as compared with companies, is small, and that a workman with capital, however little, is at liberty to invest it on the same terms as the large capitalist in almost any industry he chooses and so become a "co partner" participating in the "huge profits" he is so often falsely credited with reaping; the only condition attaching to the arrangement is that he must participate in risks and losses as well as profits, and this is the only fair and self-respecting basis. Systems of "profit-sharing" free from responsibility must inevitably be disappointing to both sides when profits vanish and the dismal duty of explanation is imposed on those who are led in generous moments to promise what unsuspected economic forces subsequently withhold. "Loss-sharing" is distasteful to all of us, and none realise it more keenly than employers in certain sections of the engineering trade, who for years have often to toil in "abnormal places," not for a legalised day, but during every waking hour, and not for a "minimum wage," but at a serious loss. It would be better if the glib labour agitator and the misguided artisan were more familiar with this aspect of the employment question. So far as co-partnership can aid, it is to be welcomed, but "profit-sharing" schemes are of doubtful value, exciting pleasure or disappointment according as the participation is great or small, and without the keen interest associated with capital acquired by thrift and strenuous endeavour.

Grooving in Lancashire Boiler End Plates.

IN some observations presented to the Manchester Association of Engineers, on Saturday last, Mr. Samuel Boswell referred to the causes and remedies for one of the most common defects in Lancashire boilers, namely, grooving in the furnace attachments or flat end-plates. The trouble has always been more or less in evidence to those familiar with the working of boilers of this type, but certain persistent manifestations, difficult to subdue, have been more frequently met with during recent years, probably as a result of the increase of pressures, coupled with larger boiler diameters and higher rates of combustion now generally adopted. Internal "grooving" or local wasting is not confined entirely to flat end-plates, it is occasionally met with in the cylindrical shell at the edge of overlaps of longitudinal and circular seams, and may be the product of simple leakage and corrosion, as it nearly always is when found on the external surface of the boiler, or of this combined with straining action when it is found on the internal surface. In the latter case, if it occurs at the longitudinal seams, it is usually due to want of circularity in the shell, or, if it occurs at the circular seams, to alternate hogging in the boiler as a whole. In flat end-plates the "grooving" may be due to local bending action caused by alternations of boiler pressure aggravated by corrosive action of the water, though severe "grooving" occurs without this being very pronounced, or it may be due, as it usually is in Lancashire boilers, to the alternate expansions and contractions of the long furnace tubes which tie the two end-plates together. Contrary to what might be thought by those who have not had practical experience, the grooving is not equally common to both ends, but is much more pronounced at the front than at the back. This arises from the fact that apart from the fluctuations in expansion and contraction of the furnace tubes as a whole, further movements occur at the front end from the severe local heating and coolings of the crowns of tubes over the fire. This gives rise to a concertina play which is more pronounced at the upper portions of the furnace tube attachments than elsewhere, and it is here that grooving troubles are most frequent, and most difficult to deal with. Sheer brute resistance by means of stiff end-plates and stays is incapable of arresting the mischief. The force of expansion from temperature is too strong to be restrained in this way. The movement must be provided for. On the other hand, the upper part of the flat end-plate, unsupported by the furnace tubes, which, of course, act as two huge stays, must be supported to withstand the working pressure, and this is usually effected by angle brackets or "gussets." The practical problem is to reconcile the staying of the end-plate necessary to resist the steam pressure with the movement necessary to accommodate the local expansion of the furnace tubes. The forces are complex, and cannot be worked out by a formula. Experience has led to the adoption of certain arrangements of gusset stays which allow a "breathing" or unstayed space between them and the furnace tubes, as the main factor in the solution generally accepted in practice. But higher pressures, coupled with high rates of combustion, have, in many cases, proved too much for the best designs on these lines alone, and as repairs arising out of grooving defects are troublesome and expensive other aids to relief have been sought. Various kinds of flanged furnace tube end attachments have been adopted, though with only partial success. Some makers insert a corrugated length in the furnace tube to increase its flexibility, while others again resort to flexible gusset stays, in which elasticity is secured by affording a certain amount of play in the holes for the rivets, uniting the webs of the end-plate angle bars to the gusset web-plate.* When grooving first makes its

* [illegible] designs of this kind was illustrated in "The Mechanical Engineer" on December 1[illegible]th last. See page [illegible], Vol. XXVIII.

appearance, its progress may sometimes be arrested by removing one or more of the lower rivets uniting the angle bars to the web-plates, or the end-plate itself may be relieved, as Mr. Boswell suggests, by taking out the lower gusset rivets and substituting a screwed stud tapped into the end-plate only, and passing through a clearance hole in the angle bar, but fitted with a nut inside the boiler which comes to a bearing, and takes up the load if the end-plate is deflected more than a predetermined amount. These various methods, however, can only be regarded as more or less imperfect palliatives for bad design, or unfair conditions of working, and the latter, it is to be feared, is in many cases the real source of grooving troubles for which boiler-makers not infrequently are unfairly blamed. Amongst unfair working conditions may be mentioned bad feed water, that is, water impregnated with an excess of lime or magnesia and, worse still, grease which leads to excessive overheating of the furnace crowns; the emptying of boilers under pressure and too rapid cooling; and, lastly, the forcing of boilers beyond their powers with a view to secure economy of steam production. In this respect Lancashire boilers will for a time permit of great liberty being taken, the amount produced depending mainly on the quantity of coal that the draught will allow of being burnt on the grate, but the fact that the rate of combustion and water evaporation can be greatly augmented for a short period without apparent distress should not blind steam users to the remoter consequences that inevitably ensue in the shape of grooving, leakage, and other troubles that end, finally, in serious bills for repairs.

Smoke Abatement Legislation.

THE text of a proposed Smoke Abatement Bill has this week been presented for discussion at the International Smoke Conference at the Agricultural Hall, but at the time of going to press this item on the agenda has not been reached and hence we are unable to say what opinions have been expressed with regard to it. We shall, however, probably not be far wrong in assuming that as an official expression of the aims of the Smoke Abatement League it will receive fairly uniform acceptance at the hands of the social enthusiasts who constitute that body. There is, of course, a long step between a proposal of this kind and its embodiment in an Act of Parliament. Nevertheless, it is useful as an indication of the views of those who are seeking to subject the community to such an instrument to attain their ends and worth consideration on that account. The principal features of the measure consist in the proposal to create special Local Smoke Abatement Authorities controlled by the Local Government Board, and supported by an army of officials with powers to inflict drastic fines on offences against the law, whether in the shape of "imperfectly-constructed furnaces" or by smoke emission from their chimneys. The penalty for contravening the law, if passed, would be, "on a first conviction a fine of not less than one pound, and not exceeding five pounds. On a second conviction a fine of five pounds and not exceeding ten pounds, and on every subsequent conviction a fine of not less than five pounds and not exceeding twice the amount of the maximum fine to which the offender was liable on the last conviction," except where an interval of two years has elapsed between successive convictions, when the offender is graciously let off with a fine not greater than on his previous conviction. These powers are obviously not lacking in stringency, and a recalcitrant offender might, if the local authority felt so disposed, have a very rough time, and every furnace user would be so liable unless he could secure the exemption which the Local Government Board would be empowered after enquiry to grant to particular metallurgical or pottery furnaces for a period of not more than two years at one time. It is also proposed to empower the same authority to order the creation of Local Smoke Abatement Authorities, whose duty it would be to enforce the law. For this purpose local smoke inspectors are to be appointed subject to the same Local Government Board control as any other officer of a local authority, whose salary is partly dependent on Parliament. These local officials in turn are to be supervised and stimulated by Government Smoke Inspectors appointed by the Local Government Board. Such, in brief, is an outline of the scheme proposed. Whatever doubt there may be as to its effects on the emission of smoke in manufacturing centres, there can be none as to its effect on rates and taxes. These must inevitably be increased by the creation of further ranks of inspecting officials to be added to the army already imposed on the back of industry and under which it is beginning to groan. Enthusiasts will, of course, urge that increased furnace efficiency and purity of town atmospheres will more than compensate for the expense incurred, but as we have more than once shown these claims are largely rhetorical, while it may be pointed out that the present powers of local authorities, if exercised, are adequate to prevent nuisance where it is proved to exist. These facts, doubtless, will be pointed out if the proposed Bill gets to the House of Commons, and, meantime, manufacturers and traders would do well to prepare themselves for active opposition on its entrance. Latter-day experience of legislation goes to show that laws are often enacted not so much by virtue of their merits as by the clamour of small bodies of mistaken, if sincere, enthusiasts, aided and abetted by parties who have axes to grind, or are on the look-out for a soft "Government job."

OPTICAL LOAD-EXTENSION INDICATOR.

IN the course of a paper read before the Royal Society, Prof. W. E. Dalby described a new instrument by means of which automatic records of load-extension diagrams could be obtained with precision, the records being free from errors due to inertia, pencil-friction, or strains caused by the yielding of the testing machine in which the specimen was being tested. The specimen to be tested was placed in series with a weigh-bar, so that the load was applied equally to both weigh-bar and specimen. The proportions of the specimen were so arranged that the load on the weigh-bar never exceeded or even approached the elastic limit of the material of which it was made, while the load on the specimen might increase to the breaking load. A small light mirror mounted on an axis was connected with the weigh-bar, so that it tilted proportionately to the extension of the weigh-bar, and thus moved proportionately to the load on the weigh-bar and measured the load acting on the specimen. A second mirror having its axis at right angles to the first was connected mechanically to the specimen, so that, as the specimen extended, the mirror received the angular motion in proportion to the extension between assigned gauge points. A beam of light from a source within the instrument was directed upon the first mirror and reflected from it to the second mirror, from which it was again reflected and focussed on a ground-glass screen, which could be replaced when desired by a photographic plate. There was no connection between the instrument and any part of the framework of the machine, the former being attached to the weigh-bar only. In use all that was necessary was to place the instrument in position and on the weigh-bar, and apply a load to the specimen by any suitable means, when the diagram was obtained automatically.

RESULTS OF TRIALS OF THE DIESEL-ENGINED SEA-GOING VESSEL "SELANDIA."*

BY I. KNUDSEN.

ON December 5th, 1910, the East Asiatic Company, of Copenhagen, placed an order with Messrs. Burmeister & Wain for two vessels of the following dimensions: Length between perpendiculars 370ft., breadth 53ft., and depth moulded to upper deck 30ft. The two vessels are fitted with Diesel engines, having a total horse-power of 2,500 i.h.p., divided between two propellers, and there are further two auxiliary motors, each of 250 i.h.p. The first of these vessels has been given the name "Selandia," and her trial trips have recently taken place. A short description of the motors and a statement of the results obtained may therefore be of some interest.

The main engines are 8-cylinder Diesel motors, working on the 4-stroke cycle system; the number of revolutions at normal speed is 140 per minute. The starting in either direction takes place by means of compressed air. The cam shaft, from which the valves are moved, being so arranged that it can be displaced lengthwise after all the rods, with the rollers connected to them, which lift the valves, have been removed from the shaft by means of a crank motion. It is thus placed in such a position as is suitable for either the ahead or astern motion.

The reversing from full speed ahead to full speed astern can be carried out in less than 20 seconds. When the reversing gear has been brought into the proper position by the reversing engine, the starting takes place by moving a handle, by means of which air at a pressure of 20 atmospheres is led to the cylinders through the starting valve, which commences to work automatically when the compressed air is admitted.

When the engine, by means of the air, has attained a sufficient speed of revolution, which it does almost immediately, the handle is moved further, the air is shut off, the starting valves close themselves, the engine is oil fed, and now works as an ordinary Diesel motor at the speed required, the speed depending upon the position given to the above-mentioned handle, which regulates the supply of oil fuel. The reversing is thus executed by means of two handles, corresponding to the two levers on an ordinary steam engine.

The speed of the engine at sea is controlled by an Aspinall's governor, acting so that, when a sudden rise occurs in the number of revolutions beyond the normal, it shuts off the supply of fuel oil, and only opens again when the revolutions have dropped down to a certain pre-arranged number. As the engine has eight cylinders, and the filling at the start is above 0·6 of the stroke, the engine can always be started at any crank position whatever.

On the shaft is a small flywheel, only 2 metres diam.; this is provided with toothed wheel gearing on the periphery, which is driven by a worm, so that the main engine can always be turned by means of an electric motor.

On each main engine there is also an air compressor, which compresses air from 20 atmospheres up to 60 atmospheres for injecting fuel oil into the cylinders. These compressors are so arranged that they can be adjusted for half or complete filling. Half filling is used when the pumps are working on each engine. In case one of them should be damaged the remaining pump is put on to the complete filling, and will give sufficient air for the injection of fuel oil for both the main engines. As a spare for the first compression to 20 atmospheres, it is arranged that the exhaust valve on one of the cylinders of the main engine can be removed and replaced by a delivery valve, so that the cylinder will be brought to work as a compressor, which compresses the air to 20 atmospheres. In that case the motor only works with seven cylinders, but trials have proved that the reversing and working are nevertheless perfectly satisfactory in every respect.

The auxiliary motors are, as already mentioned, of 250 i.h.p. each, working at about 230 revs.; they are each fitted with a dynamo and air compressor. The latter is calculated to supply air at a pressure of 20 atmospheres, which is used for reversing the main motors, and also for supplying the air compressors of the main engine with air for injection. When the ship is at sea it is intended that current should be taken from the dynamo (which is placed on the same shaft) for lighting and for working the different auxiliary engines, such as winches, pumps, refrigerating machinery, &c. There are two auxiliary motors, in order to have always one to spare. The auxiliary machinery also includes two sets of electrically-driven lubricating pumps, circulating pumps, hot and cold water sanitary pumps and bilge pump, two electric transformers, one refrigerating machine, one donkey boiler for heating the vessel, providing steam for fire extinguishing in the holds, and also for working a steam-driven compressor, which can compress the air to 60 atmospheres.

The electrically-driven lubricating pumps pump the oil (each from its own tank, which is placed in the bottom of the ship) through the main bearings, from there through the crank shaft, connecting rod brasses, through the hollow bored connecting rod to the crosshead brasses, from there through the piston rod to the top of the oil-cooled piston, back through the piston rod, and from there it is ejected over the guide. Cooling of the oil takes place on the guide faces as they are water-cooled. Further cooling can be carried out by pumping oil through an oil cooler formed as a surface condenser.

From the two compressors of the auxiliary motors, which are designed as 3-stage compressors, pipes are led from the intermediate cooler, with an air pressure of about eight atmospheres, to the siren, which is fitted on the mast. In the top of the engine-room casing two settling tanks are arranged, to which fuel oil can be pumped by an air driven pump in the engine room; each tank is of such dimensions that it contains sufficient oil for 12 hours' normal work. The object of these tanks is to have any water separated from the oil, so that comparatively pure oil will be led to the motors.

The deck machinery is electric throughout; all winches are electrically driven, and the same is the case with the windlasses and the steering engine, which is of a new type of construction (Hele-Shaw-Martineau hydraulic electric system), and seems to work well in every respect. As will appear from the description given, everything is electric, with the exception of the little donkey boiler, which is chiefly intended for the heating of the vessel. Oil fuel is used in this boiler.

The fuel oil is stored in the double bottom of the vessel, and the total provision of oil on board is sufficient for a continuous distance of about 30,000 English miles. After having made three short trial trips in the Sound, the "Selandia" last left Copenhagen on February 22nd, bound for Aalborg, where about 2,000 tons cement were loaded, and from there the voyage was continued to London.

This first trip across the North Sea aroused great interest, as it was the first real practical trial of the seaworthiness and manœuvring capacity of the motors. Throughout the voyage the machinery worked excellently, and the plant was tried both in a smooth sea at high speed, and also in a heavy fog at slow speed, and in strong winds with rather a heavy sea, but nothing seemed to influence the vessel adversely, and she stood the test perfectly under these various conditions.

Records were taken of the consumption of fuel oil, and it was found that 0·165 kg. (0·363lb.) of oil per indicated horse-power hour were consumed, it being understood that this includes not only the indicated horse power developed by the main engines for the actual propelling of the vessel, but also the consumption of all the fuel oil used by the auxiliary motors. From this it may be seen that the above named 0·165 kg. fuel oil × the 2,500 i.h.p. (which is the normal horse power of the vessel) gives the total consumption of fuel oil on board, excluding only that used for the heating of the cabins.

The arrival at the West India Docks, where the vessel stayed during her visit in London, took place on February 27th, and here there was ample opportunity to try the manœuvring capacity of the motors, the working of which, however, was satisfactory in every way.

* Paper read at the spring meetings of the fifty-third session of the Institution of Naval Architects, March 28th, 1912.

THE BALANCING OF LOCOMOTIVES.—VI.

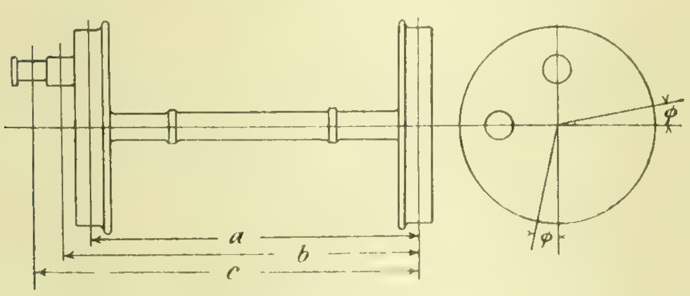
BY JAS. DUNLOP.

OUTSIDE CYLINDER COUPLED DRIVER ENGINES.

ALTHOUGH in British railway practice the great majority of the engines in use have inside cylinders, it is a fact that the great majority of the engines built in and for other countries have outside cylinders. There are quite a number of reasons that can be given for this difference in practice, but superiority of balance in outside cylinder engines is not one of them. The difference in the amount of balance weight necessary for single-driver engines, with inside and outside cylinders respectively, as illustrated in Figs. 6 and 9 of these articles, would no doubt be a sufficient indication of the fact that, under ordinary circumstances, an outside cylinder engine can never be as well balanced as an inside cylinder engine. This of course is due entirely to the fact that the reciprocating parts of outside cylinder engines are moving in planes situated at much greater distances from the longitudinal centre plane of the engine than is the case with inside cylinder engines. Consequently, as it is the necessity for leaving a certain proportion of the reciprocating parts unbalanced that gives rise to the disturbing forces, these forces will always be operating with greater effect in outside cylinder engines.

The following arithmetical calculations will be found to meet all cases of ordinary outside cylinder engine balancing.

Form of Balance Weight Calculation.



Let a = distance between centres of gravity of balance weights.

b = distance between coupling rod centre and far balance weights.

c = distance between connecting rod centre and far balance weights.

W_1 = weight of crank arm with included part of crank pin acting at distance a.

W_2 = weight of revolving masses, *i.e.*, part of coupling rod with included part of crank pin acting at distance b.

W_3 = weight of revolving masses, *i.e.*, half connecting rod with included part of crank pin acting at distance c.

W_4 = weight of reciprocating masses to be balanced in each wheel and acting at distance c in all cases.

W_P = primary balance weights.

W_S = secondary balance weights.

C = combined balance weights.

Driving Wheels.

$$W_{P1} = W_1$$
$$W_{P2} = W_2 \frac{b}{a}$$
$$W_{S2} = W_{P2} - W_2$$
$$W_{P3} = W_3 \frac{c}{a}$$
$$W_{S3} = W_{P3} - W_3$$
$$W_{P4} = W_4 \frac{c}{a}$$
$$W_S = W_{P4} - W_4$$
$$W_P = W_{P1} + W_{P2} + W_{P3} + W_{P4}$$
$$W_S = W_{S2} + W_{S3} + W_{S4}$$
$$C = \sqrt{(W_P)^2 + (W_S)^2}$$
$$\frac{W_S}{W_P} = \text{tan of angle of divergence } \phi$$

Leading or Trailing Wheels.

$$W_{P1} = W_1$$
$$W_{P2} = W_2 \frac{b}{a}$$
$$W_{S2} = W_{P2} - W_2$$
$$\left.\begin{array}{l} W_{P4} = \\ W_{S4} = \end{array}\right\} \text{as found for driving wheels.}$$
$$W_P = W_{P1} + W_{P2} + W_{P4}$$
$$W_S = W_{S2} + W_{S4}$$
$$C = \sqrt{(W_P)^2 + (W_S)^2}$$
$$\frac{W_S}{W_P} = \text{tan of angle of divergence } \phi$$

NOTE.—All weights are taken at crank-pin radius, *i.e.*, inch-pounds, and are to be reduced in ratio according to balancing moment of crescent found.

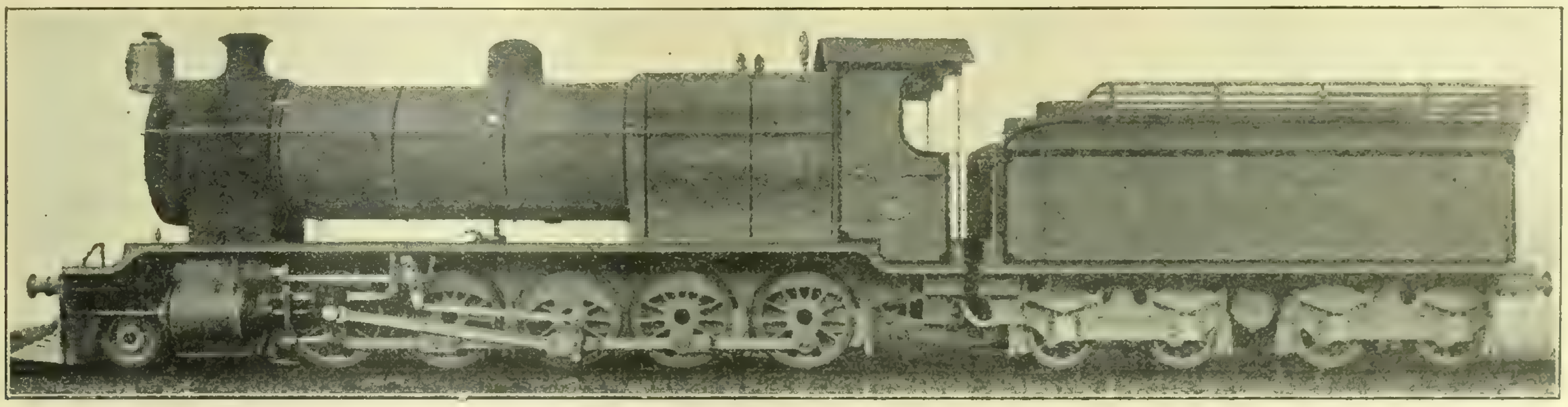


FIG. 51. OUTSIDE CYLINDER 10-COUPLED DRIVER LOCOMOTIVE, COUPLED TWO FORWARD AND TWO BACKWARD.

In the same manner as already shown for inside cylinder engines, these calculations may be performed at a glance by means of the proportional scale, and in the same way the combined balance weights may be ascertained by constructing a triangle in which the two sides at right angles consist of primaries and secondaries respectively. The length of the hypotenuse represents the amount of the combined weight and its angular position gives the angle for the balance weight in the wheels. It will be noticed from the calculations that all the weights are additive, there being no subtraction of primaries such as takes place in the balancing of inside cylinder engines. There are certain difficulties imported into the problem of balancing outside cylinder engines in consequence of this addition of primaries. These difficulties are chiefly concerned with the driving wheels of small-wheeled engines. To avoid hammer-blow set up by a deficiency in balance of the revolving parts it is necessary that all revolving parts should be balanced by weights placed in the wheels to which the revolving parts are attached. In addition, each coupled wheel should have a balance weight for its equal proportion of the weight balancing the reciprocating parts. In small-wheeled engines the coupling cranks in the driving wheels, the parts of the coupling rods attached to these cranks, and half the weight of each connecting rod constitute such an amount of weight that it is sometimes a rather difficult matter to arrange a suitable counterbalance weight for these parts, even without taking into account any balance weight for reciprocating parts. When it is found that the balance weight for revolving parts alone cannot be accommodated conveniently in the usual fashion of a crescent cast with the wheel, it will in almost every case be found that by making the crescent hollow and filling it with lead, the desired amount of balance will be attained. This will be understood from the fact that lead weighs 708lbs. per cubic foot, while steel weighs 486lbs. per cubic foot.

The 10-coupled driver engine illustrated in Fig. 51 is an example of a small-wheeled engine in which this difficulty of getting a sufficient amount of balance weight into the driving wheels was experienced. The relative sizes of the balance weights in the various wheels indicate that some care has been taken to ensure satisfactory results from the balancing carried out on this engine. The sectional half-plan drawing of the engine illustrated in Fig. 52 will convey a clear enough

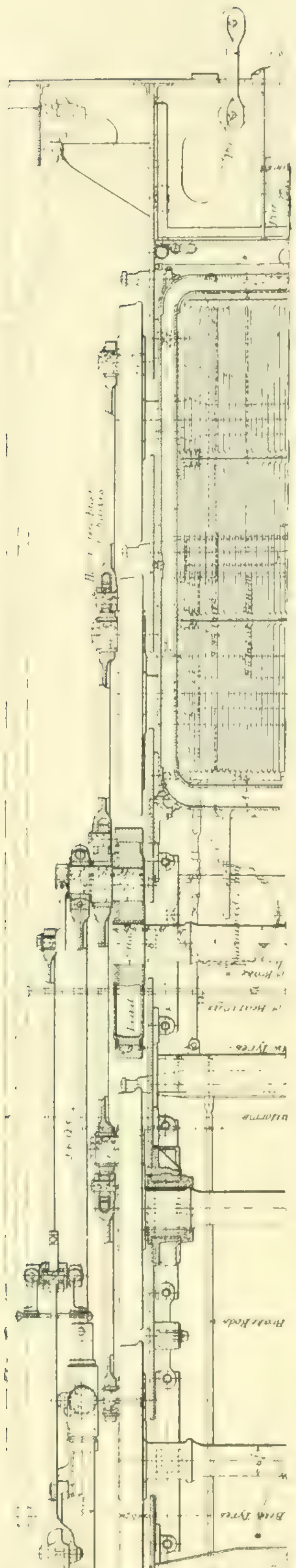


Fig. 52.—Half-plan Section of 10-coupled Driver Locomotive showing Lead-filled Balance Weight in Driving Wheel.

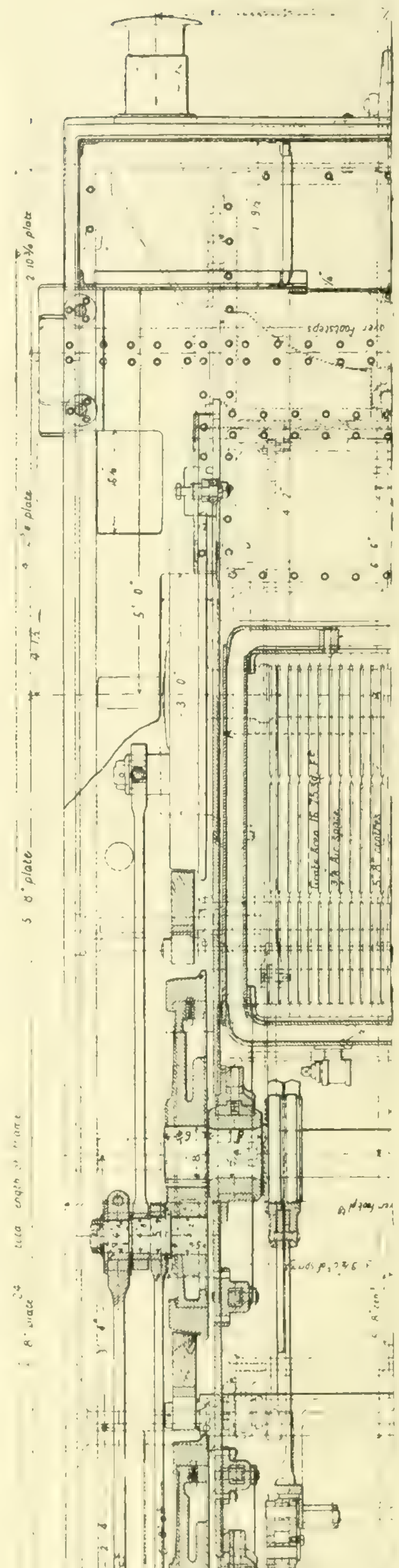


Fig. 55.—Half-plan Section of 6-coupled Driver Locomotive showing Coupled Rods Threaded in Parallel Lines.

impression of the various amounts of revolving parts it is necessary to balance in each wheel, along with their equal proportion of the balance weight for the reciprocating parts. It may be noticed that, by making the driving wheel crank pin in an eccentric form, the coupling rods are made to act at 1in. less radius than the connecting rods are acting at. This construction has two advantages, it reduces the amount of balance weight necessary for the coupling rods and coupling cranks, and even more important still, it reduces the centrifugal load on the coupling rods, consequently enabling these rods to be reduced in weight also.

From the fact that a lead-filled balance weight is used on the driving wheels it may be reasonably enough concluded that the whole of the revolving parts, as well as the due proportion of reciprocating parts, have been balanced in these wheels, but were such not the case, the omission of the due proportion of the balance weight for the reciprocating parts would not in any sense be a serious matter in any engine with the number of coupled wheels this engine has. When distributed in four only of the coupled wheels the balance weight for the reciprocating parts would in that case set up hammer-blow effects of much less intensity than are experienced with engines having a lesser number of coupled wheels. It is scarcely necessary to point out that the weight of the reciprocating parts is practically independent of the number of coupled wheels, nor should it be necessary to point out that in the case of any wheel without a complete balance of the revolving parts attached to it,. any arbitrary decision that part of such balance weight is to represent revolving parts and part of it reciprocating parts would be upset by the fact that the balance weight allocated to reciprocating parts would automatically accept the duty of balancing revolving parts. The straight threading of the coupling rods makes the number of primary and secondary weights agree with the number of motion planes indicated in the calculations.

In the case of the 8-coupled driver engine illustrated in Fig. 53 the difficulty of the driving wheel balance no doubt existed, and unfortunately it has not been met in a proper manner. Until very recent times in locomotive manufacturing establishments, through a pernicious influence exerted from the workshop end, it was regarded as an extremely meritorious proceeding to arrange that the coupled wheels of an engine should be duplicate throughout. The result was that outside cylinder engines, no matter what the number of coupled wheels, had equal balance weights in all the wheels. The total amount of balance weight provided was no doubt approximately correct, and in the horizontal direction the engine would be balanced, no matter in what proportions the total balance weight necessary was distributed in the wheels, but an increased load would be put on the coupling rods in consequence. In this engine, with the cranks at the top centre, the deficiency of balance in the driving wheels would give rise to a lifting tendency on the part of these wheels, while at the same time the excess balance weight in the other wheels would produce hammer-blow effects on the rails much greater in intensity than should have been the case. This latter would be especially so in the case of the leading and trailing coupled wheels. When the cranks are at the bottom centre the effects are reversed but not altered in intensity.

The 6-coupled driver engine illustrated in Fig. 54 is a similar case to that of Fig. 53, but is even more deceptive in its balance, as the sector balance weights shown are not solid as might be expected, but are open at the backs of the wheels, as may be seen from the sectional half-plan of the engine illustrated in Fig. 55. It may be noticed the coupling rods are not threaded in a straight line, but in parallel lines, consequently in balancing such an engine the various primary and secondary weights are determined as shown in the cross-section drawing of the engine illustrated in Fig. 56. The object in threading the coupling rods as shown is no doubt that of keeping the distance between the centres of the cylinders as small as possible, but considering the slight attention that has been given to the balancing of the engine in other respects, the mitigation of reciprocating effects thereby attained scarcely warrants this departure from usual practice, accompanied as it is by a restriction in the length of coupling pin bearing surface in the leading and trailing wheels.

As an illustration of the efforts that have been made in some engines to minimise reciprocating effects, Fig. 57 illustrates an engine built in the early days of the Stockton and Darlington Railway. This engine is a 6-coupled driver, coupled forward and backward as in Fig. 54, but in this case the connecting rods are threaded inside the coupling rods, with the result that to accommodate the movements of the leading coupling pins the connecting rods are formed with ring openings through which these pins pass to the outside of the connecting rods. Further than this limitation of the distance between the centres of the cylinders no other provision was made for the balance of the parts. The wheels were of cast iron in two parts, the inner part having the crank formed with it being keyed on the axle in the usual fashion, while the outer or rim part was fixed to the inner part by round "stake" keys such as were used by millwrights in the early days of machine fitting.

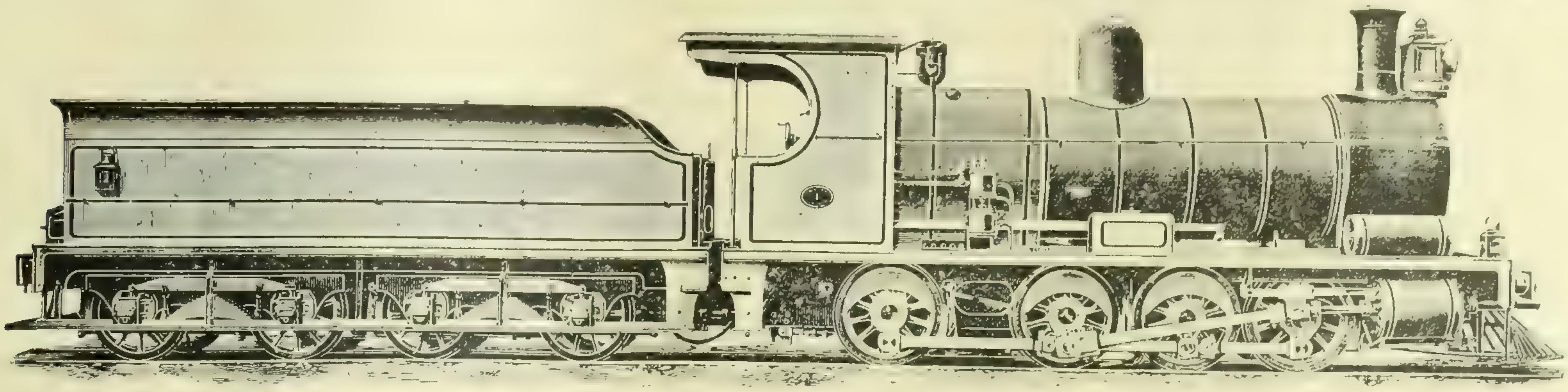


FIG. 53.—OUTSIDE CYLINDER 8-COUPLED DRIVER LOCOMOTIVE WITH INCORRECT BALANCE WEIGHTS.

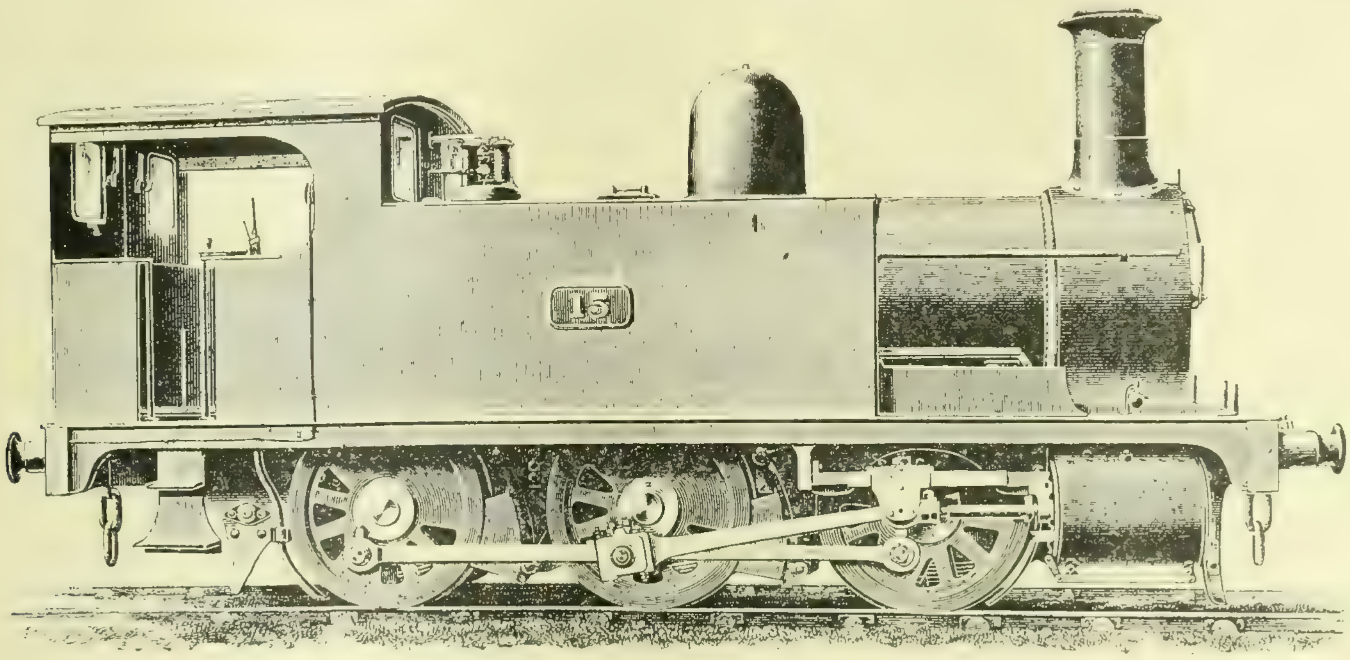


FIG. 54.—OUTSIDE CYLINDER 6-COUPLED DRIVER LOCOMOTIVE COUPLED FORWARD AND BACKWARD, BALANCE WEIGHTS DECEPTIVE.

HINTS ON MARINE ENGINE DETAILS.

AT the Institute of Marine Engineers, on Monday, March 18th, the discussion was resumed on Mr. W. Veysey Lang's paper, "Notes upon a Marine Engine," an abstract of which appeared in our last week's issue (see p. 352 ante). In the unavoidable absence of Mr. Lang, the hon. secretary read his reply to the previous discussion. The author said that the majority of high-pressure main engine valves were, doubtless, of the piston type, yet, on the other hand, the intermediate and low-pressure valves were, in most cases, of the D type. He considered it was a question of suitable metal whether a flat valve ran well or not. Although it was true to say that steam which passed the high-pressure valve was used up in the three cylinders, the important thing was that the high-pressure valve should govern consumption both of coal and steam, and unless this cylinder was doing its work economically there was no chance whatever of the other two correcting or balancing initial waste. In regard to the drift of chain blocks, the length of chain allowed in "stocked" blocks was 10ft. drift. For the tail shaft he was under the impression nickel steel was only used on high-grade engines and in the Royal Navy, ingot steel was generally used in modern shafting. In regard to piston rods, valve rods, &c., it would be very convenient, and establish a closer standard in scantlings, if classification rules gave a formula for this as for shafting. There would then be no such divergence in size as now existed on similar-sized engines by various builders, *e.g.*, one giving a $6\frac{1}{2}$in. rod and another a $7\frac{1}{4}$in. rod for the same size of cylinder. Mr. Wm. Walker said he heartily agreed with Mr. Lang's remarks as to the quality of metal. With slide valves in the high-pressure cylinders there were difficulties, not only of wear and tear, but also of noise, although lubricants reduced the latter to some extent. Mr. Timpson cited a case where the intermediate slide valve was lubricated with a mixture of graphite and plaster of paris. He did not think the intermediate slide valve was used to any great extent. He agreed that the sizes of piston rods should be standardised. Mr. A. H. Ledger said with regard to slide valves on the intermediate cylinder the chief feature was that the intermediate was a double-ported valve, otherwise the pressure was just the same as in the old high-pressure compound engine. He mentioned an instance where the high-pressure valve required steady lubrication with oil, and on this being dispensed with on one voyage, the friction wore down four phosphor-bronze pieces $1\frac{1}{4}$in. thick. There were no grooves on the valves. He did not advocate the use of oil generally, but in some cases it was absolutely necessary. Mr. G. W. Newall considered that the difference in size of the connecting rods was due to the use of iron in earlier practice instead of mild steel. He thought the number of different sizes of packings might be reduced for the various jobs. He described in detail the origin of some of the terms used in engineering. Mr. D. R. Dilworth Harrison said he had found the piston valve, when kept in good order, to be as efficient as the slide valve. The cylinder clearance in most engines, he considered, was much more than was necessary. The question of drainage was important, as where there was

a chance of water settling it militated against economy. He did not agree with the proposal to paint over the cast iron part of the condensers to avert condenser troubles. A method adopted to preserve condenser tubes was to place blocks of aluminium in the water ends of tube plates, the aluminium

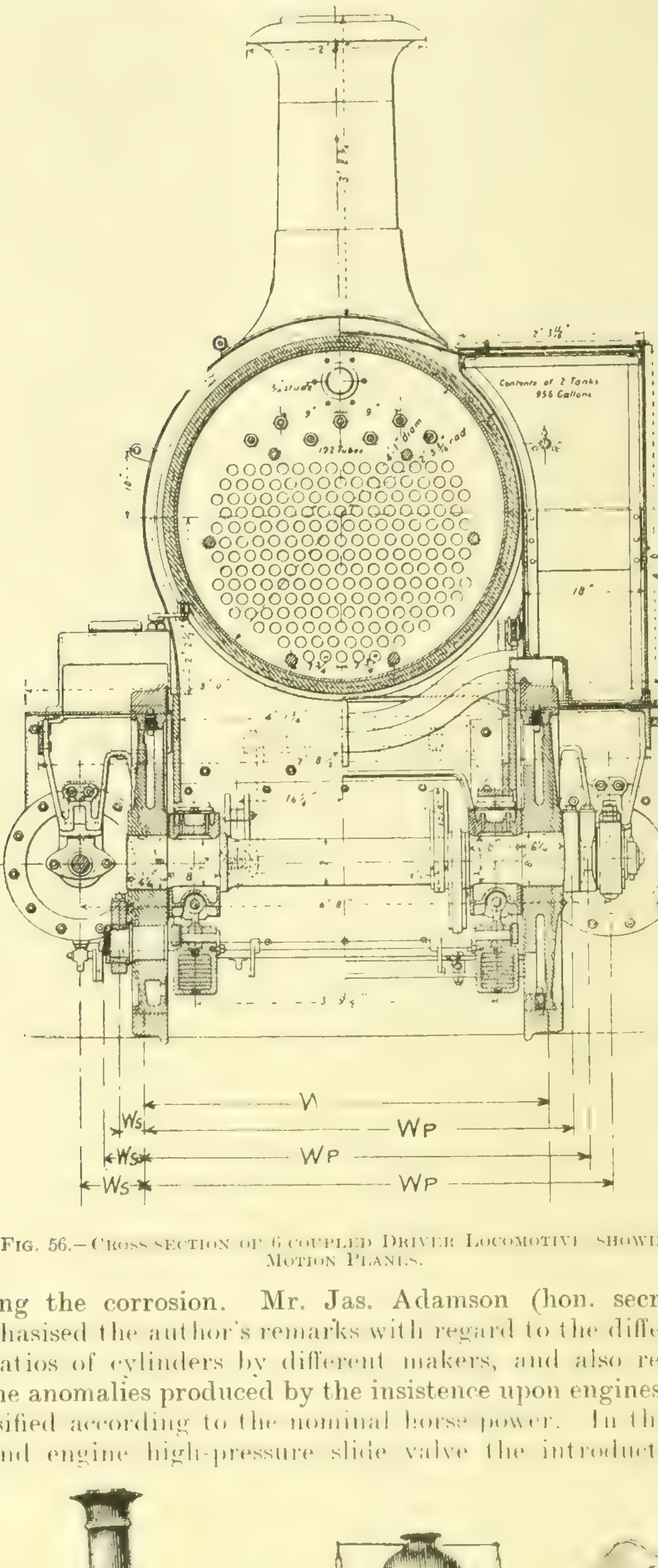


Fig. 56.—Cross-section of 6-coupled Driver Locomotive showing Motion Planes.

taking the corrosion. Mr. Jas. Adamson (hon. secretary) emphasised the author's remarks with regard to the differences in ratios of cylinders by different makers, and also referred to the anomalies produced by the insistence upon engines being classified according to the nominal horse power. In the compound engine high-pressure slide valve the introduction of

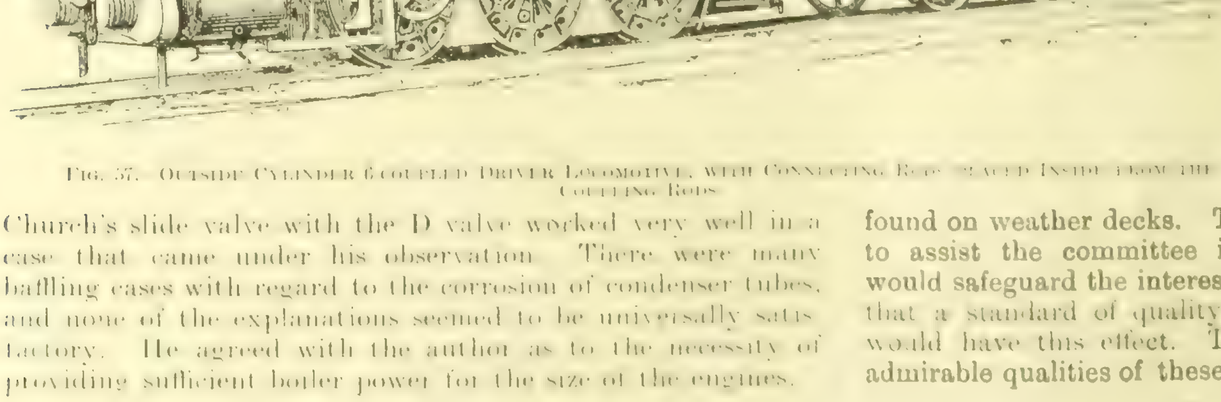


Fig. 57.—Outside Cylinder 6-coupled Driver Locomotive, with Connecting Rods placed Inside from the Coupling Rods.

Church's slide valve with the D valve worked very well in a case that came under his observation. There were many baffling cases with regard to the corrosion of condenser tubes, and none of the explanations seemed to be universally satisfactory. He agreed with the author as to the necessity of providing sufficient boiler power for the size of the engines.

APPLICATION OF GAS ENGINES TO INDUSTRIAL PURPOSES.

This subject was dealt with in the course of a lecture delivered by Mr. Alan Chorlton, of Messrs. Mather & Platt, Ltd., before the members of the Sheffield Society of Engineers and Metallurgists. The lecturer pointed out that in the last few years gas engines had been made in increasing sizes up to 6,000 h.p., and their reliability brought up to the standard of the one-time omnipotent steam engine. The invention of the producer, its progress and improvement, had extended the field of the gas engine through the increased economies that were made possible. The steady and continuous improvement in the manufacture of what was commonly known as town's gas had enabled it to be supplied at such a rate as to react against the producer, so that the economies to be obtained alone by that means were now equally realisable, when too great powers were not dealt with, by town's gas, when sold at the extremely cheap rates of the company which supplied Sheffield, with the additional advantage of the saving of extra capital cost, space taken, &c., entailed by the producer plant itself. Though town's gas and producer gas each had their economical sphere, the prospect of using waste gases from coke-oven and blast furnaces was still more alluring from the economical point of view, and there was little doubt that for large engines of the order of 500 h.p. and over, the greatest field at the present time was in the use of these waste gases. Though the advantages to be gained were so great, the progress to date in this country was nothing like what one would expect, and certainly compared very unfavourably with that made on the Continent. Mr. Chorlton gave a table of comparison between town's gas and electricity for small powers, showing the approximate cost of the former, at 11d. per 1,000 cub. ft., to be ·35d. per brake-horse-power hour, and of the latter, at ·9d. per Board of Trade unit, ·84d. per brake-horse-power hour. For the higher powers up to 1,000 b.h.p., the bituminous suction producer was now available, and another table showed the results which could be obtained with such a plant, a vertical enclosed gas engine and dynamo working on a continuous load as for electric furnaces. The plant was a producer gas generating station for 525 b.h.p., say, 350 kw. The capital cost was £4,740, and the running cost £1,535 per annum. As an interesting comparison, the results obtained by a Sheffield firm using town's electric current at ·6d. per unit were given. In this case the capital cost of a 350 kw. motor generator set was £1,530, and the running cost £7,389 per annum. Allowing for interest and depreciation at 6¼ per cent., the gas plant showed a saving of £5,653 per annum; or, if the charges named were 10 per cent., the saving was £5,533.

The Protection of Steel Decks on Ships.—Mr. F. J. Stephen, chairman of the Technical Committee of the British Corporation for the Survey and Registry of Shipping, at the recent annual meeting held at Glasgow, said that the suitability of the various compositions which were now so commonly used instead of wood sheathing on steel decks had formed the subject of prolonged investigation by the Corporation. There was a strong chemical resemblance between all the compositions, and it had been found that, under existing conditions of mixing and laying, there was grave risk of serious corrosion of the steel plating, particularly where the covering was exposed to the action of salt water or moisture, such as was found on weather decks. The manufacturers had been invited to assist the committee in laying down regulations which would safeguard the interests of shipowners, and it was hoped that a standard of quality and work might be found which would have this effect. There was no doubt of the many admirable qualities of these coverings.

FLASHING-OVER IN COMMUTATOR MACHINES.

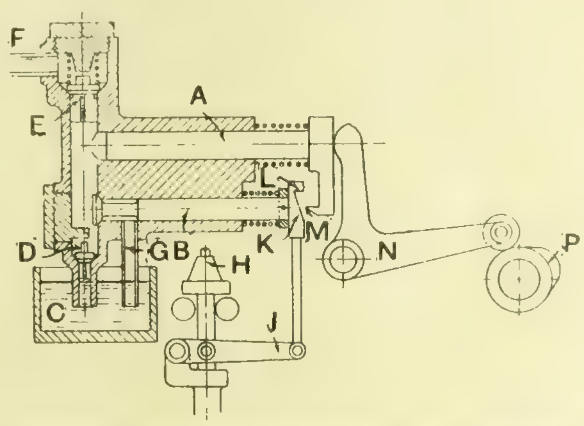
A MEETING of the Newcastle section of the Institution of Electrical Engineers was held on the 15th inst., when a paper by Mr. W. W. Frith, M.Sc., on "Flashing over in Commutator Machines," was read. The term flashing-over, the author said, meant the formation of an arc with explosive violence between the brushes of a commutator machine subjected to abnormal conditions of load. In every case the flash-over appeared to be associated with high current density in the brushes and excessive sparking. The arc formed a low-resistance path between the brushes, and the machine was virtually short-circuited as long as the arc existed. The arc was carried away from the commutator surface chiefly by the magnetic action of the leakage flux, and was finally broken at the outer portions of the brush-gear. In motor or converter cases, however, the circuit-breaker might operate, and the arc was then extinguished by the withdrawal of the power. Of all machines, the converter was, he observed, most subject to flashing-over, the usual cause being a short-circuit on the direct-current side. It also occurred frequently in motors subjected to excessive overloads or to accidental breaking of the field circuit; it seldom occurred in generators, probably for the reason that armature reaction on short-circuit greatly reduced the voltage across the segments. In multipolar machines the flash sometimes extended around the circumference of the commutator, but as a rule was confined to certain pairs of brushes. Flashing-over was a source of considerable anxiety to engineers because of the danger to attendants and the damage which usually resulted to the machine itself. A brush-gear was generally badly damaged, and often the machine was put out of commission for repair. A remarkable feature of the phenomenon was that the commutator was seldom, if ever, in the slightest degree injured, in spite of the fact that the flash started at its surface. A valuable clue to the cause of flashing-over was, in his opinion, afforded by a fact previously mentioned, that it was always associated with heavy initial sparking at the brushes. This might occur at any load, and depended upon the setting of the brushes; a machine set to run sparklessly at full load would probably not flash-over at full load, but would do so on light load if a short-circuit developed in either case.

There were, he stated, only two possible reasons for an arc forming between the brushes; either an abnormal rise of voltage or a decrease of resistance. The former was very unlikely to happen, and there was left only the second alternative, namely, the establishment of a conducting path between the brushes. The path might consist (*a*) of carbon particles liberated from the brushes by excessive sparking or (*b*) of a series of local arcs across the segments. It was, he thought, likely that both agencies were concerned—imperfect commutation as a primary cause and carbon dust as a secondary one; probably the function of the dust was to reduce the resistance of the arcs over the mica insulation. That carbon dust had some influence in producing flash-over was supported by observations on a 7½ h.p. 430-volt Westinghouse motor loaded with a direct-coupled 100-volt 50 ampere generator. Flash-over could be produced when desired by short-circuiting the fully-loaded generator through a 40-ampere fuse. The flash was always present at the upper surface of the commutator where the carbon dust was held on by gravity, but none was observed on the lower surface where the carbon dust could fall clear. Further evidence was that when the commutator and brushes had been well cleaned, flashing-over could not be produced until the machine had run for some time afterwards.

The real solution of the problem of flashing over was, he stated, in the design of machines with good commutation, and with an ample allowance of insulation between the segments, in machines which were subject to the trouble. A most effective preventive of flashing-over had been found by the author in the use of asbestos-faced wipers placed between the brushes and extending the full length of the commutator. With these wipers in position it was found to be impossible to produce a flash-over under the most extreme conditions of load and sparking. On short circuiting the loaded generator, a shower of flashes, starting from the brush tip, travelled over the surface of the commutator to the wipers, where they were instantly quenched. A further advantage in the use of the wipers was that the surface of the commutator was kept quite clean and normal sparking reduced to a minimum. The only drawback to their use was that they retained the carbon dust, and after a time became dirty. This resulted in some slight sparking under the wipers, particularly if set in the central position where the segments were carrying their maximum voltage. This pointed to the advantage of using thin wipers set close to the trailing tips of the brushes, and arranging them so that they might be easily cleaned or renewed. The arrangement now used was to make the brush box double, the second compartment carrying the wiper. On the heaviest short-circuit, sparking was confined to the narrow space between the brush and the wiper.

GOVERNING AND CONTROLLING OIL ENGINES.

THE accompanying illustration shows an arrangement for governing the speed of and regulating the amount of oil fuel delivered to the cylinder or vaporiser or atomiser or fuel valve of an internal-combustion engine, the joint invention of Mr. K. Crossley and Mr. W. Webb, of Crossley Brothers, Ltd., Openshaw, Manchester. The arrangement comprises a pump, the plunger A of which is operated by the lever N and cam P. On the suction stroke of the pump oil is drawn into the pump body from the oil tank C through the suction valve D. On the delivery stroke of the pump this oil is forced past the delivery valve E and pipe F to the engine cylinder, vaporiser, atomiser, fuel valve, or other part as may be required. If the speed of the engine rises above the normal the governor H will lift the lever J together with the governor wedge K, with the result that at some period during the early part of the delivery stroke the pusher M, which is part of the pump plunger A, will open the relief valve B, and during the remainder of the delivery stroke the oil will be returned to the oil tank C through the return pipe G instead of being delivered through the delivery valve E against the resistance of the spring shown above it. If on the other hand the speed of the engine falls below the normal, the governor lever J will be



DEVICE FOR GOVERNING AND CONTROLLING OIL ENGINES.

lowered together with the governor wedge K, and on the next delivery stroke of the pump plunger A, the pusher M will engage with a thinner portion of the governor wedge K, but will not engage with it so soon, and, consequently, a greater amount of oil will be forced through the delivery valve E before the relief valve B is opened, and a greater amount of oil will, therefore, be delivered to the engine cylinder, vaporiser, atomiser, or fuel valve, resulting in a corresponding increase in the power of the impulse of the engine. The projection shown at L may be used to prevent any oil being delivered to the engine in case the speed of the engine should become unduly reduced, in which case the governor would lower the wedge K to such an extent that the pusher M would, as soon as it began to move forward, come in contact with the projection L, and consequently all the oil would be returned to the tank owing to the relief valve opening, and no oil would be delivered to the engine, in consequence of which the engine would stop working. If operated by hand this projection L may be used as the regular method or emergency method of stopping the engine, or, if preferred, the relief valve may be opened by hand.

GAS POWER FOR SHIP PROPULSION.*

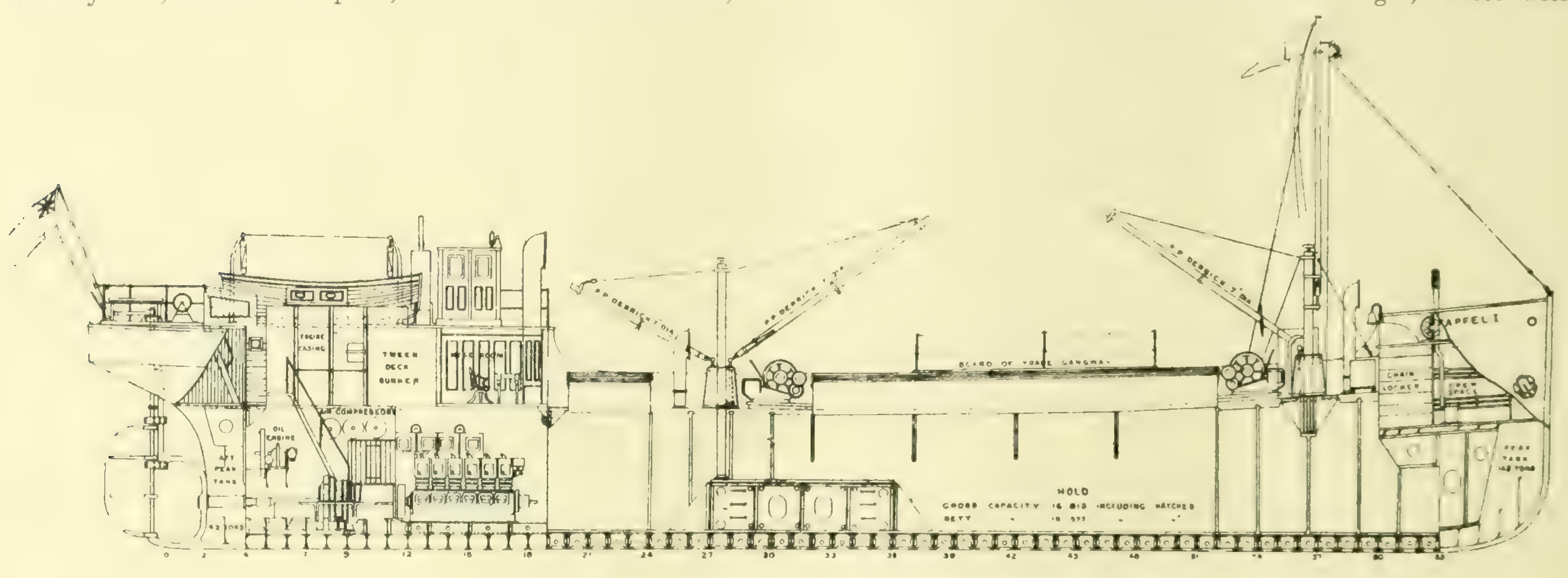
BY A. C. HOLZAPFEL.

DURING the last 10 years, particularly after the introduction of independent gas plant for cheap power gas, the feasibility of applying gas power for ship propulsion has been in the minds of engineers and others. The difficulties, however, of carrying this into effect have been considerable, and relate partly to the vastly different conditions on board ship, and partly to the practical impossibility up to now of obtaining a reversible gas engine.

Some seven years ago the late Mr. Emil Capitaine, of Frankfort, built a boat, suitable for fresh-water service only, fitted with gas engines, and he read a paper on the adaptability of this method of ship propulsion before the German Institution of Naval Architects. Mr. Capitaine had obtained various patents in connection with gas producers and gas engines. This first vessel was a tug of small power, and the engine was not reversible; she therefore depended for reversing and manœuvring on a clutch gear. Mr. Capitaine's British patent rights were acquired conjointly by Messrs. Thornycroft, of Southampton, and Messrs. Beardmore, of Dalmuir; both these firms carried on experiments with Capitaine engines, and in particular Messrs. Beardmore built a gas engine for sea-going purposes of 600 h.p., which was placed on board H.M.S. "Rattler." The engine was first tried on land, and the gas plant at that time was intended to use bituminous coal; it was subsequently changed so as to use anthracite coal and coke, the "Rattler" also depending for reversing and manœuvring on a clutch gear. So far as I have been able to ascertain, the gas engines and gas plant worked satisfactorily, but the clutch gear was unsatisfactory, and led to the abandonment of the experiment. Messrs. Thornycroft's experiments led to a similar result.

Mr. Capitaine founded in Germany a small company and established works for building gas engines and gas plant near Düsseldorf, where about a dozen engines of from 30 h.p. to 100 h.p. were built, and placed on vessels on the Rhine and other rivers. All these engines had several cylinders and were vertical, they were non-reversible and were fitted either with clutch gears or reversing propellers. One of the engines built by Mr. Capitaine's company was used for sea-going purposes; it was ordered by Mr. Walter F. Becker, of Turin, Italy, for a tug to run in the harbour of Genoa, Italy; it had three cylinders and was of 90 h.p. After some apparently satisfactory trials, so many difficulties were encountered in connection with the working of this vessel that the experiment was abandoned and the vessel sold. A like fate happened to most of the other vessels which were supplied by the Capitaine Company, of Düsseldorf, although it is possible that some may still be running. At any rate, the departure was not a sufficient success to warrant a development towards larger powers. Engines of the type supplied by Mr. Capitaine would have been practically useless for large sea-going vessels, unless they had been fitted with some electric or other transmission arrangement, enabling reversing to take place, and lower speeds to be used, as clutch gears and reversing propellers with more than 300 b.h.p. are believed to be impracticable. Mr. Capitaine died about four years ago in Brussels at a comparatively early age, a disappointed man.

Several canal boats with gas engines of small power have been run on German and Dutch canals; these are also fitted with clutch gears or reversing propellers. Two or three small cargo boats of 60 to 70 tons have recently been built in America similarly fitted, but their work is chiefly in estuaries and rivers, so they cannot be called sea-going vessels. I have still to mention the "Carnegie," fitted with



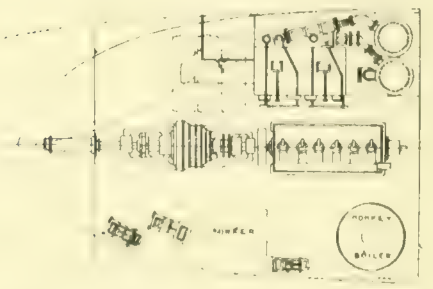


FIG. 1.—HOLZAPFEL I. GAS-DRIVEN SINGLE SCREW SHIP.
Dimensions, 120ft. × 22ft. × 11ft. 6in.

auxiliary gas engines of 150 h.p. She is the only sea-going gas-driven vessel which was built before 1911. The "Carnegie" is also fitted with a clutch gear; particulars of her performance are not in my possession.

About October last a sea-going vessel of 560 tons deadweight capacity, called the "Zeemeuw," started in Holland. This vessel has twin-screw engines of 150 h.p. each, and an anthracite coal gas plant. The engines are reversible by compressed air. I understand she has made nine trips, chiefly between Rotterdam and Great Yarmouth, and the owners inform me that they are satisfied with the economic results. They have come across some technical difficulties in connection with the producers and lubrication of the gas engine, particularly in regard to the formation of slag on the firebrick lining of the producers, and they are now fitting new producers in which they hope to obviate its formation. It will be seen in the latter part of this paper that I have also experienced the same difficulties. The owners, Messrs. Vermeer & Van Den Arend, of Rotterdam, inform me that in other respects they have every confidence in the success of the new departure.

Being unable to obtain reversible engines, the prospect of introducing this motive power for large sea-going vessels some two years ago seemed to me comparatively remote, and the only means of reversing and manœuvring high powers and speeds at that time appeared to be by electric transmission. This system, while practicable, has, however, certain disadvantages, which are the following: (i.) A loss of power in transmission of 20 per cent. to 25 per cent. (ii.) A very considerable additional weight to be carried in the form of dynamo and electric motor. (iii.) A large additional cost for dynamo and electric motor, and very expensive switching gear. (iv.) The danger connected with having a

* Paper read at the spring meetings of the fifty-third session of the Institution of Naval Architects, March 27th, 1912.

very large amount of electric power on board an iron or steel vessel.

In November, 1909, Prof. Föttinger, at that time one of the engineers of the Vulcan Engineering and Shipbuilding Works at Stettin, read a paper before the German Institution of Naval Architects describing his hydraulic transformer, which was brought out particularly for the purpose of using high-speed turbines in comparatively slow vessels, that is, for reducing the number of revolutions of a high-speed turbine to the required revolutions of ships, and also for reversing engines up to the largest powers. Compared with an electric transformer this hydraulic transformer possesses many advantages. These were appreciated by the Holzapfel Marine Gas Power Syndicate, who acquired the British rights of the transformer for gas engines from the Vulcan Company and built an experimental sea-going vessel, the "Holzapfel I.," in order to test the adaptation and installation of gas power on board a sea-going ship, and in particular to test the transformer with gas engines. In deciding upon the size of the vessel the owners were guided by the following considerations:—

Firstly, a small vessel of 300 to 400 tons, such as the "Holzapfel I.," is used only for short voyages, and therefore comes into port every three or four days; as a consequence she is more suited for repairs and alterations than a vessel which has to make longer voyages.

Secondly, the initial cost of the experiment would be reduced to the lowest practicable figure for a vessel of commercial size.

Thirdly, the sea-going conditions in a small vessel are much more severe than in a large vessel, and as a result the gas plant and gas power installation in a 300-ton vessel will show most readily all the defects which are likely to manifest themselves in a large vessel.

Fourthly, the "Holzapfel I." is a vessel of a particular commercial type, the coaster, as far as size is concerned.

Fifthly, as far as the transformer is concerned, it is not suggested that vessels of the size of the "Holzapfel I." need necessarily be fitted with an hydraulic transformer, as it is not impossible to have either a reversing propeller or a clutch gear in vessels of 180 h.p. (which is the power of the above ship); but it was considered that the installation, as a whole, was one which would be applicable to vessels of the largest size and power, and in this respect the installation is absolutely unique.

Sixthly, it was recognised that, in case of the general introduction of gas engines for marine purposes, it will be necessary to use bituminous coal instead of anthracite, but the owners decided to leave the introduction of a gas plant for bituminous coal for a second experiment, believing that the task attempted in the "Holzapfel I." was sufficient for a first experiment.

The vessel under notice has the following dimensions: Length, 120ft.; beam, 22ft.; depth, 11ft. 6in. Her gross register is 291 tons and her net register 149 tons, and she carries 370 tons deadweight on Lloyd's summer freeboard. Reverting now to the machinery installed on board the vessel, we have to deal, in the first place, with the gas plant, which was built and supplied by the Power Gas Corporation of Stockton-on-Tees. It consists of two producers, 3ft. 6in. square and 6ft. 6in. high, and of two scrubbers, 13ft. high and 2ft. 6in. diam. Exigencies of space on board so small a vessel forced the owners to agree to a somewhat cramped position for the gas plant, which, as will be seen from the plan (view Fig. 1), is situated in the engine-room on the port side. The arrangement as it exists on board this vessel is probably the only one, so far as the producers are concerned, which could be adopted on a vessel of her size with engines aft. These are placed on a platform 3ft. 9in. high, and they form part of a closed-in gas space, which is accessible by a gas-tight door from the engine-room, but is not supposed to be entered, except in case of urgent need, while the vessel is under power. The working of the producers, such as blowing on, and the working of coal cocks is by levers from the engine-room. The only openings to the engine-room are the blowing-on cocks, which can be shut by a slide, and four air inlets, which are only open while the gas plant is under suction.

The producers are lined inside with firebricks; they were originally connected with the scrubbers by horizontal pipes entering the scrubbers at the base. The scrubbers were filled with coke to a depth of 6ft.; sea water from a tank on deck trickles down through this coke and serves to cool the gas and to free it from any dust which may enter from the producers. Above the coke is a space containing wood wool as a further means of cleaning the gas. The cooling water is discharged into a tank underneath the scrubbers, whence it is pumped overboard by a drum pump running by a belt from the main engine. Originally a centrifugal pump was fitted for this purpose, but it was found to be quite useless, and had to be changed for a drum pump. Steam vapour is supplied by eight flash boilers inside the producers, and fresh water has to be supplied for this purpose, and this is carried in the after peak tank. In order to be able to use sea water a new type of vaporiser has been designed,* by which sea water can freely be used, and this will be fitted to the exhaust in the early future. I may here state that a sufficient supply of steam vapour, *i.e.*, 1lb. of water evaporated for every pound of coal used, is essential, not only for the quality of the gas, but also to reduce the formation of slag in the producers.

The vertical gas engine is by Messrs. E. S. Hindley and Sons, of Bourton, Dorset. It has six cylinders, 10¾in. diam. and 10in. stroke; it is designed to run at 450 revs. per minute. It is a similar engine to the type now manufactured by several gas engine builders for the purpose of working dynamos, and, in so far as it works on the hydraulic transformer, its task is practically identical with that of other vertical gas engines on shore. The engine has forced lubrication and low-tension magneto, and also Lodge ignition.

As regards the transformer, it consists of two centrifugal pumps driven by a main shaft attached to the gas engine and two turbines, one for going ahead and one for going astern, mounted on a secondary shaft. Either of these centrifugal pumps delivers water into its turbine, according to the movement of a lever which is fixed a little distance abaft the gas engine. By a simple movement of this lever from forward to aft, the revolutions of the propeller can be instantly changed from full speed ahead to full speed astern. While the lever stands in the middle there is no load on the engine, and the propeller remains stationary. The time required when going full speed ahead till the propeller moves in the reverse direction is about 4 secs. Between the transformer and the gas engine is fixed a small centrifugal pump driven by a bevel gear from the main shaft and absorbing about 3 h.p. This pump is to pump back such water as may be lost by leakage in the transformer, and the water so lost is again replaced from the tank underneath the transformer into which it leaks.

This small pump runs on a ball bearing, and, as originally fitted, the ball bearing was either defective or of insufficient strength. As a result, while the vessel was on her voyage the ball bearing was destroyed, and she had to put into Scarborough, where another ball bearing of larger size was fitted. This has given entire satisfaction, and on examination in October last it proved to be in perfect condition. Altogether the transformer has since done its work in an entirely satisfactory manner. There is no appreciable heating of the water in the tank, and from this fact it can readily be concluded that the loss of power in the transformer is very small. Experiments on the test plate before delivery proved it to be from 11¾ to 18 per cent., including the loss from the auxiliary pump. The transformer drives the propeller at about 120 revs. per minute.

The vessel had her trials during the end of April last, and they unfortunately terminated in a collision with another vessel. After the repairs she proceeded on service, and has since carried the following cargoes: Tyne to London, 242 tons of coke; London to Llanelly, 330 tons of scrap iron; Llanelly to London, 330 tons of lime; London to Cork, 330 tons of hardwood and cement; Cork to Newhaven, 251 tons of oats; Guernsey to London, 340 tons of granite; London to Tyne, 340 tons of chalk; Seaham to Morlaix, 331 tons of coal; Guernsey to Weymouth, 331 tons of granite.

The consumption of anthracite coal during these runs varied between 25 cwts. and 35 cwts. per day of 24 hours, and was about one-half of that of steamers of similar power. During this period several faults manifested themselves in

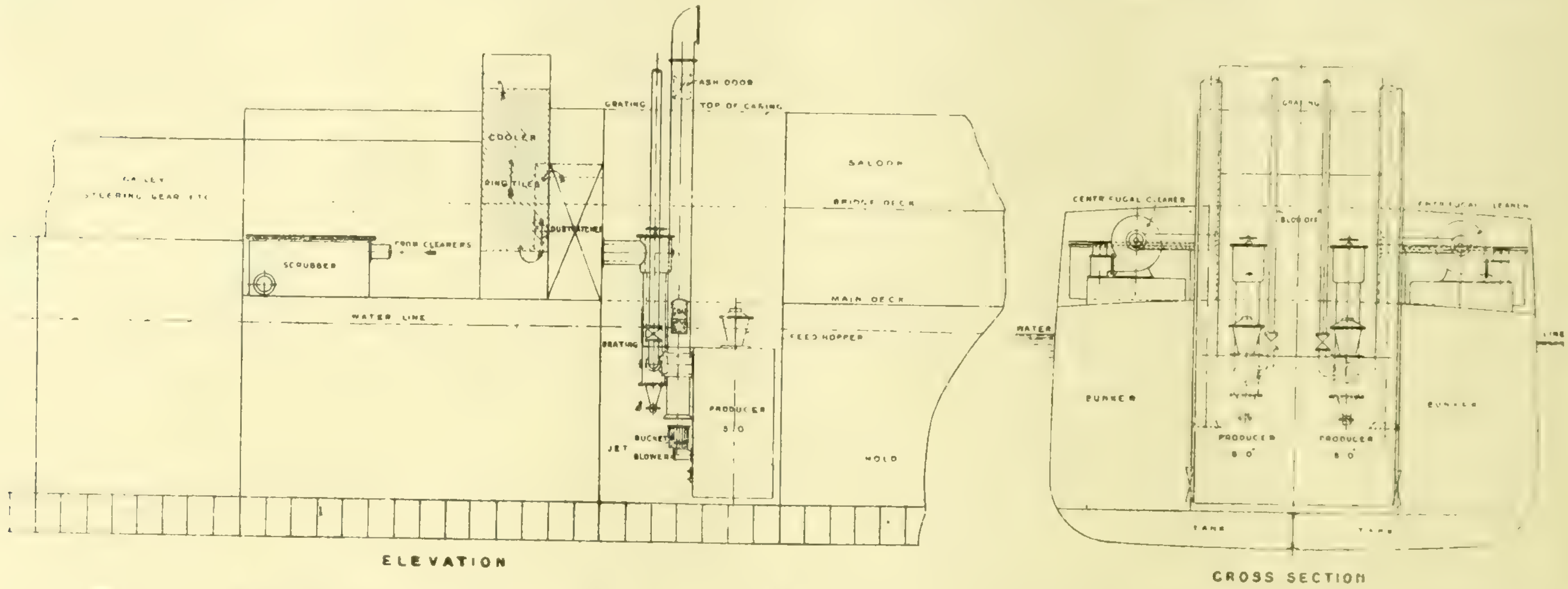
* This vaporiser is described and illustrated on page 391 of this issue.

connection with the machinery, and particularly with the gas plant; among them I should mention that the horizontal connecting pipes between scrubbers and producers several times got filled with water, when the ship was by the stern, which shut off the gas from the engine and caused a sudden stoppage. As a consequence this pipe was altered so as to slant downwards from the producers to the scrubbers. The coke in the scrubbers, moreover, was found to gradually pulverise, and it ultimately choked the outlet, so that the water rose, and even came into the producers, putting out the fires. Since that time earthenware tubes, of a design giving a maximum of surface, have been placed in the scrubbers as a substitute for the coke. The firebrick lining of the producers was frequently covered with slag, and when this was removed the firebricks were injured. I have suggested that interlocking blocks of steatite would be a good substitute for firebrick, as I am of opinion that slag will not adhere to this, and an experiment for putting a partial steatite lining into one of the producers is now being made.

The two levers for opening the exhaust valves of the producers were originally on the port side of the engine. It happened several times that in cases of sudden stoppage of the engine, burning gas came from the producers into the engine-room, when it was difficult, on account of the gas flame, to get at the levers of the exhaust valves. In order to avoid this, the shafts of the exhaust valves have been brought right across the engine to the starboard side, and so arranged that both valves can be opened by one movement. I consider it essential that such or similar arrangements should be fitted to future gas-driven vessels. The Lodge ignition, as originally fitted, and having wax as an insulating material, was found unsuitable on account of the high temperature prevailing in the engine room, and a new design of ignition, specially adapted for the vessel, is now being fitted.

Another interruption in the working of the vessel was caused by the shifting and breakage of one of the oil pressure pipes. This happened at a very inconvenient time, in very heavy weather, and caused some danger to the vessel. The oil pressure pipes are now being placed into deep grooves, and very securely fixed into position, so as to preclude the possibility of a similar accident. In other respects the gas engine has worked with fair regularity, but the power given with anthracite gas is probably nearer 160 h.p. than 180 h.p., the power guaranteed by builders, which guarantee, however, was for gas of 140 B.Th.U. The transformer has been in every way satisfactory.

It will be seen from the foregoing that the experience with this vessel has shown many essential points in regard to which the practice of gas plant on shore will have to be altered for marine purposes. I am of opinion, however, that a great deal of valuable experience has been gained, and that, with the alterations now made, the vessel will be able to do her work in a regular and satisfactory manner. Of course, the "Holzapfel I." is an experimental vessel, built in order to enable the owners to see which arrangements would be the most practicable for large sea-going vessels, and, although she has proved herself a successful vessel, capable of competing against steam-driven vessels of her size in the coasting trade on account of her very low fuel consumption, the main purpose of the owners has been to evolve from the experience of this vessel a design for ships of large size to be driven by gas engines. In this connection many important considerations have to be taken into account. First, in regard to the gas plant, it would be absolutely essential in a large vessel to use bituminous coal, as anthracite coal is not readily obtainable at many foreign coaling ports; moreover, the cost of anthracite is so considerably in excess of the cost of bituminous coal that economical considerations come into account here. Lastly, the gas derived from bituminous coal in British thermal units is of higher value than the gas derived from anthracite coal.



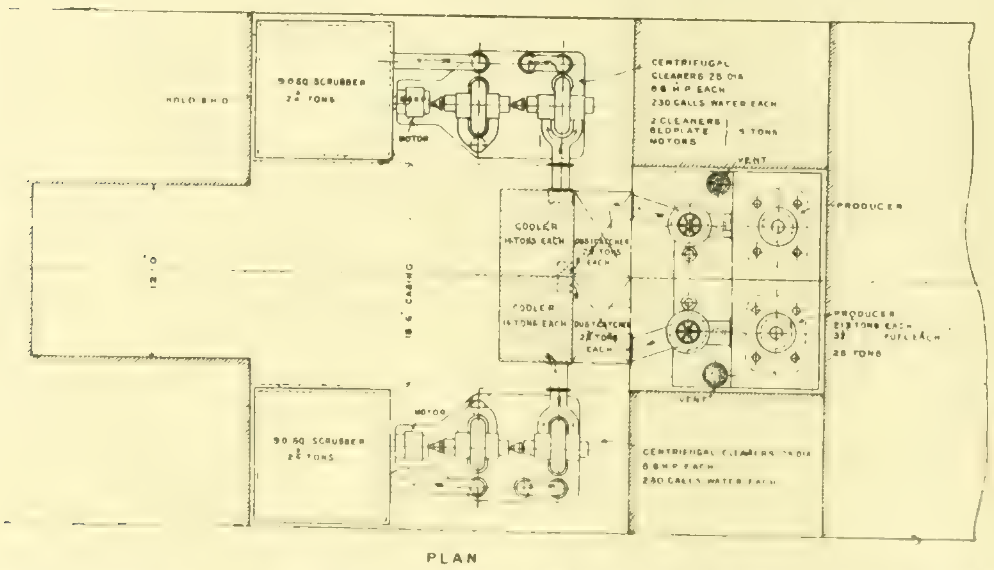


Fig. 2. Holzapfel II. General Arrangement of 800 b.h.p. Plant in two Units of 400 b.h.p. each. Exhaust gas-fired boiler about 3ft. 6in. diam. 14ft. high; heating surface, 320 sq. ft.; working pressure, 60lbs.

It will, therefore, be seen that with an engine of given size, fed with gas derived from bituminous coal, a larger power will be derived. So far as I am aware no gas plant driven with bituminous coal has hitherto been used at sea, but Fig. 2 shows arrangements for placing a bituminous gas plant of 800 h.p. on board ship. The producers stand in the bottom of the ship, in a separate compartment covered by gratings, the tops of the producers, which are each of 400 h.p., are level with the main deck, the intention being to draw the coal out of a 'tween deck bunker. An electric hoist could be fitted to lift coal from the lower bunker into the 'tween deck bunker so as to bring it on a level with the top of the producers. The coal in this case will be fed into the hoppers by hand, and the usual arrangement of ball seals to cover the four openings for stoking in each producer will be fitted. In order to make this absolutely gas tight, hinged caps will be fitted over the balls, and screwed down when no stoking is being done. From

the producers the gas passes into the coolers, or wet scrubbers; these are filled with earthenware rings, fitting tightly into position. These scrubbers will be about 15ft. high and about 3ft. 9in. diam.; the uppermost portion of each has a tank which will be fed with sea water by a pump from the engine-room. The scrubbers are placed on the main deck, and discharge the cooling water overboard on either side by gravitation. From the coolers or scrubbers the gas is drawn by centrifugal tar extractors (driven electrically) formed as fans; these force the gas under pressure through the dry scrubber to the engine. A very large number of centrifugal tar extractors are at work in connection with gas plant using bituminous coal, and they do their work to absolute perfection, giving clean gas free from any tar. Attempts to dispose of the tar by other means or to gasify it have, however, been attended with many failures.

Coming now to the gas engine, there are various considerations to be taken into account. Naturally, with an experimental form of engine, the twin-screw system offers additional security. It also has the advantage that engines of considerable power can be fitted in a vessel without piston cooling, thereby saving considerably in first cost and weights. At present, engines with cylinders up to 22in. diam. are being built without piston cooling, but this should be considered the outside limit. Some air cooling by a fan to the crank chamber, and driving cold air through it, is contemplated, and this will no doubt assist to keep the working parts of an engine at a suitable temperature. Two types of vertical engines are being built, those with tandem cylinders and those with a single row of cylinders; the former have the advantage in saving space; the latter are, perhaps, more accessible for repairs. A tandem engine with six cranks can no doubt be built up to 1,800 h.p. without water cooling of pistons, and two such engines would be sufficient to drive a vessel of 15,000 tons displacement at 10 knots speed. The stroke of gas engines is generally limited to a piston speed of about 800ft. per minute, and engines such as have been considered suitable, and of the size not requiring water cooling of pistons, will run at about 250 to 320 revs. per minute.

In order to reduce the vibration to a minimum, engines of six or more cylinders are desirable. Mr. Milton's paper last year showed diagrams giving a distribution of pressure which speak eloquently in favour of six or more cylinders. The vibration of the engine as observed on the shaft leading to the transformer of the "Holzapfel I." was not inconsiderable, so that at first the bearing between gas engine and transformer showed signs of heating; forced lubrication was subsequently fitted to this bearing with satisfactory results, and this would no doubt be desirable with larger powers. A bearing of considerable size, moreover, will be needed in order to prevent undue vibration in the transformer.

As regards the Föttinger transformer, about 85 per cent. to 90 per cent. of the original brake horse-power of a prime mover of 800 b.h.p. can be transmitted to the propeller shaft if the revolutions are reduced from about 270 of the prime mover to 100 of the propeller. The weight of the transformer and water would be about 13 tons. The cost of such a transformer is only double that of a transformer of 150 h.p.; the greater the power the lower the cost per horse-power, and the higher the efficiency, the greater also the saving in weight as compared with steam engines and boilers.

While it cannot be said that the experiment of the "Holzapfel I." has so far been a complete success, owing partly to several avoidable accidents, as, for instance, two collisions, which were in no way due to the machinery on board, and while it must be confessed that in consequence of these accidents an undeserved prejudice has probably been created in the minds of the public and of underwriters, making the economic insurance of future gas-driven vessels somewhat difficult until a continuance of regular and steady work has created a new confidence in the system, it must be admitted that the experiment has so far practically demonstrated the feasibility of using gas engines at sea in conjunction with the hydraulic transformer. It has also shown the weak spots in gas plant as hitherto used on shore, and what is necessary to adapt it for sea-going purposes.

The fact of our almost unlimited coal supply, and the cheap price of this fuel in Great Britain as compared with liquid fuel, makes the introduction of marine gas power particularly desirable in this country, not only from economic but also from national considerations. Compared to the triple and quadruple expansion steam engine of the present day, the gas engine is still an imperfect piece of mechanism, and there is an almost unlimited scope for improvement and economy in a gas plant, gas engines, and gas turbines.

So far the most perfect steam machinery has been evolved by the marine engineer, and I venture to hope that by this experiment the interest of marine engineers may have been aroused, and that the day is not far distant when their concentrated energy and intelligence will have so perfected marine gas plant and gas engines as to bring about their general introduction, with the resulting great saving of coal fuel—the most important national asset of this country.

I should mention that Mr. Max Holzapfel, of Newcastle-on-Tyne, shared with me the financial risk of this experiment, and that I was assisted in the design of the vessel and machinery by Messrs. H. A. B. Cole and T. W. Cherry, who also superintended the construction and the installation of the machinery on board. Lastly, I have to thank the Vulcan Company, of Stettin, for their generous help and assistance at a time when difficulties gave us considerable trouble, and the Power Gas Corporation, Ltd., for their unfailing help in contending with the various difficulties which arose.

RAILLESS ELECTRIC TRACTION.

AT a recent meeting of the Junior Institution of Engineers a paper was read on "Railless Electric Traction" by Mr. Bertram D. Fox, B.A. The author pointed out that mechanically-operated vehicles must be classified, broadly, as (1) those which run on rails, and (2) those which made use of the ordinary road surface; electrical power being used almost exclusively for the former, while some motive power other than electricity being used for the propulsion of the latter. Greater suitability and economy was given as the reasons for electric power having superseded all other forms of motive power on tramcars, and the same would have applied to road vehicles, but for the difficulty experienced in the application of electric power owing to the unsuitability of the usual type of trolley or current collector. Special types of trolley have been tried for the trackless car, but their construction imposes too many restrictions, due to their necessitating special overhead line construction. The difficulty in connection with the trolley was finally overcome by adhering to the usual tramway type of overhead line, and adapting the usual tramway trolley to the new conditions, and the economic and technical considerations that have made electric power supersede all other motive powers in tramways will now produce the same result in connection with road vehicles. The author commented upon the inadequacy of existing tramways to serve the remoter parts of their areas; tramways serving urban areas only; suburban areas must therefore be served by road vehicles. As the traffic problem of urban areas was only solved by electrification of rail vehicles (tramcars), so the traffic problem of suburban areas will also only be solved by electrification of road vehicles. The results of the first installations in this country, which were made simultaneously at Leeds and Bradford, where the vehicles have been in continuous service since June of last year, were given. The proceedings terminated with the announcement of the ensuing meeting on Wednesday, 17th April, when Mr. E. Kilburn Scott, M.I.E.E., would read a paper on "Dynamo Design."

British-designed Gunboats for China.—The Navy Department at Washington has, we understand, entered into a contract with Messrs. Yarrow & Co., Ltd., to design the shallow-draught gunboats which the United States intend to place on the China rivers. The vessels will be constructed in America. This act on the part of the Navy Department at Washington is owing, we understand, to the exceptional success of H.M. shallow-draught gunboat "Widgeon," which has made some remarkable runs on the Yang-tse Kiang.

THE LIGHTING OF FOUNDRIES.*

BY B. G. WORTH.

THERE are three kinds of lamps to be considered: the incandescent, the arc, and the vapour lamps. Of the incandescent lamps there are the ordinary carbon, the metallised carbon, the tungsten, and the Nernst lamp. Of the arc lamps there are the enclosed carbon, both alternating and direct current, the long burning flame arc, and the luminous arc. The vapour lamps, that is, the Cooper, Hewitt, and the Moore lamps, are not considered adapted to foundry lighting because of the lack of penetrative power of their light due to the low intensity of their light sources.

It may be said that foundries require light principally for two operations, moulding and pouring. The moulding requires considerable light and takes place usually in the early hours of the day when daylight is available. The pouring comes at the close of the day and requires only sufficient light to see to get around, which works in very nicely with the diminishing light of the afternoon. So, regarded from some aspects, the lighting in a foundry is rather unimportant, and in fact sometimes there is practically no lighting installed. However, it must be remembered that rainy days come, that it is sometimes essential to work overtime, and that in the winter it does not grow light until after the foundries are started, and evening darkness also comes very early.

It is a great deal cheaper to make good moulds in the first place than to repair castings after they have been moulded, and it is a fairly difficult matter to make a good mould unless there is sufficient light. Of course, these considerations apply only in a general way to different foundries. For heavy work a minimum of light will suffice. When you come down to very small castings a good deal of light is necessary. Building up the moulds, smoothing them off and finishing them generally requires good light. Moulding work is very difficult to see because of the dark colour of the sand and the general blackness of everything concerned. This darkness absorbs the light and very little is reflected. Moreover, as the walls and objects do not reflect light there is very little diffusion and the lighting effect is less for a given quantity of light supplied from the lamps than it would be if there were diffusion.

It is a dangerous matter to try to pour in the dark, and when men are running around with ladles full of metal and cranes operating overhead accidents can be very serious. As bearing on this I wish to mention a curve given in a paper by John Calder before the American Society of Mechanical Engineers. This curve shows in a remarkable way how the percentage of accidents increases greatly in the darker weather of the year, the inference being that this increase is due to the decrease in illumination. According to this curve there are about 75 accidents in December or January as compared to about 50 in July or August, or 50 per cent. more in the dark months. Statistics have also been published which show that in the United States alone 500,000 preventable accidents take place every year. Of these it is believed by the authorities who have made a study of safeguards for the benefit of employés that 25 per cent. are caused by poor illumination.

A foundry is always more or less full of dust, dirt, and smoke, and to penetrate through this murk requires, of course, more light than would be necessary otherwise. Lamps of high brilliancy are required. This is the reason why vapour lights are not available, as it has been found that light from lamps of this type does not penetrate readily through smoke and dust.

Foundry lighting must not be too uniform in its character as shapes of moulds are difficult to see, due to the darkness of the material and the consequent fact that shadows are not so apparent as on lighter materials. If the illumination is too uniform the mould will appear flat. Again, moulds contain deep recesses into which the light must penetrate, and unless there is considerable direction to the light rays it will fail to penetrate into the interior of the mould. This condition is more or less opposed to the condition requiring shadows, as the rays should be oblique to make shadows and should be vertical in order to see the inside of the moulds. There must be a compromise between these two requirements.

* Abstract of address delivered before the Newark Foundrymen's Association, Newark, N.J., March 1st, 1912.

Another thing which must not be lost sight of in a foundry is the effect on the lamps of dust and gas. If the lamp contains an elaborate mechanism, then the gases and dirt are liable to affect this mechanism and the lamp will not be always in working order. If it has a complicated system of shades, or diffusers, these become dirty and a large part of the light is cut off.

Foundry lighting therefore requires a good and possibly concentrated illumination for moulding purposes, and on the other hand a general illumination for pouring, which latter must be of a character to penetrate through the smoke. These two requirements are more or less contradictory, and it must be decided which is the more important. This brings into the matter the question of costs.

The best way to get a good illumination is by general lighting of a high character, and then this is naturally also available for pouring purposes. On the other hand, a general illumination of a high character is expensive. If it is not desired to spend much money, this can be done by a fair general illumination provided in the first place, and then special localised illumination provided where it is required for good work. This compromise is not altogether satisfactory, because practically the only way to provide the special illumination is by the use of extension lamps. These are a nuisance, as they clutter up the floors and wear out rapidly, and are always a source of trouble and maintenance. If capital is available it is much better to provide a general illumination.

The amount of illumination required ranges from about ½ft. candle to 3ft. candle. One-half foot candle is very low, and is just sufficient to enable large work to be carried on. On the other hand, 3ft. candle is very good illumination and would be sufficient under certain circumstances for a reading room. Such good light may be considered extravagant, but it is not in fact, because light goes a great deal farther in a reading room, due to the good conditions, than it does in a foundry.

Somewhere between the two extremes is the proper amount, and this must be determined by the character of the work. For foundries working on large heavy castings where finish of the mould is of not much importance, about 1ft. candle should be sufficient. On the other hand, in foundries casting small objects requiring great detail and careful finish of the mould 3ft. candle is none too much. This question of the amount of illumination is one of the most vital points to be considered, inasmuch as it determines the cost of installation and operation of the whole system. No rules can be given by which it is possible to determine how much light is needed. The workman naturally wants as much as he can get. The owner wants to hold the expense down as far as compatible with good efficiency in his workmen. It must boil down in every case to a question of judgment to be decided by the owner and his engineer after due study and investigation by actual personal inspection of plants in operation, the characteristics of which can be ascertained. In other words, it is a matter of arbitrary decision, and not of scientific deduction.

There are two methods of getting at the amount of candle-power capacity necessary. One is the flux of light method and the other is the step by step method. The first involves the calculation of the total amount of light required by multiplying the area by the illumination required and reducing same to lumens (the lumen being the quantity of light necessary to illuminate 1 sq. ft. to an intensity of 1ft. candle), then figuring the necessary number of lamps required to supply this number of lumens from tables which have been worked out in detail and which take into account the reflection from the walls, the absorption loss, &c. For standard work which duplicates conditions which have been experimentally studied this is a quick, accurate, and sure method. But for foundries the conditions vary too much to depend upon this method except as a check. Again, if there are only a few large units the flux method cannot be used because it does not give any data as to the distribution of light.

The point by point method is in my opinion the best for foundry work. This method consists in assuming a certain arrangement of lamps and certain positions or stations in the foundry, and calculating the illumination at each station. These calculations, although tedious, are easily made from

the distribution curves of the lamps in question. Of course, this method involves considerable labour, because several tentative plans must be worked out. After working out these plans, however, it will be possible by inspection to decide just about what is wanted and a result which will be suitable can be had.

Lamps, of necessity, must be hung above the crane in order to permit its operation, and for this reason it is not feasible to use small units, as the number required brings the cost per unit of light up very high. Thus it works out that in general high-power lamps, such as arcs, can be used to the best advantage. These lamps, in order to avoid glare and secure good distribution, should be hung very high. As it is difficult under these circumstances to clean and adjust lamps, the cost of trimming becomes serious unless a long-burning lamp is used. The flame arc is probably the most efficient solution of the foundry lighting problem. It is the most efficient source of lighting known. It can be used on both alternating and direct current. Certain makes are suitable for multiple work, *i.e.*, each lamp can be operated separately and controlled. Its light has penetrative power. The only objection of the lamp is that its mechanism is more or less complicated in the types which have the highest efficiency. Some less efficient types, however, have mechanism which is the acme of simplicity. While flame lamps throw off a certain amount of gas, this is of no consequence in a foundry and can be neglected.

It is well, of course, always to use a highly efficient lamp if it can be done. Sometimes the employment of the highly efficient lamp seriously cuts down the efficiency of sight because of the impossibility of installing it in such a way as to prevent glare. In this case it would be better to use a unit which is better adapted to the circumstances and which has a lower efficiency in itself which, by making the efficiency of sight higher, will in the end produce a better over-all efficiency. Of course, where either type of unit can be used with good efficiency of sight, the more efficient light source should be employed.

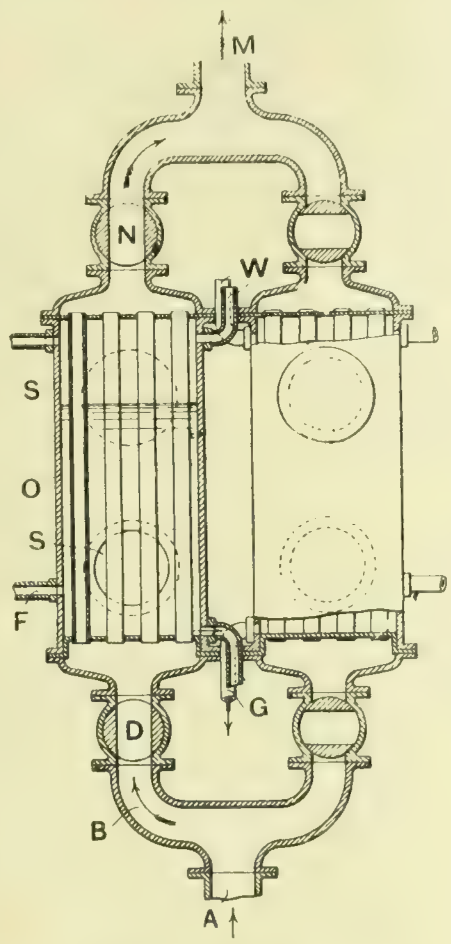
In some small foundries and in old ones where the ceilings are not high it will be impossible to use the flame lamp because it is of a size which needs to be hung high to get the distribution. These foundries must come to a smaller unit. The flame-arc lamp, because of certain inherent features, cannot be constructed in very small units, and it then becomes a choice between a luminous arc lamp and an incandescent. The luminous lamp is midway between the flame and the incandescent and has all the good qualities of the flame lamp, except its mechanism is more complicated, and it cannot be used on alternating current.

Of incandescents there are the Nernst and the Mazda lamps. While the Nernst lamp has a higher efficiency than the Mazda, I do not feel that it is so well adapted to foundry work as the Mazda. This latter, since the introduction of tungsten wire filaments, has become very reliable. The carbon incandescents, due to their low ratings, are hardly adapted for general illumination except in certain circumstances.

Methods of Inventors.—Mr. R. M. Neilson, M.I.Mech.E., recently deliverd a lecture on "Invention" before the Royal Technical College Scientific Society, Glasgow. The lecturer divided inventions into two classes: (1) Those which were the result of suggestion, and (2) those which resulted from an investigation set on foot in order to find the best means of attaining an end, the inventor starting with a definite object in view but without any knowledge as to how his object was to be attained. Mr. Neilson laid stress on the necessity for considering problems of invention from a business standpoint and on the benefit which was to be derived from training the mind, not only to assist one to decide when and where not to expend time, money, and energy on any invention, but also to assist in working an invention out to a successful issue. With regard to commercial establishments, he advocated a judicious combination of method and routine with a continuous striving after improvements. As examples of the working out of inventions on correct and incorrect lines, the lecturer cited the cases of the sewing machine, the type-writer, and the Babbage calculating machine.

VAPORISER FOR GAS PRODUCERS.

The vaporiser for gas producers shown in the accompanying cut has recently been patented by Mr. A. C. A. Holzapfel, 57, Fenchurch Street, London, and has been designed mainly with a view to enable sea water to be used for the purpose of supplying water vapour to the producers. To the outlet A where the gas leaves the producer for the scrubber there is fitted a double branch pipe B provided with shut off valves D to each branch. To the branch pipes is fitted a vaporiser consisting of two cylinders O containing a number of small tubes so arranged that the cylinders can be fed with sea water through the pipes F, and that the gas from the producer will pass through the small tubes contained in the vessel. Each vessel is provided with a blow-off cock G which is so regulated as to allow about half the intake of sea water to escape from the vessel, so that the concentrated sea water is constantly being discharged, and thus incrustation around the tubes is prevented as far as possible. From the top of each vaporiser pipes W conduct the water vapour to the bottom of the gas producer. These vapour pipes are provided with reducing valves so that the pressure of the vapour is reduced to about 2lbs. pressure, and each cylinder is also provided with a safety valve which allows the vapour to blow off should the pressure exceed, say, 10lbs. pressure per square inch. The top of each producer is provided with branch pipes leading to the gas outlet M, suitable valves N being provided in the pipes. It is intended to use only one of these vaporising vessels at a time, the other being shut off by the valves D N until such time as it may be necessary to thoroughly cleanse the first vaporising vessel. The arrangement is essentially suitable for vessels remaining at sea for more than three or four days, but for vessels only doing short journeys of less than three days only one such vaporising vessel is necessary as it can readily be cleansed at the end of each voyage.



Vaporiser for Gas Producers.

Instead of arranging the double branch pipe and its vaporising vessels on the pipe leading from the producer to the scrubber, it can be arranged in some suitable position in the exhaust from the engines. In practice it is found advantageous to have such vaporising vessels arranged in both the gas pipe leading from the producers to the scrubbers and also in the exhaust, as the heat obtained from either is scarcely sufficient to evaporate the necessary quantity of sea water to supply the water vapour required by the producer.

Tramcar Brakes on Steep Gradients.—With a view to preventing a recurrence of the disastrous tramway accidents that have occurred in the Stalybridge district, the Joint Tramways Board for Stalybridge, Hyde, Mossley, and Dukinfield have been experimenting with brakes for increasing the safety of tramway cars on the hilly routes of the district. The Spencer mechanical slipper brake and another brake were fitted on two cars which were taken over the steep gradients, including the scenes of the two accidents, and thoroughly tested. As a result, the Tramways Committee have fitted the cars with the Spencer type.

THE DIESEL OIL ENGINE AND ITS INDUSTRIAL IMPORTANCE.*

BY DR. RUDOLPH DIESEL.

(*Concluded from page 357.*)

TWO-STROKE CYCLE ENGINES.

As very often stated by the author, the Diesel principle is essentially suitable as a 2-stroke cycle engine, because the scavenging is not done with a fuel-air mixture, but with pure air, so that not only untimely ignitions but also fuel losses are avoided, and the scavenging can be done more effectively, and with almost any quantity of air desired. The first 2-stroke cycle engines on the Diesel principle were built in 1900 and 1901 in Germany and England, after drawings made by Güldner, but without success, because these drawings still followed too closely the 2-stroke cycle gas engines, and because the constructional arrangements were unsuited to the Diesel engine.

Successful attempts to construct a 2-stroke cycle Diesel engine on entirely new lines have, however, been made recently by Messrs. Sulzer Bros., of Winterthur, so that to-day this type is on a nearly equal footing with the old 4-stroke cycle engine. This has been effected by working entirely on the original Diesel principle. The author says "on a nearly equal footing," because the 4-stroke cycle engine still has a better combustion and a more economical fuel consumption, and is, above all, simpler in its method of working. It thus remains the standard perfect engine, and still predominates for medium-sized stationary plants up to 500 h.p. or 600 h.p. (no exact limit can be given) wherever the highest perfection and the greatest economy are desired; but engineers are now doubtful whether this supremacy will last much longer. On the other hand, the 2-stroke cycle engine with its smaller cylinders has now come into favour for stationary plants of higher horse-power, and, as a marine engine, has become the only standard type.

Two considerably different fundamental types of 2-stroke cycle engines have so far been competing. To explain the principal difference, the author shows some sectional drawings. The first fundamental type is the engine made by Messrs. Sulzer Bros., Fig. 12, with separate scavenging pump. The second—the M.A.N. engine, Fig. 13—was brought out much later; in it the scavenging pump, which has an annular piston, is placed underneath each combustion cylinder. Both engines are single-acting. The author does not wish to comment upon the advantages and disadvantages of the different types, but would leave them to be discussed. Their relative merits can only be settled by experience.

A 3-cylinder 750 h.p. Sulzer-Diesel 2-stroke cycle engine, and a still larger Sulzer-Diesel 4-cylinder 2-stroke cycle engine on the same system of 2,000—2,400 h.p. were illustrated in Mr. Schubeler's paper, read at the Zürich meeting of the institution last year. For such large engines two scavenging pumps are necessary.

An addition to the 2-stroke cycle engines of an entirely new type has been recently made. It was built by Prof. Junkers on the lines of the old Oechelhäuser gas engine, with two pistons working in opposite directions in one cylinder, but acting on the Diesel principle. This 2-stroke cycle process is explained in the diagram, Fig. 14. A horizontal 1,000 h.p. engine of this kind is at present being tested at the laboratory of Prof. Junkers at Aix-la-Chapelle. The merits of this type of engine are left for discussion.

MARINE ENGINES.

The first marine Diesel engine of 20 h.p., Fig. 15, was constructed in 1902-3 in France, for use on a canal boat, by the French engineers, Adrien Bochet and Frédéric Dyckhoff, in conjunction with the author. This engine had, like the Junkers engines already mentioned, two pistons working in opposite directions in one cylinder, but the flywheel shaft was not at one end of the cylinder, as in Junkers' engine, but traversed a cooled chamber passing straight through the combustion chamber. The engine worked on a 4-stroke cycle. The great feature of this arrangement was the very high speed which was made possible by the perfect balance. This small engine was, as stated, used to drive a canal boat, and worked quite satisfactorily. Others were also built in various sizes up to several hundreds of horse-power for some French submarines by Sautter, Harlé, & Co., Paris.

This type of engine is of no further practical interest today; but while its first application to a canal boat is of no importance in itself, it has at least the historical interest of being the first Diesel engine to be used on a boat. Since the date named the evolution of the Diesel marine engine has steadily continued, chiefly on the demand of the French submarines and Russian river boats. The author has already mentioned that later on the high-speed 4-stroke cycle engines, built for electric power stations, were made even lighter than before, and used for French submarines and for Russian river vessels. These engines were not originally reversible; on the contrary they were used to generate electricity by means of which the propellers were driven indirectly for manœuvring. In the most favourable case ("Delproposto"), the propulsion of the vessel was performed directly by the engine, whilst the manœuvring and slow driving were done by means of electricity. Thus Fig. 11 represents an engine which has been worked originally, not only as a stationary, but also as a marine engine, although it was not really designed for marine purposes.

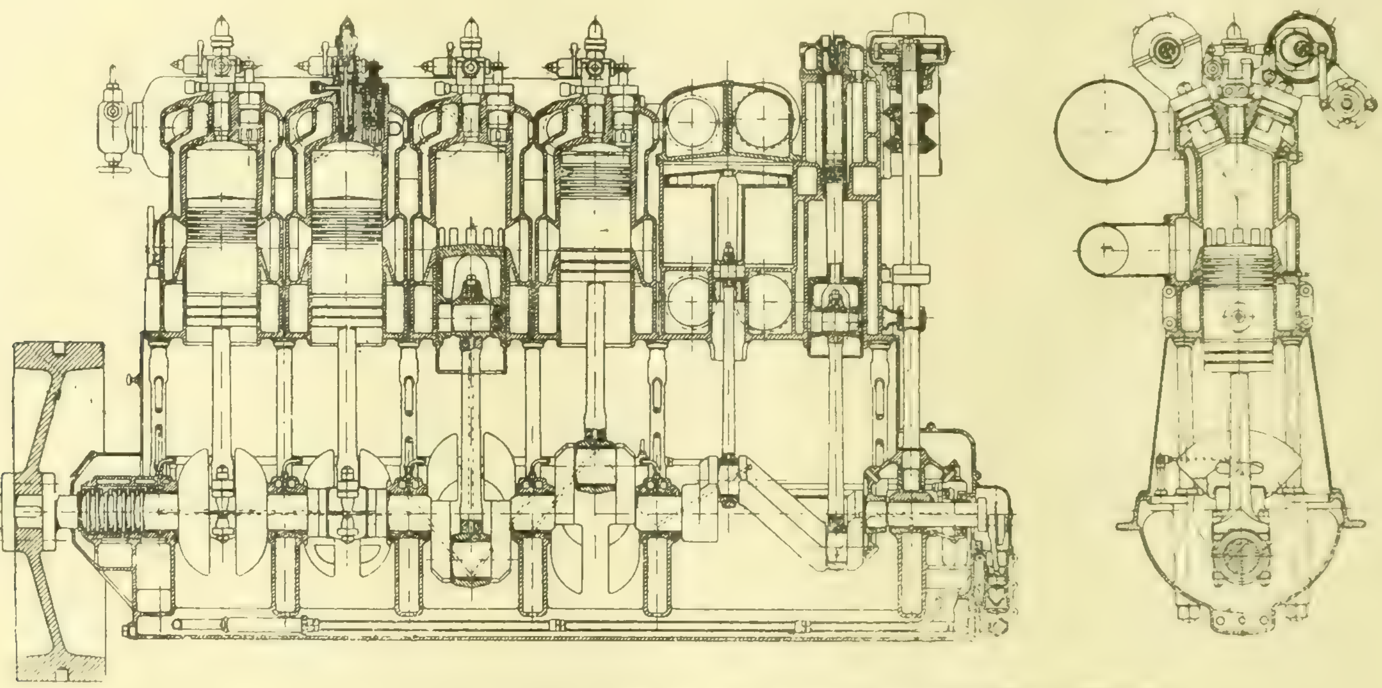


FIG. 12.—SINGLE-ACTING TWO-STROKE CYCLE ENGINE, WITH SEPARATE SCAVENGING PUMP. (SULZER.)

* Abstract of paper read before the Institution of Mechanical Engineers, March 15th, 1912.

The first reversing marine 2-stroke cycle Diesel engine was built in 1905 by Messrs. Sulzer Bros. at Winterthur; it was exhibited in 1906 at Milan and fitted to a vessel on Lake Geneva in the same year. At that time engineers were not quite clear as to the importance and value of the 2-stroke cycle principle, and many firms went on trying for years to make the 4-stroke cycle engine reversible. The first engine of this kind was built by Messrs. Nobel Bros. at St. Petersburg in the year 1908, and was fitted to a Russian submarine. Great mechanical complications were at first caused by the reversing of the 4-stroke cycle engine. This problem has recently been solved in a much more simple and neater way, in a 6-cylinder 150 h.p. reversible 4-stroke cycle engine of 350 revs., constructed in the year 1911 by the French firm, Messrs. Delaunay-Belleville. This engine is fitted with two air pumps, of which a spare one is for manœuvring.

In many factories reversible 4-stroke cycle marine engines are still built, but, on the whole, engineers are, for navigation purposes, inclined to abandon the 4-stroke cycle engine entirely, and to replace it by the 2-stroke cycle engine. The small 4-cylinder engine of 30 h.p. and 600 revs. per minute, illustrated in Fig. 16, is also a reversible 4-stroke cycle engine. It was built for experimental purposes in the year 1909, after designs by the author, as an automobile engine for heavy loads, but it can also easily work as a marine engine. The cam shaft is mounted on the cylinder cover, and the illustration shows the engine with the cover lifted. The illustration, Fig. 16, is again of historical value in so far as it illustrates the first attempts to construct the Diesel engine as an automobile engine for traction wagons, and no doubt in future years these experiments, carried out in some different way, will lead to satisfactory results.

Fig. 17 shows a quite new Sulzer 6-cylinder marine engine working at 300 revs., in which an innovation may be noted. The scavenging valves are not fitted on the top within the cover, but below in the scavenging air reservoir. Quite recently double-acting vertical 2-stroke cycle Diesel engines have been built. Fig. 18 shows one of these double-acting 2-stroke cycle engines with one cylinder of 1,200 h.p., made by Messrs. Carels Frères, the results of the tests of which are as yet little known to the public. It is generally known, however, that in the Nürnberg works of the M.A.N. important experiments with double-acting 2-stroke cycle engines are being carried out.

In these works prolonged official tests of a 3-cylinder double-acting 2-cycle engine of 850 h.p. were made in August, 1911, and the results proved highly satisfactory. At the present time a double-acting 2-cycle 3-cylinder engine of 2,000 h.p. per cylinder is being tested at Nürnberg. The dimensions of these cylinders are as follows:—

Diameter	800 mm. ($31\frac{1}{2}$ in.).
Stroke	1,050 mm. ($41\frac{3}{8}$ in.).
Revolutions per minute...	160.

The air-supply pump for fuel injection is driven by a special Diesel engine, whilst the scavenging pumps are driven direct from the crank shaft.

If, as seems probable, these tests also give satisfactory results, the era of very large Diesel engines has begun, especially low-speed marine engines suitable for driving propellers. This last engine has already yielded considerably more than 2,500 h.p. per cylinder, so that an engine unit of this kind with six cylinders would give 15,000 h.p. or 45,000 h.p. for a vessel with three propellers. This kind of marine engine requires six cylinders to ensure a regular turning moment and balancing, so that the number of cylinders cannot be considered abnormally high; on the contrary, it must be accepted as the most suitable and proper number. The opinion which

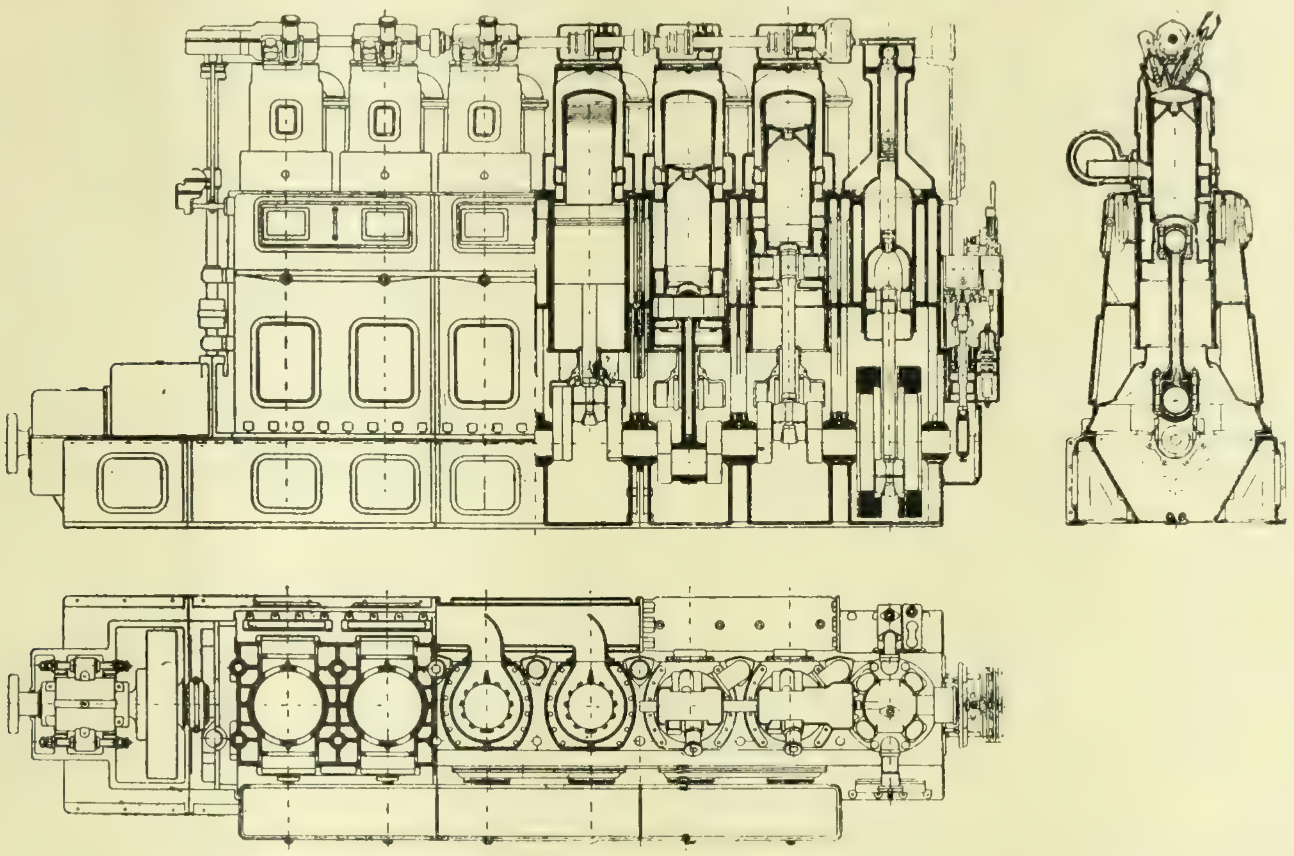


FIG. 13.—SINGLE-ACTING TWO-STROKE CYCLE ENGINE, WITH SCAVENGING PUMP UNDERNEATH COMBUSTION CYLINDER. (M.A.N.)

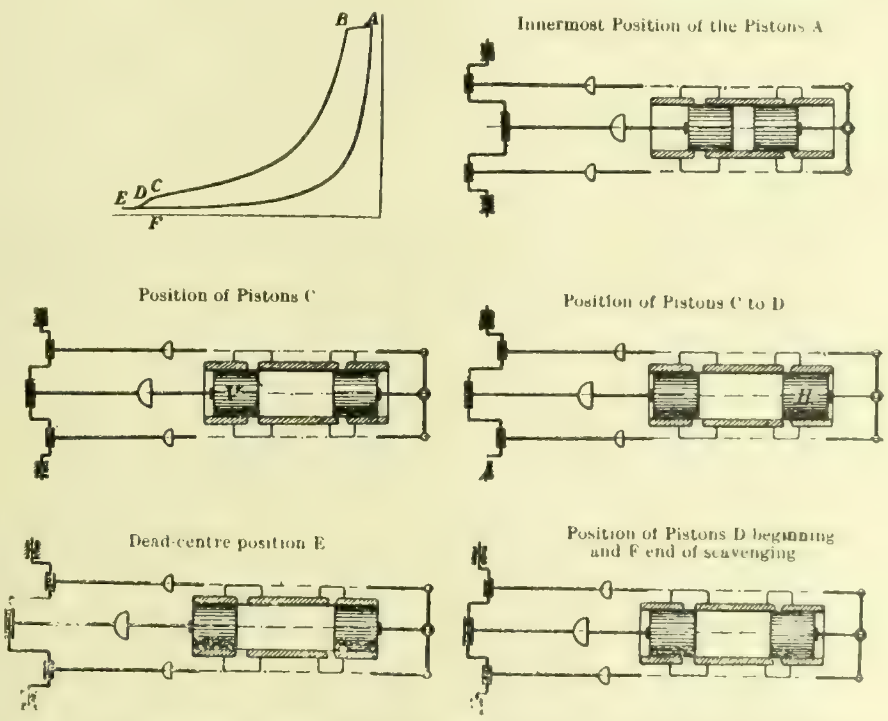


FIG. 14.—TWO-STROKE CYCLE SINGLE-CYLINDER MARINE OIL ENGINE. (JUNKERS.)

was still prevalent some months ago, that about 1,000 h.p. per cylinder is the maximum for Diesel engines, has therefore been quickly overthrown by these facts, and it may be safely assumed that the day of the large marine engine is already very near at hand. At Messrs. Krupps' Germania Works cylinder units of 2,000 h.p. double-acting 2-cycle are also being tested at present; also at Sulzer's Works a single-acting 2-cycle cylinder of 2,000 h.p. Junkers' system, illustrated in Fig. 14, is used for vertical marine engines. The author regrets that he has not a photograph of a finished engine.

From motives of prudence, the various navies which are now fitting some large warships with Diesel engines started

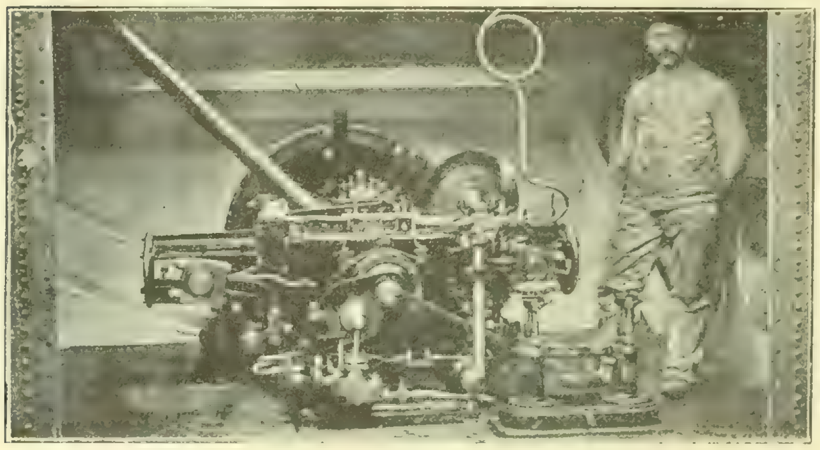


Fig. 15. First Marine Engine for Canal Boat, 20 h.p. 1902–3

with one Diesel only out of the two or three engines on board; the Diesel works alone when the ship is running at normal speed, but for high speed, steam is used as an auxiliary. It is evident that larger warships will not be fitted solely with Diesel engines until practical tests on the high seas have proved to be completely successful.

Conclusions.—As will be seen from this historical summary, countless different types of Diesel engines have been so developed that it has become very difficult for even the expert to choose between them. If one looks through the technical Press, numerous other schemes will be found on which the author will not dwell, as they have never been actually carried out. To-day, if a new firm is about to manufacture Diesel engines, it is almost impossible to give them sound advice as to the type and size they should choose from this bewildering variety. The fads, habits, and tastes of the purchasers, and the kinds of machine tools in use in the works, have to be taken into consideration rather than technical points of the engine itself. Development is proceeding so rapidly at present that, within a few months, opinions even on important points may easily be changed.

Still, the author believes that this period of chaotic production will soon be over. At present it is generally agreed that the 4-stroke cycle engine from 5 h.p. up to 600 h.p. may be regarded as the exclusive type for stationary plants; but it will probably not remain so much longer in spite of its perfection, in view of the development of the 2-stroke cycle engine, especially that of the double-acting type.

The use of the 2-stroke cycle engine has increased slightly, but it is to be hoped that it will be still further extended. Although this engine may never equal the 4-stroke cycle engine as regards thermal efficiency, its initial cost is so much lower that its slightly higher fuel consumption will be more than counterbalanced by the greater interest and amortisation on the higher-priced 4-stroke cycle engine. When this stage is reached, the question is simply one of economy. In the author's opinion the 2-stroke cycle engine will thus soon make headway for stationary plants. It will, therefore, be necessary to produce from the various systems of 2-stroke cycle engines a simple standard type, with which the more complicated types will not be able to compete. It is the author's belief that this simple standard type will make its appearance very soon, and that thus the Diesel engine movement will leave the unsettled stage and enter on a period of quiet expansion.

Special Importance of the Diesel Engine for Great Britain.

After this short summary about the importance of the Diesel engine for the world's industry in general and the historical review of Diesel types, the author desires to add a few words on the importance of the Diesel engine especially for Great Britain. In this connection the three following facts must be borne in mind:—

(1) Great Britain is an exclusively coal-producing country;

(2) Great Britain has the largest colonial Empire in the world; and

(3) Great Britain is the greatest shipping nation in the world.

Dealing with (1), Great Britain has had, at least until to-day, no natural liquid fuels of its own; it is an exclusively coal-producing country. Based on these statements, it has often been seriously put forward in recent times that England has no interest in the Diesel engine, and that it is against her most vital interest to participate in the development of this engine, as she would neglect her wealth in coal, and make herself dependent on foreign markets when using liquid fuels. England has made great progress in power generating with gas, whilst she has up to the present given relatively little attention to power generating with liquid fuels.

But the foregoing arguments in favour of coal are not correct; the contrary is true. England has the greatest interest in replacing the coal-wasting steam engine by the more economical Diesel engine, and this, firstly, because she can therewith effect enormous savings in her most valuable treasure—coal, and thus defer the exhaustion of her stock; and, secondly, because she can run her coal industry and the independent chemical industries on more economical lines, when using the coal in the more rational and refined way, as already mentioned. Finally, because she will also make herself free and independent of foreign markets for the supply of liquid fuels by using coal in this way, that is, by working the tars and tar-oils in the Diesel engine. It is not intended to imply that the whole demand of fuel for England could be produced in this way in the country itself, but through the inland production, increase of prices for foreign oils, and the establishment of trusts and monopoly companies will be prevented. In this sense independence is meant.

(2) It is not possible to foresee to-day what England can obtain for her Colonies from the Diesel engine; even when

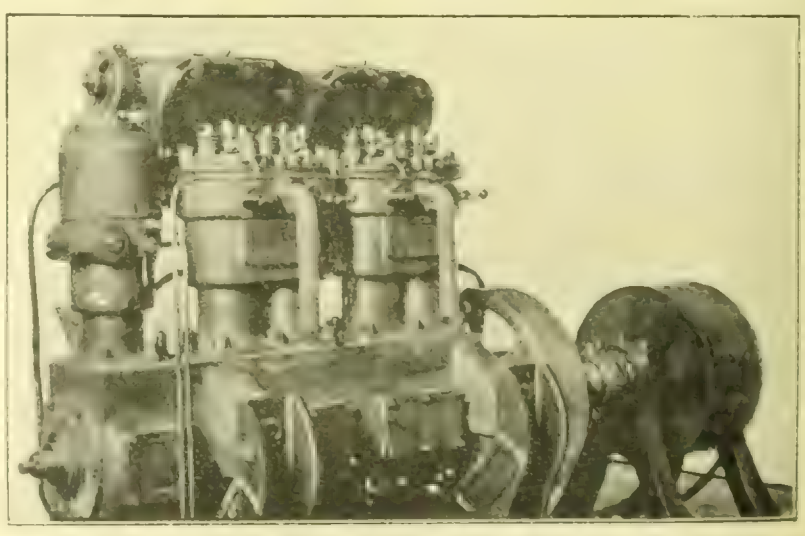


Fig. [illegible] Experimental Reversible Four-Cylinder Four-Stroke Cycle Type, [illegible]

using only the natural mineral oils, the Diesel engine is the predestined colonial engine, because only about the fourth or sixth part of weight in fuel has to be transported for it to the Colonies and their hinterlands, as compared with the steam engine. For a colonial engine the cost of freightage for fuel is generally the determining factor. Further, the transport of these liquid fuels is considerably easier and more convenient than the transport of coal, especially when tank vessels and pipe lines are used; and, finally, the difficulty of working

a boiler plant will only occasionally come into consideration in the Colonies, especially in the interior, except, of course, for small plants using wood, straw, and the like.

It may be mentioned, in this connection, that a pipe-line of 400 km. (about 250 miles) in length for crude petroleum is being built on the River Congo from Matadi to Leopoldville, by means of which this extensive district will be supplied, in the simplest and cheapest way, with a constant flowing fuel source, from which navigation and the railways, agriculture as well as other industries, will get their element of life, viz.,

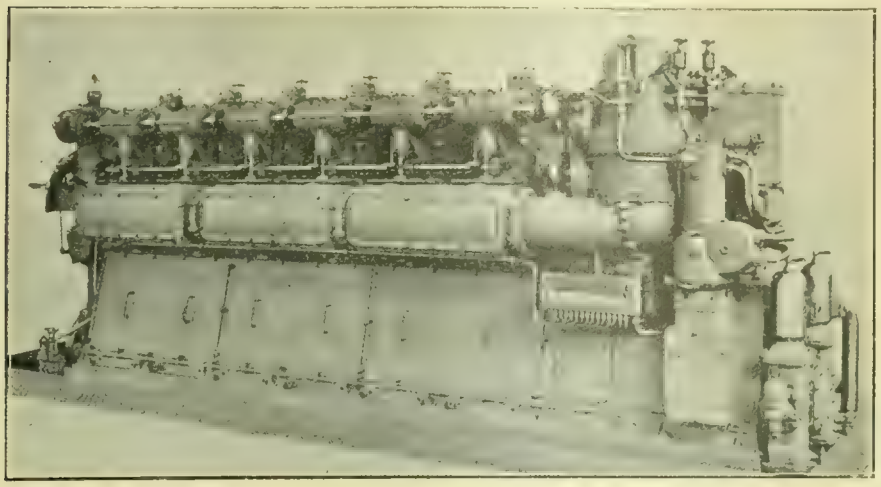


FIG. 17.—SIX-CYLINDER MARINE ENGINE. 300 R.P.M. 1911. SCAVENGING VALVES BELOW.

motor power. This magnificent example ought to be followed in the English Colonies; it is not necessary to specify in detail the great importance of such an undertaking for them.

If one also considers that the Diesel engine can utilise vegetable oils, entirely new prospects are brought to light for the cultivation and expansion of industry in the Colonies, which are for no other country of such eminent importance as for Great Britain; and this is where she ought to start as soon as possible. The Diesel engine can be worked with the Colonies' own resources, and thus again can influence to a great extent the further expansion of agriculture in districts where it is predominant. This sounds to-day somewhat like a dream, but the author ventures to prophesy, with full conviction, that this way of using the Diesel engine will one day be of the utmost importance.

(3) When the first successes of the Diesel engine, as a marine engine, were heard of in England recently, and it was published that already numerous small mercantile and war vessels were fitted with Diesel engines, and the possibility of more important plants was mentioned, and when it was realised that larger ocean vessels were destined to be fitted with Diesel engines, and that even a warship with a very large Diesel engine was in construction, it provoked a great movement and excitement in Great Britain, which is still fresh in our minds. Moreover, the reports about successful voyages with Diesel vessels under very difficult weather conditions are already increasing in number. The captains who have had Diesel engines on their vessels report on the great security and comfort in working; shipbuilders publish the figures of their savings. It is unquestionable that one of the greatest evolutions of modern industry will be connected with this development of the Diesel engine, and that Great Britain as the greatest shipping nation of the world will derive the greatest advantage from it.

APPENDIX I.

SUITABLE OILS.

The Swiss fuel-testing laboratory at the University of Zürich, under the direction of Prof. Constam, decided to undertake the examination of the qualities and composition of all liquid fuels which can be used for Diesel engines. These researches included the investigation of the following points:—

(1) On the physical properties, such as
- (*a*) Properties when cold,
- (*b*) Properties on heating (boiling analysis).

(2) Chemical properties, such as
- (*a*) Chemical constituents.
- (*b*) Percentage of H_2O and ash.
- (*c*) Calorific power.

From tests and examinations already made, power oils have been divided into the following three classes:

1. *Normal oils which can always be used:*

(*a*) Mineral oils freed from benzene (gas oils) - -	Hydrogen over 10 per cent. Calorific power over 10,000 cal (39,680 B.Th.U.) No solid impurities.
(*b*) Lignite tar oils - - -	Hydrogen over 10 per cent. Calorific power over 9,700 cal. (38,489 B.Th.U.)
(*c*) Fat oils from vegetable or animal sources, such as earthnut oil, castor oil, fish oils, &c.*	Scarcely any researches have been made on these. Earthnut oil has 11·8 per cent. hydrogen, and calorific power 8,600 cal. (34,124 B.Th.U.)

2. *Oils which can be used only with the aid of special apparatus:—*
- (*a*) Pit coal-tar oil.
- (*b*) Vertical-oven, water-gas, and oil gas tars, probably also coke-oven tars, the tests on which have not yet been completed.

General characteristics:

Hydrogen not over 3 per cent.;
Amount of free carbon not over 3 per cent.;
Residue on coking not over 3 per cent.;
Calorific power not under 8,600 cal. (34,124 B.Th.U.).

3. *Oils which cannot be used:*

Tars from horizontal or inclined retorts.

It must not be understood that these will not be used in Diesel engines under special conditions; but, on the whole, the above classification is accurate in the present state of development of the Diesel engine.

It is evident that for estimating the value of power oils, not only the above qualities, but all their chemical and physical properties must be considered, which is only possible after a thorough investigation of each kind of oil.

APPENDIX II.

SPECIFICATIONS OF TAR-OILS SUITABLE FOR DIESEL ENGINES.

(From the German Tar Production Trust at Essen-Ruhr.)

(1) Tar-oils should not contain more than a trace of constituents insoluble in xylol. The test on this is performed as follows: 25 grammes (0·88oz. av.) of oil are mixed with 25 cm.³ (1·525 cub. in.) of xylol, shaken and filtered. The filter paper before being used is dried and weighed, and after filtration has taken place it is thoroughly washed with hot xylol. After redrying the weight should not be increased by more than 0·1 gr.

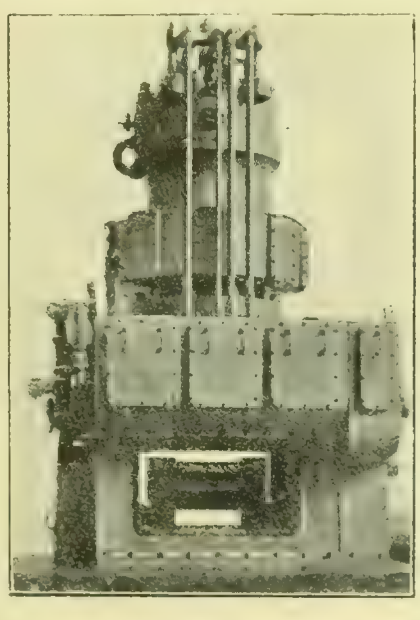


FIG. 18.—SINGLE-CYLINDER DOUBLE-ACTING TWO-STROKE CYCLE ENGINE. 1,200 H.P. 1911.

(2) The water contents should not exceed 1 per cent. The testing of the water contents is made by the well-known xylol method.

(3) The residue of the coke should not exceed 3 per cent.

(4) When performing the boiling analysis, at least 60 per cent. by volume of the oil should be distilled on heating up to 300° C. The boiling and analysis should be carried out according to the rules laid down by the Trust.

(5) The minimum calorific power must not be less than 8,800 cal. per kilogram. For oils of less calorific power the purchaser has the right of deducting 2 per cent. of the net price of the delivered oil for each 100 cal. below this minimum.

* This class of oil has been added by the author from his own investigations of earthnut oil.

(6) The flash point, as determined in an open crucible by Von Holde's method for lubricating oils, must not be below 65° C.

(7) The oil must be quite fluid at 15 C. The purchaser has not the right to reject oils on the ground that emulsions appear after five minutes' stirring when the oil is cooled to 8°.

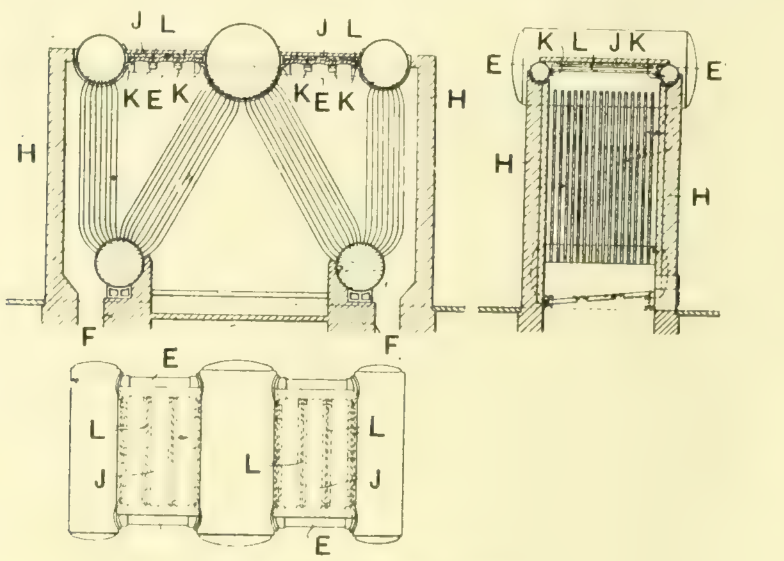
Purchasers should be urged to fit their oil-storing tanks and oil pipes with warming arrangements to redissolve emulsions caused by the temperature falling below 15° C.

(8) If emulsions have been caused by the cooling of the oils in the tank during transport, the purchaser must redissolve them by means of this apparatus.

Insoluble residues may be deducted from the weight of oil supplied.

KRUPP'S WATER-TUBE BOILER.

For the purpose of securing free expansion of the parts of water-tube boilers, in which upper and lower drums connected together by tubes are employed, the upper drums are usually suspended in a supporting frame in such a way that the nests of tubes can expand downwardly together with the lower drums. An arrangement of this kind, however, demands, especially in the case of large boiler constructions, a very powerful and consequently heavy and expensive supporting frame for the upper drums. In the design of boiler illustrated herewith, the invention of Fried. Krupp, Kiel-Gaarden, Germany, this heavy supporting frame is dispensed with. The boiler consists of three upper drums and two lower drums, which are connected together by four nests of tubes between



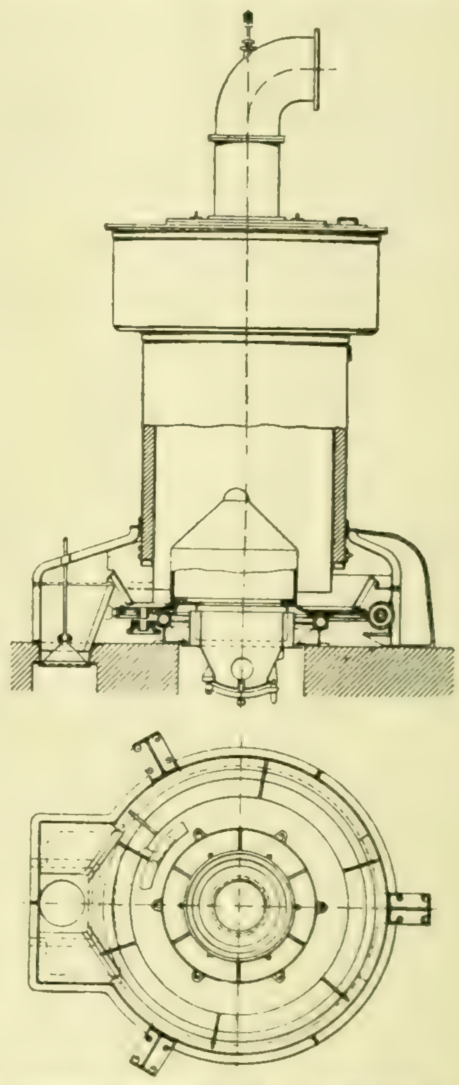
KRUPP'S WATER-TUBE BOILER

which is placed the furnace. The upper drums are connected to each other by two circulation tubes E of large diameter, and arranged transversely thereto. The lower drums are supported by cast-iron feet, upon the foundation F. At the sides and ends the boiler is closed in by masonry H, which reaches, with a slight amount of clearance, up to the periphery of the upper drums and the circulation tubes E. The boiler covering J is built into the spaces which are bounded by the upper drums and the circulation tubes, and is carried by these parts of the boiler. For this purpose the circulation tubes E have angle bars K riveted to them, upon which rest girders L running parallel to the upper drums. Against these girders are supported the arched portions which carry the fire-clay covering J. In this arrangement the lower drums, supported upon the foundations F, can expand freely upwards inside the masonry. The weight of the upper parts of the boiler and the boiler covering act in opposition to the tendency of the steam pressure to strip the upper and lower drums from the nests of tubes, so that the danger of the tubes becoming leaky at the points where they are rolled is, it is claimed, considerably diminished. In addition to this the heavy and expensive supporting frame, which has been hitherto necessary, is entirely dispensed with.

THE USE OF SMALL-SIZED FUEL IN THE GAS PRODUCER.

A DESCRIPTION of a Kerpely producer, especially designed to gasify small-sized fuel, together with a table showing some of the results obtained, were given in an article in "Stahl und Eisen" for December 28th, 1911. Many attempts have been made in recent years to develop a producer capable of gasifying successfully finely divided waste fuels; but usually tests of the producers advertised have quickly shown that the amounts of fuel gasified per hour and per square foot of shaft surface were unsatisfactory and that the ash contained considerable ungasified fuel. The chief problems involved are: First, the great resistance which the small fuel offers to the passage of the blast; second, the production of ash sufficiently free from combustible material.

Many tests have been carried out with an ordinary Kerpely gas-producer plant to determine the lowest limit in size of fuels which will allow successful operation. Varying results were obtained. More fine material can be used in the case of caking coals than with other fuels; and, generally speaking, with a caking coal varying in size from fine dust to pieces 0·59in. diam. satisfactory results can be obtained with about 40 per cent. to 50 per cent. fines under 0·197in. diam. This because the caking changes the size of the pieces and to some extent makes a coarse material.



KERPELY HIGH-PRESSURE GAS PRODUCER

With fuels such as coke breeze, brown coals, semi-anthracites and anthracite with much dust, there is difficulty with 20 per cent. of material under 0·197in. diameter. The condition of the fuel plays an important part, for if the last-named fuels have much moisture the driving off of this moisture in the upper part of the producer often causes them to decrepitate, and consequently increases the percentage of dust. When this happens it is always more difficult for gasification to take place over the whole cross-section of the producer. The amount of fuel gasified per unit of time and the quality of the gas sink very quickly with increasing dust contents, and the fuel actually used is low in amount because of the large percentage found in the ash.

For a long time tests have been carried out at the plant of the Oesterreichisch Alpinen Montangesellschaft at Donawitz with a small gas producer of 43·3in. diameter. The final results were so favourable that a larger producer, 78·7in. in diameter, has been built based on the same principle. The fuel used is breeze from blastfurnace coke, and the producer has been in continuous operation since it was built. It is shown in Fig. 1, and is called a Kerpely from the name of the inventor. It is a revolving grate producer with the lower part completely closed. The blast passes through the many fine openings of the specially constructed grate at a pressure varying from 15·75in. to 27·56in. of water, depending on the size of the fuel. It is distributed in many fine streams over the whole section of the producer, and because of the force

with which it comes in contact with the fine particles of fuel brings about complete combustion.

The ash is collected by means of a very simple automatic arrangement in a pit arranged with a bell. This is emptied two or three times a day, depending on the kind of fuel used. The lower part of the shaft of the producer is formed of a water-cooled mantle that passes into an upper and somewhat wider part lined with firebrick, which carries a central combined gas main and charging arrangement.

Due to the great interest taken in this producer extensive tests were carried out with other fine fuels, the results of which are given in the accompanying table. The analyses were made on large samples weighing about 100lbs. The gas analyses were made on samples taken hourly in the daytime and once before and once after midnight. The values given are average results. The pressure of the gas taken at one of the poker holes amounted to 0·59in. to 0·78in. of water, and so was rather under than over the normal. Because of this the amount of dust in the gas was also very low.

Table of Results obtained with Small Sized Fuels in a Kerpely Gas Producer.

Kind of Fuel.	Breeze from Blastfurnace Coke.	Breeze from Gasworks Coke (strongly clinkering).	Coke Breeze from Orlan.	Coal Dust from Orlan (caking).	Coal Dust from the Dump of the Oheim Mine.	Brown Coal Briquettes.
Size—inches—Above 0·472 diam.	8·5 per cent.	2·2	6·2	6·2	4·4	Brand
„ „ 0·315 to 0·472 diam.	10·6	20·4	6·3	11·3	10·1	"Union,"
„ „ 0·197 to 0·315 diam.	24·4	21·6	12·8	20·0	23·9	pieces
„ „ 0·118 to 0·197 diam.	19·5	17·2	16·2	19·0	20·1	weighing
„ „ 0·039 to 0·118 diam.	25·6 } 56·5	26·2 } 55·8	33·8 } 74·7	25·5 } 62·5	30·4 } 61·6	about
„ „ 0·019 to 0·039 diam.	7·6	7·6	12·1	8·1	7·0	5·54 oz.
„ „ below 0·019 diam.	3·8	4·8	12·6	9·9	4·1	
Analysis of Fuel :—						
Carbon, per cent.	69·42	68·60	71·30	66·10	60·97	56·70
Moisture, per cent.	5·44	2·40	10·10	3·60	9·25	10·80
Ash, per cent.	18·25	24·40	13·00	14·80	14·60	5·22
Heating value of fuel in B.T.U.	10144·8	10548	10854	10260	10170	8802
Amount gasified in 24 hrs. in lbs.	19180	20062	17637	25573	21385	46297
Average analysis of the gas, per cent. CO_2	5·57	7·9	7·5	4·71	5·18	4·40
Average analysis of the gas, per cent. CO	26·90	23·4	23·45	26·32	26·66	29·80
Average analysis of the gas, per cent. CH_4	-	-	0·60	2·80	1·90	2·70
Average analysis of the gas, per cent. H_2	11·91	12·5	12·20	12·10	15·01	11·90
Lower heating value of the gas, B.T.U. per cu. ft.	125	116	121	151	152·4	159
Amount of carbon of the fuel lost in ash	1·8 per cent.	2·2 per cent.	4·2 per cent.	2·25 per ct.	2·60 per ct.	0·2 per cent.
Tar and dust in the gas. Grains per cu. ft.	0·655	1·18	1·57	not determined	4·63	not determined
Blast pressure, inches of water	13·78 to 17·72	15·75 to 19·68	19·68 to 27·56	17·72 to 19·68	22·83 to 26·77	9·84 to 13·78

The table also shows in the last column the results obtained with a several days' test of brown coal briquettes from the Rhine provinces. As is well known the hygroscopic property of the ash from these briquettes, containing over 50 per cent. lime, gives trouble in ordinary plants. The water and the ash form a gummy mass that easily stops up the grate openings if the fire zone is too high. Because of the special grate construction of the new producer and the fact that no water seal is used these difficulties did not appear and the test gave splendid results in every respect. Before the test the producer was filled with burnt lime to somewhat above the peak of the grate in order to prevent the action of foreign ash on that of the briquettes. The results certainly lead to the conclusion that this type of producer has made possible an important step forward in the use of lower value fuels.—"The Iron Age."

TWO NEW DREADNOUGHTS.

DURING the past week two new battle-ships for the British Navy were launched, the "Queen Mary," from the yard of Palmers' Shipbuilding and Iron Company, Jarrow-on-Tyne, and the "Ajax," from the yard of Scotts' Shipbuilding and Engineering Company, Greenock. The "Queen Mary," which was laid down on March 6th, 1911, although of the same class as the "Lion" and "Princess Royal," is an improvement over both these vessels. Her dimensions are: Length 660ft., breadth 88½ft., draught 28ft., displacement 27,000 tons. The horse-power is 75,000, at 275 revs., and the designed speed 28 knots. The armament consists of eight 13·5in. guns in four turrets on the centre line of the ship and an anti torpedo defence battery of 16 4in. breech loading guns. The protection comprises a main belt, 9in. thick, surmounted by another belt of 6in. thickness, while there will also be 9in. armour on the heavy guns. The propelling machinery is of the Parsons turbine type, and is being supplied by Messrs. John Brown & Co., Clydebank, who are also making 28 of the 42 Yarrow boilers required, the remainder being manufactured by the builders of the hull. There are four shafts, each of the wing shafts having a separate high-pressure ahead and an astern turbine, while on each of the centre shafts there is one turbine casing, combining the low-pressure ahead and the astern rotors. The "Ajax" is of the same type as the "King George V." The class to which the "Ajax" belongs displace slightly over 23,000 tons, and have a length of 555ft., and a beam of 89ft. The shaft horse-power is understood to be 31,000, and the designed speed 21 knots. As with all the Dreadnoughts, Parsons turbines are the type of propelling machinery used, and those for the "Ajax" are being manufactured by the Scotts' Company. The arrangement of the turbines corresponds with that in all recent British battle-ships. The boilers of the ship will be of the Babcock type. In the main battery are 10 13·5in. guns, mounted in five twin turrets on the centre line of the ship, while the guns for repelling torpedo attack are 20 of 4in. calibre. The keel of the "Ajax" was laid on February 27th, 1911.

Iron Ore Concentration Methods.—At a recent meeting of the West of Scotland Iron and Steel Institute, held in Glasgow, a lecture was delivered by Prof. Henry Louis, of the Armstrong College, Newcastle-on-Tyne, on "Magnetic Methods of Concentrating Iron Ore." The lecturer dealt with the principles upon which magnetic concentration depends, and described the various separators which may be used on an industrial scale. Many ores, he explained, were commonly called magnetic on account of the fact that they might easily be separated by a magnet without further preparation. Others were non-magnetic, but many of these could by the simple process of calcination be rendered magnetic. The subject of the concentration of iron ores is of special interest at the present time in view of the fact that Prof. Louis has recently been successful in concentrating Cleveland iron ore by this method, and that the same treatment may possibly be adopted with advantage in the case of the recently discovered deposits in Raasay, which are similar in many respects to the Cleveland ore. The lecture was illustrated by experiments and lantern slides.

ON THE WIDER ADOPTION AND STANDARDISATION OF WATER-TUBE BOILERS.*

BY M. E. SPEAKMAN.

(*Concluded from page 365.*)

Size of Unit.—In no direction has the advance of water-tube boilers made such strides as in the individual size of unit. The first Yarrow boiler, fitted in H.M.S. "Hornet," had a heating surface of 1,027 sq. ft., and a grate surface of 20·5 sq. ft.; while the corresponding Thornycroft boiler had a grate surface of 47·3 sq. ft., though this was divided into two furnaces, as in the modern Schulz type. The early Belleville boilers varied between 53 sq. ft. and 58 sq. ft. of grate surface, and burned on an average about 26lbs. of coal per square foot per hour. The large-tube Yarrow boilers, which first made their appearance in the "Swiftsure" class,† were of 53 sq. ft. each, a figure from which the large-tube type varied but little until it recently followed the general tendency to increase. The earlier Babcock & Wilcox boilers in this country were of 64 sq. ft. per unit, and this has gradually been increased to about 90 sq. ft. per unit, burning about 22lbs. to 24lbs. per square foot of grate. In the United States Navy, where, compared to English practice, larger and fewer units are generally fitted, some of the earlier Babcock and Wilcox boilers were of 96 sq. ft., rising to 103 sq. ft. in the "Delaware" class, and 119 sq. ft. in the "Utah" class, and burning from 30lbs. to 36lbs. of coal per square foot of grate per hour. In the small-tube 3-drum type of 12 years ago from 55 sq. ft. to 60 sq. ft. was common. More recent boilers for small craft have risen first to 70 sq. ft. and later to 85 sq. ft. In the recent United States torpedo-boat destroyers 90 sq. ft. is common; in the German torpedo-boat destroyers 100 sq. ft., and in one case 125 sq. ft. in a two-furnace unit, has been adopted. This boiler is about 22ft. wide over the lower drums. The largest individual coal grate of the author's experience in this country is in a White-Forster boiler recently built at Birkenhead for a foreign torpedo-boat destroyer, and which has 111 sq. ft. Messrs. Yarrow's double-ended boilers for the Brazilian torpedo-boat destroyers of the "Matto Grosso" class exceeded this, but in their case the furnace was completely divided transversely into two separate parts by a brick wall, and the individual grates of this double-ended boiler did not exceed 70 sq. ft. These exceptional areas, except for the double-ended type,† are quite outside mercantile use, but are quoted as examples of limiting size in coal units. A reasonable average of from 70 sq. ft. to 80 sq. ft. of grate in a 3-drum type is a feasible project in small mercantile vessels, but for economy the coal burnt per square foot of grate per hour should be between the economical limits of the large and small tube types, say, from 30lbs. to 40lbs. per square foot, although these boilers at full power burn easily 25 per cent. more for long periods. Strictly speaking, the size of coal-fired units rests entirely on the maintenance of clean, level fires on a large grate; 120 sq. ft. is exceptionally large, and is only possible with most systematic stoking and picked fuel. Even so, no difficulty has been experienced in keeping good fires either on 110 sq. ft. on one grate or 125 sq. ft. on a Schulz grate when burning about 60lbs. per square foot of grate per hour. Such a consumption is only possible for a short period, say from 6 to 8 hours, without considerable cleaning, and for runs of 100 hours—an Atlantic passage—a much lower consumption per square foot would, of course, require to be adopted. Obviously, for short run routes, larger grates might be adopted than on the ocean services.

When oil fuel is used instead of coal, the question of firing is of vastly less importance, and greatly lessens the limitation of size of unit. In fact, this might almost then be determined by the loss of power due to an accident to one unit forming too great a proportion of the evaporating plant. Oil-fired boilers of from 6,000 sq. ft. to 7,000 sq. ft. of heating surface are now common. The largest individual boiler of which the author has experience is the unit in the Argentine torpedo-boat destroyers of the "San Luis" class, built by Messrs. Cammell Laird, & Co., at Birkenhead, which has a heating surface of 8,500 sq. ft. It is of the single-ended White-Forster type, and has a combustion space of 915 cub. ft. With 5in. air pressure it has generated from feed water at 212° Fah., about 120,000lbs. of steam per hour at 230lbs. pressure, without the slightest difficulty of operation or adverse effect on the boiler. The two tube rows nearest the fire are 1¼in. diam., the 20 others are 1in. diam.; the upper drum is 4ft. 8in. diam. Transversely overall the boiler measures 19ft. Probably this is the largest boiler yet made, but experience of it indicates that oil-burning units having from 10,000 sq. ft. to 12,000 sq. ft. of heating surface are perfectly possible, and, with adequate combustion space, would be even more economical. Boilers of such a size, however, should have oil burners at each end, as in the latest German practice. The "San Luis" boiler referred to has an evaporative value exceeding 14 when burning 1lb. of oil per square foot of heating surface. At 12lbs. per shaft horse-power, this is equal to 10,000 h.p. from one unit. Eight such boilers would produce nearly the same amount of steam as the "Lusitania" required on trial! The author would have no hesitation in building for naval work a 12,000 sq. ft. double-ended oil-fuel unit, but other considerations than individual full power limit the advisability of such immense boilers.

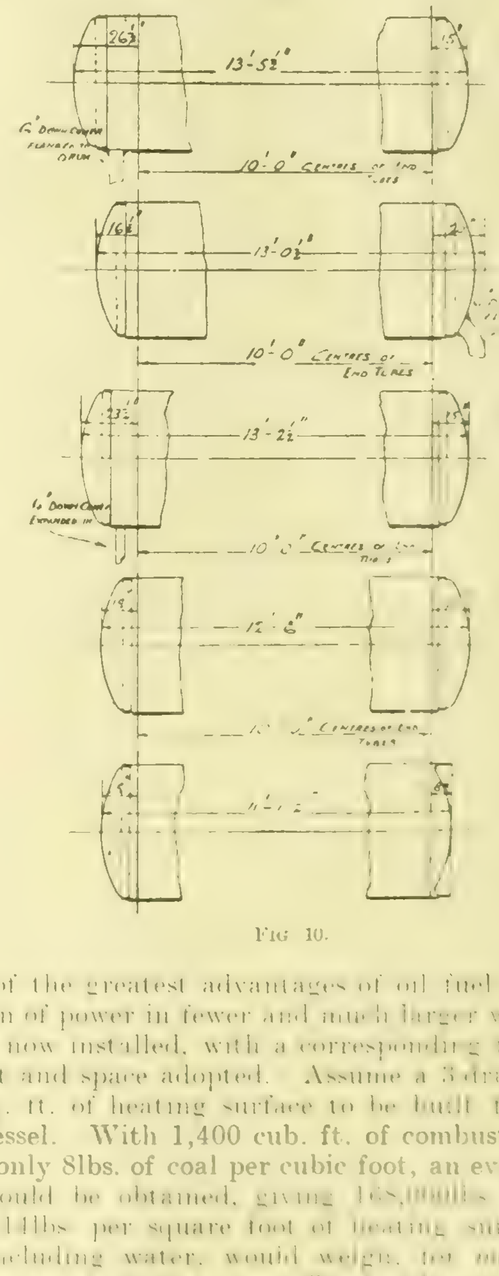


FIG. 10.

One of the greatest advantages of oil fuel lies in the concentration of power in fewer and much larger water-tube units than are now installed, with a corresponding immense saving in weight and space adopted. Assume a 3-drum unit having 12,000 sq. ft. of heating surface to be built for a large passenger vessel. With 1,400 cub. ft. of combustion space, and burning only 8lbs. of coal per cubic foot, an evaporation of 15 times should be obtained, giving 168,000lbs. per hour per unit, or 14lbs. per square foot of heating surface. Such a boiler, including water, would weigh, for merchant service requirements, about 80 tons. The fuel burnt per hour would amount to 5 tons.

Possible Modification in Design and Standardisation.—The wide divergences in the conditions accepted by Admiralties and registration Societies are not easily mergeable into one conglomerate whole, because the policy of the former must essentially be to accept those very risks that the latter must strive to avoid, and the differences reasonably have been, and are at present, too great for the respective margins to overlap. This is a position which, perhaps, a comparatively small change in the engineering policy of both sides would go far to eradicate. Reference to Table II. shows the percentage weight of naval boilers to be so low in some cases that an appreciable addition

* [illegible]

† H.M.S. [illegible] Boiler Committee Report [illegible]

would hardly affect the ship as a whole. Torpedo-boat destroyers are not included in this remark, owing to their exceptional nature, but such an addition might render it possible to strike a mean between commercial efficiency, reliability and durability on the one hand, and adequate steam production in relation to the low weight and capability for forcing that, at times, is so essential to naval engineering on

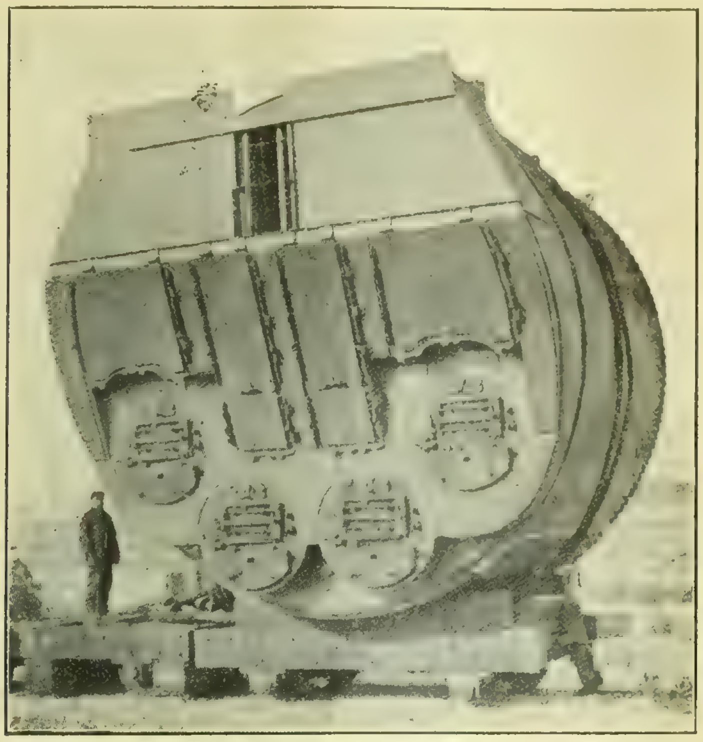


FIG. 11.—SINGLE-ENDED BOILER.
17ft. 6in. in diameter, 215lbs. pressure.

the other. With the ever rapidly increasing size and speed of ships, greater power on less weight is essential. The oil engine, whatever its future, cannot at present offer any solution for large powers. Since the turbine has rendered main engine overhaul in port a matter of rapidity and relatively of small importance, the principal factor influencing the time required to turn round on the high-speed services is now that of boiler attention and the stowing of fuel. Two great questions arise in this connection. Is oil or coal to be the fuel for high-speed vessels; and, if the former, what is to be the type of boiler? Obviously, these queries are restricted to special classes of vessels—those in which the machinery element is a larger proportion of the ship. It must also be remembered that cylindrical boiler troubles are by no means as scarce as is often supposed. Comparatively little progress, perhaps, has been made in this design for some years past, whereas the water-tube boiler has distinct potentialities before it. At the lower limit of pressure, the advances made in condenser design in the last decade offer little scope for improvement in economy; higher initial pressures are then the only resource, and while the cylindrical boiler may not have reached its zenith, its weight in relation to its steam production cannot be reduced.

Of water-tube boilers applied to merchant work, of course the Babcock & Wilcox boiler is, so far, the most widely used, especially abroad; incidently, in foreign countries economy of fuel is, perhaps, even more seriously considered than in this. This boiler in its own type has reached a very high degree of standardisation and efficiency, and the variations in design and scantlings between the naval and mercantile type are insignificant. As regards the rather lighter 3-drum type, there are few instances of its application, in spite of its obvious suitability. Several features in its design recommend it, provided that the curvature of the tubes is either small, as in the White-Forster type, or nil, as in the Yarrow type.

The first modification to render the latter acceptable to registration societies will probably be in the thickness of tubes and their diameter. The German Navy adopts a standard tube of 36 mm. outside diam., and 3 mm. thick, that is, 1$\frac{3}{8}$in. (full), and between 10-11 L.S.G. This is distinctly lighter than the United States 1$\frac{3}{8}$in. tubes. The adoption of large tubes of 1$\frac{3}{4}$in. diam. for large vessels, and small tubes of 1$\frac{1}{8}$in. diam. for small ships does not seem logical at first sight, nor, unless it has been purely evolutional, does the use of tubes varying in one-sixteenths of an inch in diameter. There is no doubt that a tube of 1$\frac{3}{4}$in. diam. of 9 L.S.G. should last longer than one of 1$\frac{1}{8}$in. diam. of 11 L.S.G., but not necessarily longer if that tube be increased to 10 L.S.G., that is, from ·116in. to ·128in. thick. A point of no little difficulty to arrive at will be the diameter of tube. To abandon the smaller sizes reduces the weight advantage and capacity for higher consumptions per unit of grate surface. The larger tubes admit of easier cleaning. It is in the excellence of the quality of the tubes, their treatment, and the workmanship lavished on their installation and preservation that the required durability of the boiler will largely depend. In view of recent naval experience, there should be no need to doubt that a design based on mercantile service requirements would prove suitable, provided that ample care was taken in regard to the quality of tubes accepted.

Merchant service fire-bars, doors, and casings will be required as well as heavier brickwork than is found in naval boilers. The drums and ends of the usual boilers will probably require thickening, and they might also be somewhat increased in size with advantage. Funnels and uptakes will remain as before. Nevertheless, in spite of this, the weight saved—of which the gain is largely in water carried—will still be very considerable. As a set-off against the additional weight, the downtake tubes outside the boiler might well be dispensed with, though builders are not in agreement on this point. It will be seen from Fig. 10 what difference in overall length to the same boiler is made by the adoption of these tubes. It is very doubtful if any economical advantage is gained from them. For boilers with sharply-curved tubes, in which the flow of water must necessarily be less rapid than in straight tubes, they are probably necessary, but the former type is not here considered. Table IV., compiled at random from various types, shows how little consistent relationship there is between the areas of these external pipes and of the generating tubes. That one boiler capable of producing three times the amount of steam as another should have the same size and number of downtake tubes as the lower-powered one, seems to indicate that external pipes are quite unnecessary in Yarrow-type boilers.

A further advantageous modification, which is, perhaps, an adaptation from condenser design, would seem to lie in a greater variation of longitudinal tube pitching between the fire rows and the outside tube rows. General practice is for the two fire rows to be of slightly greater diameter, and consequently further apart than the remainder. For instance,

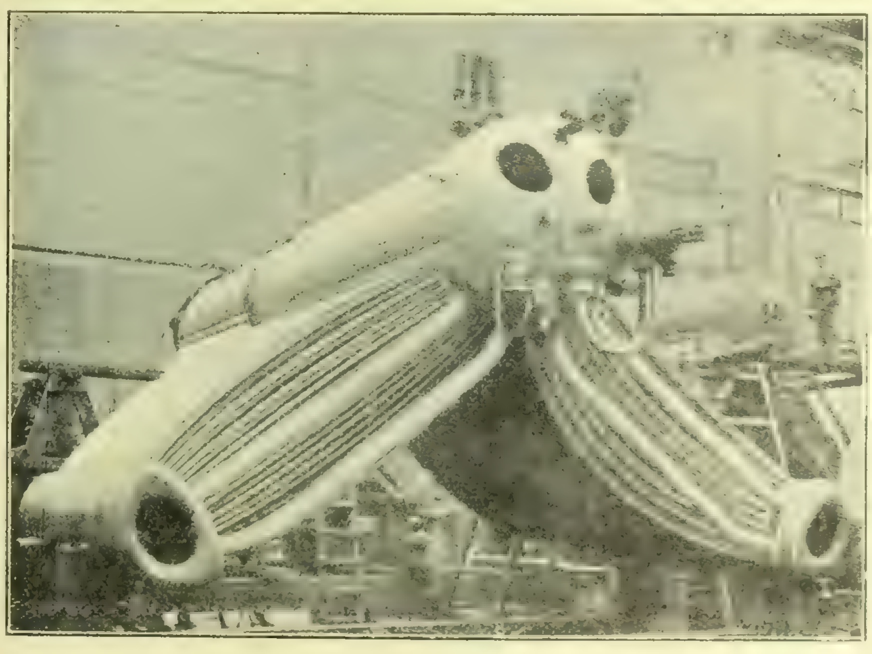


FIG. 12.—COAL-BURNING BOILER OF 110 SQ. FT. GRATE.
White-Forster Type, Generator portion only erected in shop.

in a 20-row nest, the two fire rows may be 1$\frac{3}{8}$in. diam. with a longitudinal pitch of 1$\frac{15}{16}$in. the remaining 18 being all 1$\frac{1}{8}$in. tubes, pitched 1$\frac{11}{16}$in. In the larger units that seem probable in future, greater economy might possibly be maintained by making, in a 24-row boiler, a variation both of tube diameter and pitch, such as six, eight, and 10 or five, seven, and 12 rows, the latter being the outer ones, though obviously this

would involve greater trouble in manufacture, and in cleaning after use. The temperature drop, however, across a nest of water-filled tubes is so great, and the consequent volume of gas so greatly reduced, that investigation in this line would seem to be worth undertaking. Just as existing furnaces are standardised, in view of the present amount of repetition work in boiler manufacture, so the corresponding portions of water-tube boilers can be. Upper drums, except for special cases, vary little in diameter and need vary less. Bottom reservoirs, consequently, as well as the chamber ends, could also, as far as

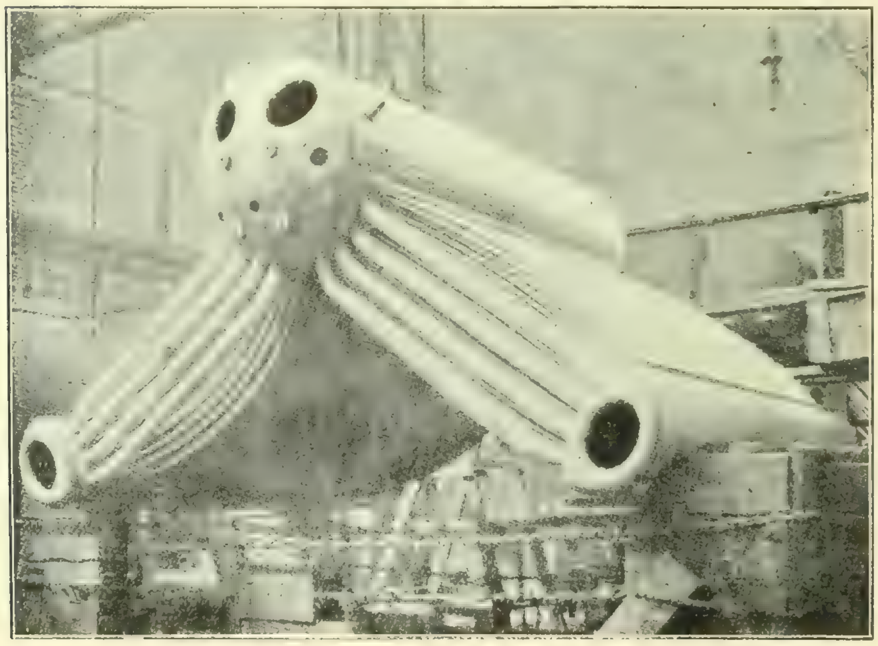


FIG. 13. OIL-BURNING BOILER, 8,500 SQ. FT. HEATING SURFACE. Generator portion only erected in shop.

radius and thickness, be brought to a greater state of similarity. In England and the United States, top and bottom drums are made of riveted plates; in France and Germany, especially the latter, they are often made solid drawn or welded in the circular form necessary for the bent tubes employed.

TABLE IV.

Boiler	Heating surface, square feet.	Steam production, lbs. per hour.	Lbs. steam per square foot heating surface.	Rates of downtake area. Generating tube area.	Type of ship and fuel.
A	3,660	28,700	7·55	4·18	Cruiser, coal
B	4,200	31,500	7·5	4·21	Cruiser, coal
C	3,750	25,000	6·66	3·15	Battle-ship, coal
D	5,100	46,000	9·0	4·5	Destroyer, coal
E	6,400	80,000	12·5	3·03	Destroyer, oil
F	8,500	130,000	15·2	4·9	Destroyer, oil

APPENDIX I.

Of the cases of vessels whose boiler weight is relatively great in proportion to the displacement, it is interesting to take two cases in order to analyse the problems involved.

LARGE FAST LINER—"LUSITANIA" TYPE.

The existing arrangement comprises 23 d.e. and 2 s.e. cylindrical boilers of 17ft. 6in. diameter, with a heating surface of 158,350 sq. ft. and a grate surface of 4,048 sq. ft. The steam production, when burning about 24lbs. per square foot of grate per hour, is about 1,000,000lbs. per hour, or, say, 250lbs. per square foot per hour. The coal used for this is about 44 tons per hour, costing on an average perhaps £35 per hour for fuel.* Of the steam production, 15 per cent. is used by the auxiliary machinery. The actual ratio of evaporation, with speed at 196° Fah., is 10·2; that is 10·9 from and at 212° Fah.†

By adopting a combustion rate of 36lbs. per square foot of grate per hour for Yarrow boilers, and allowing for a corresponding ratio of evaporation equal to 9·5, 342lbs. of steam per square foot of grate per hour should be obtained, and for the same steam production 2,920 sq. ft. of grate and 161,000 sq. ft. of heating surface would be required if the ratio of heating surface to grate surface = 55 : 1. This would entail a coal consumption of 46·9 tons per hour at a cost of £37·5. Apart from coal burnt in harbour, if the vessel is credited with 30 single trips a year, of 120 hours each, the additional cost for fuel would be—

$$£2{\cdot}5 \times 30 \times 120 = £9{,}000 \text{ per annum}$$
$$= £300 \text{ per trip, and the extra weight to be carried would be}$$
$$2{\cdot}9 \times 30 \times 120 = 10{,}450 \text{ tons per annum}$$
$$= 348 \text{ tons per trip.}$$

At first sight these figures, due entirely to the assumed lower evaporation value of the three-drum type of boiler, appear rather formidable.

To instal 2,920 sq. ft. of grate would require 40 boilers of 73 sq. ft. each, though 46 of 63·5 sq. ft. each would correspond better with the existing arrangement. As a steady steaming unit burning 36lbs. per square foot of grate per hour an area of 73 sq. ft. is probably just about as large* as could be conveniently handled under the circumstances. In this connection reference might be made to the double-ended boilers† of this type which has been adopted in a few torpedo-boat destroyers, but in no larger vessels, and is not considered here, although it is hard to see why, if a single-ended boiler will do, a double-ended one should not equally be adopted with the consequent avoidance of one of the principal objections to the single-ended type—that is, multiplicity of units. When the additional steam and feed piping, uptake connections, &c., are considered, together with the greater supervision necessary, it must be admitted that the increased number of units introduces a distinct objection to the adoption of water-tube boilers, unless large units are accepted.

Again, the "Lusitania" double-ended boilers are 22ft. long. The length of the boilers proposed would not be less

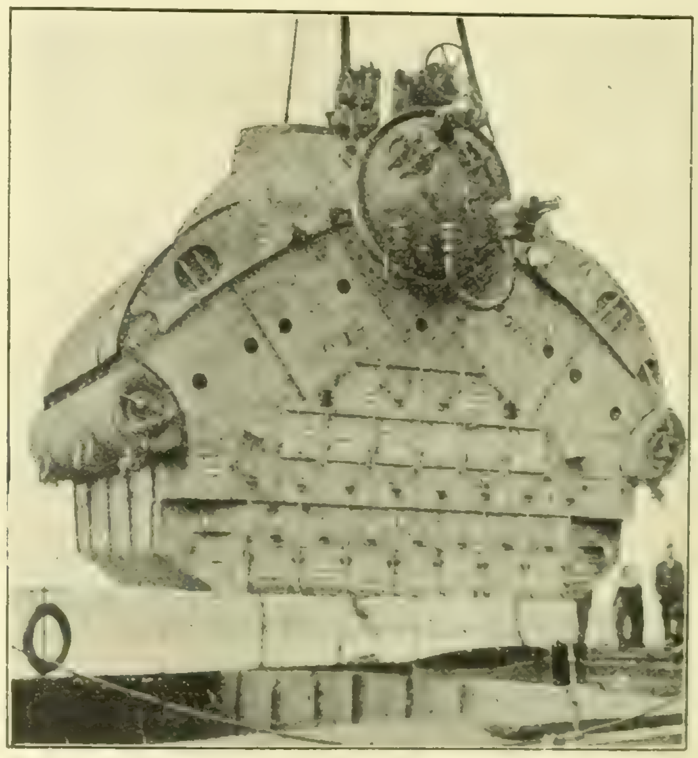


FIG. 14—OIL BURNING BOILER, 8,500 SQ. FT. HEATING SURFACE. White-Forster Type, being put on board

than 12ft. each, with, say, 1ft. 3in. between them, so that they would require an additional frame space in each stokehold—say 32in., because it would not be advisable to reduce the existing length of firing space in a ship of such size. The objection to increased length rather emphasizes the desirability of double-ended boilers, and the adoption of the water-tube

* The cost and quality of coal used by the large liners fluctuates considerably; 16 shillings a ton in the bunkers is not an excessive figure as an average.

† See Mr. Thomas Bell's paper, Trans. Institution of Naval Architects, 1908.

* Many of the U.S. battleships, fitted with Babcock & Wilcox boilers, have grates of 120 square feet, and burn as much per square foot on trial, but this is of short duration.

† In a paper presented to the Institution of Naval Architects in 1897 by Mons. Sigaudy, the suggestion was made to fit double-ended water-tube boilers to ocean liners.

type is in itself a sufficiently large step to render these a relatively less risky additional experiment. The number of units would then be the same as at present, except for the two double-ended and two single-ended boilers forward. Assuming, however, the adoption of 40 single ended boilers, the weight of generators only, even with increased scantlings, would amount to about 1,800 tons, a saving probably of 2,200 tons on the existing design, against which is set the additional 350 tons of coal, reducing the total to a net amount of about 1,800 tons. The lower weight of seatings may be assumed to counter-balance the increased weight of connections.

There are then the following advantages:—

(1) A slight saving in fore and aft space of about 8 frame spaces, or
(2) A gain of 1,800 tons for cargo, at, say, 10s. per ton per trip, or
(3) A vessel of 34,200 tons, against 36,000, or
(4) A draught of water reduced from 32ft. 9in. by at least 12in., or
(5) A slightly finer ship, together with rather less power required, or, vice versa, higher speed.

disadvantages, which, by the way, are probably more anticipated than actual, as modern naval practice goes far to prove, the influence of reduced weight on a ship as a whole is so great as to render it difficult to form an absolutely definite opinion without most careful investigation of the details involved. The attraction of such a saving is very tempting.

The use of oil fuel should not be overlooked in conjunction with the proposed boilers, as with the large units possible the combined influence on the design of ship is enormous. With oil fuel the stokehold complement would at once be reduced to one-fifth of the present number, and the simplification in stokehold design should go far to balance the higher cost of water-tube boilers. If the arrangement of the "Lusitania's" three after stokeholds were retained, each containing six boilers, each of the 18 would require to supply about 56,000lbs. of steam per hour. This would mean relatively small units, and 12 boilers providing 84,000lbs. apiece would be more suitable. An evaporation of 15 times at 200° Fah. feed temperature should be obtained, requiring 5,600lbs. of oil per boiler per hour. By burning 8lbs. per cubic foot, units of 7,000 sq. ft. of heating surface, and 700 cub. ft. of combustion space would suffice. This should enable the vessel to be built

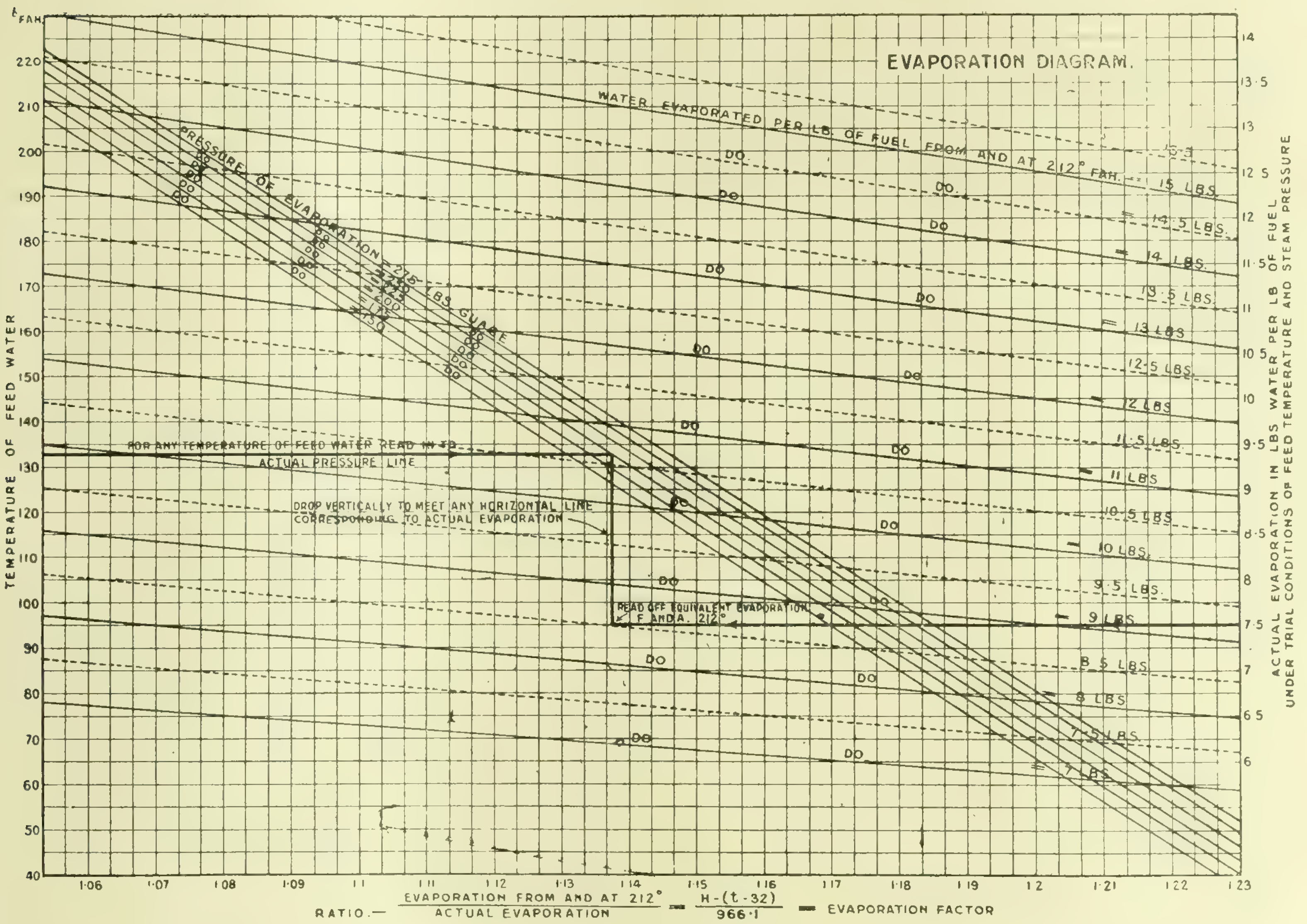


Fig. 15.

It is assumed that it would be possible to stow the extra 350 tons of coal with very slight rearrangement of bulkheads, because the overall width of the boilers proposed would only be 16ft. 6in., against the existing 17ft. 6in., and that this, in conjunction with any cargo carried, would probably sufficiently compensate for the altered centre of gravity of machinery.

If only half the available cargo space were filled, the additional revenue would be, say, $900 \times 30 \times £0{\cdot}5 = £13,500$, reducing the additional fuel bill from a loss of £9,000 to a gain of £4,000. But it is, in the author's opinion, still doubtful if the case for Yarrow or other water-tube boilers is not under-stated.

In the event of double-ended boilers being adopted, the efficiency would probably be even higher, and the weight saved rather more. In any case, apart from any practical

with two funnels instead of four at a large gain of passenger accommodation, and to carry only 60 per cent. of the fuel now required. With the enormous gain in weight of boilers and fuel, together with the smaller space occupied, any additional cost in maintenance, or doubt as to regularity of supply, must assume an aspect of relatively small amount.

Channel Steamers.

In the case of Channel steamers the considerations are very different. The longest run is barely four hours; economy is of relatively less importance, the dimensions of the ship are usually restricted, and the proportionate weight of cylindrical boilers is generally very high.

Several 23-knot Channel boats of about 2,700 tons and 12,000 s.h.p. have recently been built, carrying eight single-ended boilers of 180lbs. pressure, which weigh, say, 65 tons apiece, making together very nearly 20 per cent. of the total

displacement of the ship. When burning 36lbs. per square foot of grate surface per hour on 465 sq. ft., the evaporation is 9·6 times from feed at 120° Fah., that is, 11·06 times from and at 212° Fah. For Yarrow boilers, burning 40lbs. per square foot, an evaporation of 10·5 times is assumed, and is equal to 9·15 times at 120° Fah. In the former case the steam produced per square foot of grate is about 350lbs. per hour; in the latter 366lbs., necessitating 440 sq. ft. of grate surface. Six boilers, each with 73 sq. ft. of grate surface and 3,800 sq. ft. of heating surface, would be sufficient. Increased to Board of Trade scantlings they would weigh about 33 tons apiece with water—say, 200 tons in all, or a gain of over 300 tons, which is more than 10 per cent. of the displacement.

The reduction in power possible would be

$$12{,}000 \times \frac{2{,}400\frac{2}{3}}{2{,}700\frac{2}{3}} - 11{,}050$$

which again would admit of a further reduction in weight of boilers of 20 tons.

The vessel is 350ft. by 41ft. by 13ft. draught. As in the larger ship, the saving can be applied in many ways. The alteration to centre of machinery weight is more serious in this case, and the engines and boilers would require to be moved bodily forward.

If the saving be used for additional cargo, this matter is of less importance. If it be used to fine and lighten the vessel, an obvious saving in fuel burnt must result. Fore and aft space will be saved to the extent of six frame spaces, rendering a rather smaller ship possible.

If oil fuel is burnt in place of coal, the number of boilers would be reduced to four, and the heating surface also reduced considerably. In fact, to produce 12lbs. of steam per square foot of heating surface from feed at 120° Fah. would require four boilers of less than 3,500 sq. ft. each. In this case the gain in the ship as a whole would be very great indeed. Instead of two funnels, only one need be fitted. The size and initial cost of the vessel are reduced. The total fuel burnt per hour in the original design at full power is about 7·5 tons, which would be equal to 5·5 tons of oil, or, say, rather under 5 tons with the reduction probable in the ship.

The monthly requirements for such a service would be such that no difficulty should be experienced in obtaining a regular supply of oil.

APPENDIX II.—OIL FUEL.

Two-thirds of the world's present oil supply comes from the United States, the larger portion being Californian; Russia supplies 24 per cent., the remaining 10 being very widely distributed over about 15 different countries. The total production of oil in 1905, the year when oil fuel alone was adopted for certain of H.M. ships, was about 37,000,000 tons; in 1911 it was nearly 53,000,000 tons. For United States oil fuel, as used in Europe, a calorific value of 19,400 B.Th.U.'s per pound is a fair average, giving an equivalent evaporation from and at 212° Fah. of 20·1lbs. of water. The cost in England is now about one-half of what it was five years ago. The tendency for the sources of supply to increase is still accompanied by a slight reduction in cost per ton.

The two principal objections to the use of oil fuel are:—

(1) *Uncertainty of Supply.*—The United States are in a very strong position in regard to oil fuel, and the decision of the United States Navy Department to instal an oil burning system only in their last two battle-ships is very significant; the potential advantages of doing so are greater for them than for anyone else. Oil-burning European liners would require to take in fuel on the American side, and the certainty of being able to do so is perhaps rather doubtful, compared with the United States Navy supply. A number of large fast liners burning oil would make a serious inroad into the world's production as it stands at present. For instance, 10 large Atlantic liners, each burning 40 tons per hour on 15 round trips a year of 120 hours each way, would require 3 per cent. of the world's present output. The question of the site and cost of storage plant in close proximity to the liner's docks are other matters of considerable difficulty.

(2) *Cost.*—Unless the cost of oil fuel per ton, multiplied by its evaporative value in a boiler, and minus the financial gain in reduction of staff, cost of stowing fuel, less weight and increased space available, &c., be as low as that involved in using coal fuel, the latter must remain the more financially profitable. A ton of coal at the present bunker cost of 16s. will produce 11 tons of steam at a cost of 1·453s. per ton. A ton of oil, producing 15 tons of steam, must be obtained for 22s. for the fuel cost only not to exceed that of coal. The present price in this country is nearly double this figure, and even if obtained in large quantities for as low a price as 30s. per ton, the oil fuel cost would exceed that of coal by 33 per cent. This difference, however, would probably be made up in the advantages of reduced staff, &c., as described above.

SUMMARY.

There is little doubt that the present reputation of the water-tube boiler as an efficient and durable steam generator has suffered from its early history. It has become so much a matter of course to instal cylindrical boilers in fast ships, that the water-tube type has been largely ignored by shipowners, and, when suggested by builders, has been ruthlessly suppressed by survey conditions. Many practical questions of steamship operation that find no place in considerations of thermal efficiency enter into ship design. In many cases, the vagaries of tonnage laws render space occupied of little moment. Actual weight in others, though large in absolute measure, may be proportionately small in comparison to the durability it provides. For passenger and merchant vessels, that quality is of the very first importance. It is not sufficient for a boiler to possess adequate strength to withstand ordinary conditions; there must be a margin beyond this. Again the ability to realise on service the result of short runs on trial trips remains to be more widely proved. It should be remembered that no advocacy of high combustion rates for mercantile work is expressed in the paper, although for oil boilers it is hard to see why rates relatively high to those of coal should not be employed without the slightest danger.

It appears extremely probable that in the near future we shall see the gain to the ship in reduced weight of boilers and fuel valued to a considerably greater extent than is at present the case.

The question of superheat from water-tube boilers is not to be ignored. Even a moderate amount has a most marked effect on engine economy on board ship, but the question is too long to discuss in the present paper.

In Fig. 11 is shown the front view of an ocean-going vessel's boiler, with Howden draught fittings.

In Fig. 12 is shown the generator portion of a White-Forster coal boiler of 110 sq. ft. of grate surface.

In Fig. 13 is shown the generator portion of a White-Forster oil boiler of 8,500 sq. ft. of heating surface; while Fig. 14 shows the same boiler being placed on board the vessel.

In Fig. 15 is a diagram by means of which actual evaporation values from any feed temperature may be rapidly converted into equivalent values from and at 212° Fah.

WROUGHT IRON.*

BY HERBERT PILKINGTON, M.INST C.E.

THE writer has been much impressed by the fact that a great many users of mild steels for some years have again reverted to wrought iron, and in such a serious proportion that it is becoming evident that the future position of wrought iron is assured. It is well known that in America wrought iron manufacture is largely creeping back again to its old position. This paper deals largely with comparisons of wrought iron and basic mild steel on such subjects as corrosion, mechanical structure, strengths and mechanical tests involved, fatigue, certain considerations with regard to the finished iron puddled from pig iron only, and the composition of the finished bar.

It is notorious that under the head of corrosion the British railway companies universally have come to the conclusion

* Abstract of paper read before the West of Scotland Iron and Steel Institute.

with regard to rolling stock that they must revert to wrought-iron frames. The railway companies have also undertaken the conduct of extensive experiments with regard to the subject in a strictly practical manner. The writer's attention was first drawn practically to this subject of corrosion by the fact that certain Whitwell stoves at Sheepbridge ironworks had been running 18 to 20 years with iron plating. A third and a fourth stove had been put down, under precisely similar conditions, with basic mild steel plating. The third and fourth stoves, with the steel plating, had to have the upper plates renewed within six years in one case and seven years in the other; but only circumstances of internal brickwork in the first two, with wrought-iron casings, caused them to have to be renewed, this giving a life of three to one in favour of iron plates under exactly similar conditions of temperature and atmosphere. Of course, it must be remembered that the atmosphere close to a blastfurnace is considerably impregnated with acid-forming gases, particularly sulphurous gases from the slag tuyeres, as well as carbonic oxide (CO) and carbonic acid (CO_2).

It is notorious that in the tube trade of the Midlands an enormous quantity of iron strip is now used in preference to steel because of its greater durability in use, and its better welding qualities, and the same remarks with regard to corrosion apply to hoops.

Recently it has been shown that various Government Departments have chosen to specify iron made only from pure puddled iron, merchant scrap being strictly prohibited, for purposes of submarine cables, particularly those which lie between the ebb and flow of the tide and which are attacked by oxygen every time they are exposed to the air, and it has been found, generally speaking, that the life of the steel-woven telegraph cable has been something like one-third that of iron under such circumstances. Consequently there is now an extensive demand for iron for rod rolling and the consequent wire drawing for such purposes.

Of course it is matter of common knowledge that any sort of wrought iron which is exposed to the atmosphere or to water, whether sea or river water, alternately, will stand an almost indefinite time, and not fail in its work until it is simply worn down by mechanical usage.

There are plenty of ships' cables and ironwork in railway wagons which have lasted 40 years and more, but no such instance can be produced with regard to basic steel. It is also well known to every steel manufacturer that when steel was first used in place of iron for shipbuilding purposes, Lloyd's allowed a considerable reduction of scantling in favour of steel, according to the section or position in the vessel. This margin has now entirely disappeared, mainly for reasons connected with corrosion.

The writer has been told by competent railway authorities that the steel frames of railway wagons will not last more than 15 years on the average without the strength being so much reduced by corrosion as to render the wagon useless. Mr. Bain, the carriage and wagon superintendent of the Midland Railway, informed the writer that in coal-carrying wagons the corrosion of the standard steel sections of the underframe amounts to $\frac{1}{8}$in. in 15 to 16 years. The main members become so weakened in consequence, that when the trucks receive a sharp impact the parts are knocked out of shape and the life of the wagon immediately comes to an end. He further says that it has been proved in railway experience that the corrosion in the case of iron wagon fitting is from 40 to 50 per cent. less than in the case of steel.

The Midland Railway have treated a number of steel wagons used for carrying locomotive coal with various kinds of special paints to prevent corrosion, the surface having been thoroughly cleaned before the paint was applied, and while this has had the effect of preserving certain portions of the underframe to some extent, in those portions near the doors, where the coal dust comes into contact with the metal and the parts underneath the floor, where the weather comes through the bottom—mostly when the wagon is empty, but also through the coal when loaded—the special painting has been of little benefit and the cost of painting has been excessive.

In bridge work and other exposed structures there are several foreign Governments who are declining to use steel and who are putting in iron in preference, because of corrosion. Some of the English railway companies are doing the same thing, and there is one notable railway company whose engineer stuck tenaciously to wrought iron for bridges until he retired.

The writer regards mild steel as a more or less homogeneous material, not quite like glass, because glass is an absolutely homogeneous material, but still similar from the point of view that it is a fused cast mass, only modified by the heat treatment and work it subsequently receives. On the other hand, wrought iron, properly rolled, is not homogeneous even in the same sense as steel, but is a bundle of fibres absolutely welded together and not to be dissociated. Any shock coming on this bundle of fibres must be very great indeed, relative to the section, if it fractures them all, whereas the shock on mild steel might fracture the whole section very quickly after the first surface crack occurred, as there is no resistant fibre structure present.

In the case of many services in which wrought iron has been substituted by steel grave mistakes have been made, particularly in the case of crank shafts for engines, connecting rods, crank pins for locomotives, and bolts for pumps and water services generally, both with regard to resistance to shock and corrosion. There is also another point, and that is in the case of boiler plates; although the use of the copper firebox in English locomotives is pretty universal, there are very considerable numbers of locomotives which have steel fireboxes, copying American practice. It is a matter of common experience that those who have used wrought-iron plates for this purpose have done far better than those who have used steel. It is well known that many portable and semi-portable boilers for agricultural purposes, &c., and vertical crane boilers also, have their fireboxes made in wrought iron, although so many iron plate mills have gone out of existence that it has for some time been difficult to get the materials.

In the case of railway wagons, although some people have had dreams of steel chains, coupling links are still made of wrought iron, for two simple reasons; first of all, their fibrous nature resists shock far better than steel; secondly, steel links will not weld properly and securely. There is no successful steel coupling, although several have been tried and are on trial still.

In the case of cable chains for ships, it is, of course, well known that they are all made of fibrous wrought iron; there is no successful substitute at present, and as far as the writer is aware, being an extensive maker of Admiralty and other irons for ships' cables, no attempt with regard to steel has yet been countenanced. In this particular field of chains it seems very unlikely that any kind of steel can supplant fibrous wrought iron, or, indeed, any other process of making chains other than by the old-established custom of welding fibrous-rolled or forged-iron bars. Recent attempts at methods of manufacturing iron chain cables other than from solid round bars, have proved failures. In all these attempts the margin between the specified test figures, and those actually obtained, show a wide difference in favour of rolled bar iron welded in the links, as the results in Table I. will show. It will also be observed from the figures that the iron broke with 90 per cent. in the case of the $2\frac{3}{4}$in., and 232 per cent. in the case of the $1\frac{3}{4}$in., over the specified Admiralty proof tests, and these are results which could not possibly be obtained from any other class of material.

TABLE I.

Size of Chain.	Proof Load Specified by Admiralty.		Actual Breaking Load when Tested to Destruction.		Overproof
Diam. In.	Tons	Cwts.	Tons.	Cwts.	Per Cent.
$2\frac{3}{4}$	129	10	244	13	90
$1\frac{3}{4}$	33	2	110	6	233
$1\frac{3}{4}$	33	2	110	0	232

The writer has heard of steel nuts and bolts, but they are freaks, like steel rivets, for however well made steel rivets may be, after the heat treatment and punishment received in riveting, instances are only too frequent of heads flying off in practice. In the case of bolts the writer would go so far as to say that 90 per cent. of the bolts and nuts made in the United Kingdom are made from wrought iron, although a quantity of foreign and also English bars for this trade

are made from a mixture of iron and steel. This, of course, is done for cheapness.

Everyone knows perfectly well that while wrought iron can be welded successfully, even with the very mildest of steels a safe weld cannot be sufficiently assured for cable chains, railway wagon couplings, and crane chains subject to sudden stresses, and, therefore, in anything that demands the safety and security of life wrought iron is the essential material to use. For ordinary blacksmiths' purposes, and for almost all wagon materials requiring the services of blacksmiths, steel cannot be used by reason of its bad welding qualities, and one of the most significant things in connection with wagon building is with regard to wagon springs (or even locomotive springs), where the binding buckle that holds the centre of the spring plates is invariably made of wrought iron, and it is obvious that this is not on account of cheapness.

Much has been said at times with regard to the mechanical tests as between mild steel and wrought iron, but the writer is personally unable to see any advantages which mild steel possesses with regard to such tests. He has endeavoured to show that on other accounts wrought iron is infinitely superior to basic mild steel for many purposes, and it would be easy to show that so far as these mechanical tests are concerned, it is also superior as regards destructive tests. Tests of different grades of wrought iron contrasted with mild steel show that the scantling required with decent wrought iron is not more than that demanded from mild steel, therefore no more weight is necessary in the case of wrought iron than mild steel.

It cannot but be admitted that on the question of shock, bar iron, as contrasted with mild steel, must be far superior. In tensile tests it may be shown that the reduction of area in the case of mild steel, basic or otherwise, is greater than that of wrought iron, but any sudden impact upon such a material as mild steel is more likely to cause fracture than in the case of fibrous wrought iron. The writer is quite sure that those with most experience in the use of either iron or steel will agree with him that the reduction of area test is somewhat of a shibboleth, affording very little evidence of the particular material's resistance to shock. For certain purposes, such as crane chains, cable chains, &c., the writer would pin his faith to an iron giving a reduction of area of 35 to 40 per cent. rather than to one giving 50 per cent. reduction of area.

One of the most important points as between the use of wrought iron and mild steel is the question of fatigue, which occurs in both materials. Even taking the case of iron chains, the practice is to anneal them at least once a year to restore them from their crystalline condition, due to fatigue caused by vibration and shock, to renew the fibrous state again. If any life was lost by the breakage of a chain the first thing His Majesty's Inspector would want to know at the inquest would be when the chains were last annealed.

In taking the cases of such materials as crank pins and shafts, this crystallisation has always been observed by engineers, and is well known, but the opportunity of annealing and restoring the crystalline structure which always ensues is not so possible as in the case of chains and other such articles; there is any amount of evidence, however, that such crystallisation does occur, particularly in the case of locomotive engines subject to sudden reversal.

The real point, however, that the writer wishes to make is that under such circumstances as these fibrous wrought iron is always the most reliable of the two materials in its resistance to crystallisation through fatigue or work, because its fibrous nature always stands this fatigue and work far better than any material without fibre.

Fatal Flywheel Burst.—A serious accident recently occurred at the works of Messrs. Ruston, Proctor, & Co., Lincoln. The accident happened in the oil engine department, where a gas engine was being tested. The flywheel of the latter burst, and a fragment caught one of the men on the head, inflicting an injury from which he died. The cause of the wheel bursting was not ascertained. Several other men had narrow escapes, five pieces of the wheel flying in various directions. At the inquest, which was subsequently held, the jury returned a verdict of "Accidental death."

INDIVIDUAL MOTOR DRIVES.

BY G. E. SANFORD.

One of the advantages of individual drive over shaft drive is the saving in power. With individual drive, the power is consumed only when actually needed, and none goes to waste when a machine is stopped; while with a shaft drive a large amount of power is continuously being wasted by friction in bearings and belting. As an example of this, the writer recently made a test to determine the power lost in a certain group drive, as a result of a complaint to the effect that the motor was not large enough to do the work satisfactorily. The motor was a 10 h.p. machine and was belted directly to a main shaft, 30ft. long, running at 300 revs. per minute. From this were driven loose pulleys about 10in. by 4in. on six countershafts, as well as loose pulleys about 12in. by 3in. on seven drills and miscellaneous machines. A reading taken with only the main shaft and the loose pulleys running, showed about half-load on the motor, this being calculated on half-load efficiency of the motor. The saving in power otherwise lost by friction of shafting is more noticeable when a plant is running a few men overtime, and long lines of shafting are running with only one or two tools in use.

With the individual drive there is a saving in the labour of shifting belts from one step of a cone to another, or from a main shaft to a countershaft. A department usually possesses only one or two belt poles, and it often requires some time to find one or to wait until some other user has finished with it; and then if in getting the belt back on a main shaft pulley, it is knocked off the countershaft pulley, further delay ensues while a ladder is obtained. The labour involved in re-aligning the shafting, replacing worn-out bearings, &c., is also saved. This job has to be done, of course, when the shop is shut down, and is paid for on an overtime basis. There is also considerable time lost in looking for ladders and planking for a temporary staging, to say nothing of danger to the millwrights through working on an insecure footing. The last point may include, too, the loss of time and labour due to a burn-out in a motor driving a group of machines, as most of these motors are located on the ceilings so as to be out of the way. With a burn-out in one of these motors or trouble with a main shaft during working hours, a number of operatives will be idle an hour or more; whereas if the trouble occurs on an individually-driven machine, the operator can usually be temporarily transferred to another machine without loss in production.

With individual drive the machines can be located to better advantage as regards floor space and light. As an instance of economy of floor space, I may cite a case where formerly all punch-presses were run from shafting, and all the flywheel shafts had to be parallel with the main shaft. With this arrangement, space had to be provided for the troughs which held the uncut stock for each press. A motor was put on each of 50 or 60 punch presses of one style, and they were re-arranged with the flywheel shafts at an angle of about 45° from the aisles, so as to let the stock trough of each extend out behind the adjacent press, and also by putting two of these rows back to back. By this means nine presses were placed in a space formerly occupied by five.

A point in favour of individual drive is the facility with which the work can be taken to and from the machine by a crane. In this case the machines are wired from underneath the floor. Motors are especially well adapted to the drive of portable drilling machines and other tools used in machining pieces which are too large to be easily taken to the stationary tools.

In connection with locating with respect to light, probably everyone is familiar with the ordinary method of arranging engine lathes, end to end, and two lines back to back, the whole line being parallel to a side of the building. With this scheme, half of the men are at a disadvantage in being between their work and the light, while the other half are worse off on account of facing the light. On the other hand, if the centre lines of the lathes are arranged at right angles to the side of the building, with the tail stock toward the window, the men then get the light over their right shoulders.

The amount of light in a room equipped entirely with individual drives is far better than that with shaft drive, as the shafting, pulleys, and belts throw considerable dirt on ceilings and walls; and this, together with the black hangers, shafting, pulleys, and belts, makes a dark combination, which gets worse with age instead of improving. The writer knows of one building with a floor space of approximately 90ft. by 190ft. which has on the third floor a large number of screw machines, these having from two to four belts each, from the countershaft to the machine, depending on make and style. The height of this building relative to that of the surrounding buildings is such that no shadows are cast on the windows of the room from 8 a.m. until nearly sunset; but in spite of this it is necessary to keep incandescent lamps burning all day at the machines in the middle of the room.

In a modern shop, if the management is at all progressive, it is necessary to provide for additions and re-locations of machinery from time to time. With motor-driven tools it is a simple matter to remove the wires between the mains and the machine; whereas with the shaft outfit it means that, to remove the pulley belonging to that particular countershaft, it may be necessary to uncouple and take down part of the main shafting (if the pulley is solid, as most of the old ones are); and it is then a lengthy business to strip off anywhere from one to a dozen other pulleys in order to get the one which is required, put back the others, set up the shafting, and re-align each pulley moved. The whole performance has to be gone through again when putting the pulley up in the new location.

With individual drive on a machine, the efficiency is greater than with the shaft drive, on account of the motor being nearer the work. This difference in efficiency is most noticeable in a comparison of adjustable-speed machines, when a direct-current motor having a number of points with slight variation in speed between points, and in other cases where there are four or five steps on the machine cone. With the individual drive the operator is able to keep the speed at the maximum by a touch of the controller, for both tool and material, when working on stock of varying diameters, as, for instance, in facing a disc.

On punch presses, power shears, &c., the number of accidents to operators is noticeably less with individual drive, as the general arrangement with shafting drives consists of a belt from a pulley on the main shaft to the machine flywheel; a touch of the treadle will cause a complete cycle on the machine, with possibly disastrous results to a man engaged in setting a die or adjusting a shear blade. Instances have been known of men being seriously injured by accidentally hitting the treadle. With individual drive the motor may readily be shut down before any adjustments are made.

If a manufacturer is considering a new building, new tools, &c., the methods of driving the tools will be an important question. Some will go into the subject as far as to find that the initial cost of the individual drive is much in excess of that of the group drive, and decide immediately in favour of the latter without making a proper study of the question of maintenance and other points.

In connection with the selection of motors to drive tools where the power required is not known, it is customary to set up a temporary motor large enough to carry the maximum load on the machine, and make careful tests to determine the average and maximum loads. It is usual then to select a motor based on the average conditions, provided that the maximum is not so great as to stop the motor or slow it down to such an extent that it cannot regain normal speed before the maximum is on again. This is based on an overload rating of six hours at 25 per cent. and momentary at 50 per cent. overload. In cases where the load varies rapidly, as for instance the reverse of a planer, it is usual to add a flywheel to the main-driven shaft to help over the peak load.

It appears from tests which have been made that machine tool-makers in many cases use motors which are altogether too large. The following data were obtained on a 48in. planer fitted with a 20 h.p. motor: Cutting stroke, 4 tools each ⅛in. feed by ⅛in. deep, two in scale and two in second cut, cast steel at 37ft. per minute, 9·8 h.p.; reversing bed to run back, 25 h.p., approximately; running back, 10 h.p.; reversing to cut, 25 h.p., approximately. This machine was fitted up by the maker, but if a 15 h.p. motor had been used it probably would not have given any trouble.

A test on a 24in. planer showed the following: Cutting stroke, 3 h.p.; reversing bed, 8 h.p.; running back, 6 h.p. We fitted this planer and three or four others like it with 3 h.p. induction motors about two years ago. All but one have given no trouble; that one, however, is set for a very short stroke, only two or three inches; and after we melted the solder out of several rotors we changed to a 5 h.p. We are having a 3 h.p. rotor made with conductors and end rings cast in one solid piece, and intend to put a 3 h.p. motor back when we get this. Other cases of over-rating on the part of machine tool-makers are as shown in table below. The figures in the second column are the sizes specified by certain machine makers, while those in the third are sizes which we have in use on the same make of machine operating satisfactorily.

Machine.	Maker's Equipment.	Our Equipment.
48in. planer	25	10
Grinder 24in. wheel	5	2
Grinder 18in. wheel	2	1
6ft. radial drill	5	3
36in. upright drill	5	3
26in. engine lathe	10	4
60in. gear cutter	5	3
Circular milling machine for R. R. gears	15	10
Gear hub milling machine...	10	5
12in. slotter	5	1
4in. tapping machine ...	7½ (shunt)	3 (comp'd)

Another palpable case where an unnecessarily large motor is installed recently came under our notice. In this instance a 26in. disc grinder was driven by a 20 h.p. motor with the shaft extended on each end, carrying two steel discs about ¾in. thick with emery sheets pasted on them. A test was made with two men, each holding a piece of cast iron with a bearing surface of about 24 sq. in. Both men were above the average in strength and had pieces of stock on which they could get a good grip. They were instructed to stop the motor if they could. The maximum horse-power noted was 6·3.

Another interesting grinder test was made on a machine with wheel 24in. by 3½in. This was equipped by the maker with a 5 h.p. shunt motor, and connected to the wheel with a silent chain. Under these conditions it was apparently considered necessary to have a fairly large motor in order to overcome the inertia in starting the wheel, since, of course, there was no momentary belt slip to aid the motor in getting up to speed. A test with large planer tool under ordinary conditions took 2·4 h.p. A test with a man holding the end of a ¾in. by 2in. machine-steel bar against the stone with all the pressure he could exert, took 4 h.p. This motor was removed and replaced with a 2 h.p. induction motor with the ordinary belt, and this has been running for nearly four years. We find that most small engine lathes are fitted about right, the only ones under-motored which are recalled are the 12in. and 14in. of one certain make. These two sizes have given us considerable maintenance trouble due to armature burn-outs from overload.

A certain tool company could easily use smaller motors on any of their lathes under 24in. For example, they use a 3 h.p. motor on a 16in. machine. We had a case some time ago where a lathe of this size was speeded too high for the class of work required of it, so we replaced the 3 h.p. motor with a 2 h.p. slow-speed motor. The department foreman was somewhat afraid of this reduction in power, as he did not want to be responsible for burning out the motor; so we arranged a maximum load test, where the writer watched the instruments and he operated the lathe, each of us taking the responsibility of our own part of the outfit. The first cut in cast steel, $\frac{3}{32}$in. chip, 0·01in. feed, 47ft. per minute, took 1 h.p. This shook some tools off the lathe bed. With the second cut the depth was doubled, and this took 1·6 h.p. The

test was stopped while some of the screws in the machine, which were loosened, due to jarring, were fixed up. The stock was changed and the test continued, using machine steel. The machine then jarred excessively on the following tests:—

$\frac{1}{4}$in. chip, 0·022in. feed, 72ft. per min. ... 3·1 h.p.
$\frac{1}{4}$in. chip, 0·044in. feed, 10ft. per min. ... 3·8 h.p.

We then tried doubling the feed again, and after two or three revolutions of the stock broke the lathe. These tests showed that a 2 h.p. motor would do any work that the lathe could carry. We have since changed over more of these, putting on $1\frac{1}{2}$ h.p. motors.

With regard to attaching the motors to machines, many tool manufacturers are building their machines with the motor drive included as a part of the machine. With old machines, however, it is an entirely different proposition. The motors should be located so that as far as possible they will not add to the floor space occupied by the machines, while they should also be so arranged that the shop attendant can easily get at them to clean or make repairs. They should be out of the way of the operators, but the controller or switch should be within easy reach. In some cases, *e.g.*, a band-saw, it is practically impossible for a man to reach the main switch from the operating position, so we have located emergency switches under a corner of the saw table which can be used to stop the motor. Large machines may be equipped with circuit-breakers having a no-voltage release, and small switches connected to this coil may be located at operating points.

The cost of installation should be kept down to a minimum, but should not be done so cheaply as to prejudice a visitor against changing his machines. Cast brackets should be used in preference to forgings, as a few well-designed patterns can often be used on several different machines by trimming fitting strips and filling the crevices with soft metal. Attention should be given to the appearance of the drive, as a set of brackets with square edges and corners looks decidedly out of place when attached to a machine the general lines of which are well-rounded. It is surprising how much improvement can be made in the looks of a casting if the pattern-maker spends a little extra time in rounding the corners and edges of the pattern.

In laying out a drive for an old machine, it is necessary to make careful measurements of the machine, and to make an outline sketch to scale of that part of the machine to which the motor will be attached, leaving out all parts not actually required. With an outline sketch of the motor it is then an easy matter to select the relative location. We have a number of cardboard motor outlines which are tacked over an outline drawing of the machine, and which often save time in determining the exact location for the motor. Most of these layouts are made on a scale of 3in. to 1ft., but we also use $1\frac{1}{2}$in. to 1ft. on some of the simpler jobs, and half-scale on some of the complicated ones. We have on rare occasions made a full-scale layout on the floor in order to get certain measurements or to exactly locate a belt.—"General Electric Review."

Auxiliary Machinery on Ships.—At the annual general meeting of the Scottish Students' Local Section of the Institution of Electrical Engineers, recently held in Glasgow, a paper was read by Mr. E. T. Caparn on "The Electrical Working of Auxiliary Machinery on Modern Steamships." After classifying the various items of auxiliary machinery required on a steamer, the lecturer gave a detailed comparison of their working with steam and with electrical power in the case of a 20,000 ton steamer designed for carrying both cargo and passengers. He showed that in practically all cases the superiority of the electrical drive in steadiness, convenience, and economy was very marked. In dealing with steering gears, Mr. Caparn stated that the electrically operated gear installed on the steamer "Orama," built recently at Clydebank, had proved itself, under severe testing conditions, very much more sensitive and prompt in action than the steam gear with which the vessel is also equipped. He gave details of the transmission losses with steam and with electrical plant, showing the great economy which may be effected in this respect by the use of electricity.

INDUSTRIAL AND TRADE NOTES.

Trade Circulars.—We have received from O. N. Beck, 11, Queen Victoria Street, E.C., circulars and price lists of various types of tube expanders and tube cutters. From Donovan & Co., Cornwall Street, Birmingham, catalogue and price list of electrical heating and cooking appliances.

Orders for Tank Steamers.—The Mexican Petroleum Company has, we learn, placed orders for tank steamers with Messrs. Armstrong, Whitworth, & Co., and with Messrs. Swan, Hunter, & Wigham Richardson. These steamers are designed to carry oil fuel to distant markets, and two of them will have a capacity of 60,000 and 40,000 barrels respectively. Oil fuel will be burnt on board, and the oil pumps and pipes are of specially large size, enabling rapid loading and unloading.

The Johannesburg Gas Plant Action Settled.—In the Court of Sessions, Edinburgh, on the 20th inst., it was intimated that a settlement had been reached in the action by the Municipal Council of Johannesburg against D. Stewart & Co. (1902), Ltd., Glasgow, and William Beardmore, steel manufacturer, Glasgow, for the payment of sums of over £100,000 in respect of the abandoned contracts for the installation of gas and electrical plant at Johannesburg. In the terms of settlement the plaintiffs have accepted £100,000, and are allowed to keep the plant, each party to pay their own expenses.

Catalogues of British Manufactures Required in New Zealand.—H.M. Trade Commissioner in New Zealand (Mr. W. G. Wickham) has notified his intention to set aside a room in his office, to be used as a Reading Room, where catalogues of British goods may be filed for the benefit of firms in New Zealand desiring to obtain information as to British sources of supply of goods they may wish to purchase. It is believed that British firms will find it to their advantage to have their catalogues filed in this room. Mr. Wickham is prepared to receive such catalogues, and firms desirous of availing themselves of the opportunity may send them addressed, "H.M. Trade Commissioner, P.O. Box 369, Wellington, New Zealand." It may be noted that catalogues which do not mention New Zealand or give New Zealand prices are not dutiable.

German Machine Industry.—A report by Sir F. Oppenheimer, Commercial Attaché to H.M. Embassy at Berlin, on the foreign trade of Germany in 1911, states that the machine industry in 1911 undoubtedly experienced greatly improved times, if compared with the business of the years immediately preceding; but the complaints never ceased that the conditions of payment imposed were often onerous and unsatisfactory. Thus important contracts from the iron industry could only be obtained by placing large counter orders for raw material; the credit to be granted for goods delivered was unusually long. In the electro technical industry the smaller concerns complained of the unfair competition of the larger, who use their vast capital to crowd the smaller factories out. Cases transpired where the construction of large central power stations was undertaken solely upon the guarantee of a certain minimum annual consumption of power, and on the understanding that out of the profits an amount should annually be put aside as part payment of the capital outlay. No concern, unless it has command of enormous financial resources, could compete against such offers.

Sheffield v. German Steel.—Speaking at the recent annual meeting of the shareholders of Hadfield's Steel Foundry Company, Ltd., Sheffield, Sir Robert Hadfield said that during his recent visit to Germany he saw most of the leading scientific and technical institutions in Berlin and elsewhere, and he was also allowed to go through Krupps' works. Comparing Sheffield with German steel, he said he did not think any well educated metallurgical engineer in Germany would claim that that country was ahead of us. What they had been trying to do was to come up to us, and he did not think that even to-day they were quite up to the very best Sheffield standards in the production of the highest qualities of steel. Some things that he saw in Germany—the tramways, for instance—were very antiquated, and would not be tolerated in Sheffield, so that in one respect we were ahead of Germany. He wished, at the same time, to recognise the wonderful amount of attention that the Germans gave to scientific observation, and the amount of money they spent on encouraging education. Fortunately, Sheffield had now come up to that, and he paid a tribute to the high standard of work reached by the University, and the amount of support given to it by the Corporation.

The Coal Strike and Our Steel Trade.—Speaking at the annual meeting of William Jessop & Sons, Sheffield, Mr. A. J. Hobson, the chairman (and the Lord Mayor of Sheffield) said that although the trouble caused by the coal strike had already greatly affected industry, it would still be some time before full resumption could be made in the large works, and in all probability would mean permanent loss to trade to the country. As an instance, he said that the previous week one order to the extent of £5,000 which

Jessop & Sons usually got had gone to Germany. Another of their best customers was chafing, as he could not wait indefinitely, and would probably have to place an emergency order with one of the firm's rivals outside England. They had to bear in mind that wherever an emergency order went there was always a risk that other orders would follow, and there was great risk that some of their best accounts might be more difficult to keep in the future. One particular account of Jessop & Sons meant many tons of steel, and as some nine or ten tons of coal were required for each ton of steel produced, they would see that if an order for some hundreds of tons of steel was diverted from their firm by this strike, not merely would the workpeople of the firm suffer, but the colliers would lose the hewing of some thousands of tons of coal.

Cammell, Laird, & Co.—The report states that the results of the year's working, although the arrears of preference dividend have been reduced, are disappointing. The profits, after providing full depreciation and after paying debenture and bank interest and all charges, amount to £120,962, and the net surplus for distribution is £127,660. An instalment of $2\frac{1}{2}$ per cent. on the cumulative preference shares was paid in October, and the directors recommend a final dividend of 5s. per share on the preference shares, making 18 months' dividend in all. The arrears of cumulative preference dividend as at December last will then amount to £91,892, the equivalent of 18 months' dividend. The following table shows the results for the last three years:—

	1911.	1910.	1909.
Net profit	£120,962	£218,836	£50,714
Debit brought forward	—	122,907	171,320
Credit brought forward	6,698		—
Available	127,660	95,929	—
Preferential dividend (18 months)	91,932	86,531	—
Carried forward, less or plus fees	†35,768	†9,398	*120,606

† Credit balance. * Debit balance.

The Use of Petrol: Sequel to the Bradford Beck Explosion.—An action which raised points of importance to users of degreasing plants in woollen mills was concluded in the Chancery Division, before Mr. Justice Warrington, on Friday last. The plaintiffs were the Attorney-General, at the relation of the Bradford Dyers' Association, who asked for an injunction to restrain the defendants, Messrs. John Smith & Sons, Ltd., of Fieldhead Mills, Bradford, from working any degreasing or other plant in which petrol or other volatile spirit was used, and from discharging into the Bradford Beck or into the sewers any petrol or effluent containing petrol or other volatile spirit. When the action first came on it was stated by counsel that in the defendants' works, which were near the Bradford Beck, a very large quantity of petrol was used. On the 1st of December last there were very violent explosions in the Beck, and parts of the plaintiffs' premises were destroyed, three of their workpeople being killed and 40 injured. It was alleged that from February, 1911, to December, 1911, the defendants were working the petrol plant, and that explosions were caused by the igniton of petrol vapour in the Beck, which petrol had escaped from the defendants' works. His Lordship granted an injunction on an ex parte application made by the plaintiffs, and this was continued a fortnight ago, when the case stood over for the defendants to answer the plaintiffs' evidence. When the case was called on, Mr. Astbury, K.C., said that, with his lordship's assent, the motion would be turned into the trial of the action, and the defendants would submit to a perpetual injunction on the terms of the notice of motion. Mr. Cave, K.C., M.P., for the defendants, said they were advised that the explosions were not due to the petrol effluent from their works. They had decided, however, to give up the use of the degreasing plant complained of, as they did not want to be a menace to their neighbours, or to enter on a costly litigation.

British Iron and Steel Industry.—In the first of a series of two lectures on "The Economics of the Iron Trade," delivered by Mr. Harold Jeans at the London School of Economics on the 20th inst., he said that 50 years ago the world's production of pig iron was under eight million tons. The most recent figures showed it to be something like 55 to 56 millions. Up to 1870 we produced more than half of the total of the world's output. In 1910 we only produced 15·5 per cent., whereas the United States produced 41·6 per cent., and Germany 22·5 per cent. The finished iron trade had been declining in recent years. Formerly we made as much as three million tons a year of wrought iron. We had now got down to well under one million tons. Steel had taken its place. There were, he observed, some people who held the view that finished iron was going to have a revival because of its use for purposes where there was apt to be "fatigue" in the metal. It had been found that the under-frame of railway wagons corroded very much less than steel frames. He personally did not think there would be a revival because of the difficulty of getting men to engage in the arduous labour of the puddling works. The output of steel in Britain was something over six million tons a year, of which about $1\frac{1}{2}$ millions was made by the open hearth process and 1,750,000 tons by the Bessemer process. The basic process for many years was hardly used in this country, although it was practically by far the largest means by which steel was made in Germany. The process was making rapid strides, and was gradually ousting the acid process. The Bessemer process still held the field as regards output in the world, but so far as this country is concerned, more than twice the amount of open hearth steel was made than was made by the Bessemer process. The mainstay of the Bessemer process was the manufacture of steel rails originally located at Barrow, Sheffield, South Wales, West Cumberland, and Cleveland, but recently the tendency had been to make rails in open hearth furnaces, and it looked as if the Bessemer process, so far as this country is concerned, was doomed. There were 104 firms owning 111 steel works, which had collectively about 536 open hearth furnaces, of which 122 were commonly in operation.

METAL QUOTATIONS.

TUESDAY, MARCH 26TH.

Aluminium ingot	67/	per cwt.
,, wire, according to sizes, &c. ......from	102/-	,,
,, sheets ,, ,, ... ,,	120/-	,,
Antimony ...... £27/-/ to	£27/10/	per ton
Brass, rolled	$7\frac{7}{8}$d.	per lb.
,, tubes (brazed)	$10\frac{1}{8}$d.	,,
,, ,, (solid drawn)	$8\frac{1}{4}$d.	,,
,, ,, wire	$7\frac{7}{8}$d.	,,
Copper, Standard	£68/7/6	per ton.
Iron, Cleveland	$51/7\frac{1}{2}$	,,
,, Scotch	$57/7\frac{1}{2}$	,,
Lead, English	£16/12/6	,,
,, Foreign (soft)	£16/3/9	,,
Mica (in original cases), small	6d. to 2/	per lb.
,, ,, ,, medium	2/6 to 4/-	,,
,, ,, ,, large	4/6 to 8/6	,,
Quicksilver	£8/12/6	per bottle.
Silver	$26\frac{13}{16}$d.	per oz.
Spelter	£26/10/-	per ton.
Tin, block	£197/10/-	,,
Tin plates	$13/10\frac{1}{2}$	,,
Zinc sheets (Silesian)	£29/-/-	,,
,, (Stettin; Vieille Montagne)	£29/5/-	,,

Obituary.—The death took place suddenly on the 20th inst. of Mr. John Ward, of Dumbarton, the well-known Clyde shipbuilder and engineer. He was a partner in the firm of Messrs. Denny Bros., Dumbarton, and participated in the building of many famous ships. He was president of the Institution of Shipbuilders and Engineers in Scotland.

The Prevention of Overwinding in Mines.—At a meeting of the Midland branch of the National Association of Colliery Managers, held at Mansfield on Saturday last, a paper was read by Mr. J. Strachan, of Pinxton, on "Automatic Controllers for the Prevention of Overwinding." He said a detaching hook did not prevent overwinding; it only helped to lessen one of the effects. The ascending cage might be safely detached, while the cage, on its downward journey, might be violently dashed into the bottom. When that happened often great damage was done by the engines running away and often wrecking the engine-house. By this remark he did not wish to under-rate the value of detaching hooks, because in a good many cases they had acted successfully, whilst in others, owing to the increased loads and the speed with which they had run into the headgear, they had failed. Much was to be said in favour of automatic winding arrangements. Such a controller ensured regular and steady winding. The object of the controller was to take the control of the engines out of the winder's hands should he at any time fail through oversight or illness to work his engines properly, such as by starting the wrong way or by failing to close the throttle valve at the right time. The contention that controllers tended to make the enginemen careless had little or no foundation, because they corrected him openly every time he made a serious mistake, and also prevented slovenly winding. He had discussed this point with several winding enginemen, and they all agreed that controllers made them more attentive to regular and steady winding.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1910.

Apparatus for producing an explosive or combustible mixture of liquid fuel and air. Dawson. 28158.
Boilers, condensers, and radiators. Shuman and Sun Power Company. 28273.

1911.

Rotary condensers and self condensing turbines. Rees. 2731.
Process in precipitating and recovering metals from hydro metallurgical solutions. Merrill. 2801.
Carburetting apparatus for internal combustion engines. Lindblom. 3162.
Means for removing dust in coal mines. Rollin. 5191.
Steam injectors. Brooke. 5194.
Apparatus for conveying and lifting red hot material. Pohlig. 5204.
Gas producers. Pratt. 5286.
Feed water filters. Rankine. 5322.
Fasteners for driving belts. Zeyen. 5342.
Process for carburetting gases. Moss & Carroll. 5343.
Miners' safety lamps. Best, Best, Best, & Best. 5518.
Turbines. Deutschmann. 5539.
Valve mechanism of internal-combustion engines. Scott. 5690.
Car axle journal boxes. Hewitt. 5830.
Furnaces of steam boilers. Hulme. 5893.
Two stroke internal combustion engines. Scott. 5985.
Methods of operating pumps for supplying liquid fuel to oil engines. Petter. 6114.
Manufacture of solidified petroleum. Demuth. 6165.
Piston or connecting rods for radial or rotary motors. Scott, Scott, and Peet. 6215.
Process of purifying iron and steel. Bonnafoux. 6301.
Cross slide mechanism for automatic lathes. Herbert, Vernon, and Harrison. 6347.
Locking of nuts upon their screws. Larrad. 6420.
Compressors for air or gases. Seddon & Seddon. 6786.
Apparatus for governing and operating valves. Grices' Gas Engine Company, and Willshaw. 6882.
Rotary pump of the revolving cylinder type. Cavanagh. 6990.
Means for starting internal-combustion engines. Brooks. 7463.
Steam engines. Crawford & Pears. 8173.
Steam boilers and their furnaces. Ellis. 8207.
Railway vehicle couplings. Riedweg. 8221.
Apparatus for the elevating and conveying of coal. Stebbing. 8324.
Apparatus for removing scale from boiler tubes and plates. Clay. 8380.
Safety devices for winding engines. Siemens Schuckertwerke Ges. 10600.
Means for controlling the combustible charges to internal combustion engines. Webb. 11180.
Meters for liquids. Brooke. 11441.
Apparatus for preventing and removing incrustation in steam boilers. Middleditch & Fenn. 11547.
Two stroke cycle internal combustion engine. Behrend. 11643.
Compound fluid pressure turbine. Metais. 12140.
Foundry moulding. Stoddart. 12437.
Pneumatic hammers. Evans. 13062.
Vaporisers for internal combustion engines. Mumford & Boothroyd. 13077.
Liquid meters. Burnett. 13440.
Compression release devices for internal combustion engines. De Veulle. 13953.
Grinding tools. Crocker. 15273.
Device for measuring the current velocity of fluids, vapours, and gases flowing through pipes. Schultze. 15532.
Apparatus for shaping file blanks. Feilen und Maschinenfabriken vorm. Geb. Ufer Akt. Ges. 15652.
Carburetters for internal combustion engines. Thompson. 15762.
Pump valves. Corn. 16159.
Manufacture of ingot iron and steel. Hatton. 16601.
Fluid pressure operated hammer tools. Lake. 17012.
Throttle valves. Chatt. 17103.
Blowpipes. Fletcher, Russell, & Co., and Fletcher. 17318.
Gas producers. Climie. 17469.
Marine propulsion mechanism. Evinrude, and Evinrude Motor Company. 18412.
Composition for removing scale and preventing corrosion in steam boilers. D'Amore. 19775.
Heating devices for liquid fuel. Irinyi. 19820.
Method of constructing hulls of ships. Lehmann. 19961.
Feed devices for lathes. Atkins & Cohen. 20092.
Apparatus for estimating the percentage of a combustible gas in a gaseous mixture. Levy. 20692.
Steam generators. Steinmüller. 21004.
Connections for superheating tubes. Platz. 21251.
Steam superheaters for marine boilers. Frederiksen. 21515.
Regenerative coke ovens. Fabry. 23562.
Processes of direct nickelling of aluminium and its alloys. Chirade and Canac. 24019.
Emery sharpening tool. Cole & Alexander. 24423.
Emery wheels. Osterman. 24573.
Automatic railway coupling. Wirsching & Borst. 24967.
Fluid pressure braking apparatus. Turner & Cady. 26158.
Steam traps. Royles, Ltd., and Royle. 26991.
Apparatus for supplying and controlling feed water to steam generators. French. 27106.
Charging devices for furnaces or gas generators. Hoeller. 27546.
Pipe wrenches. Hjorth. 27707.
Valves and valve gear for internal combustion engines. Industrieele Maatschappij Trompenburg. 27941.
Reciprocating steam engines. Schmidt. 28384.
Elastic fluid reciprocating engines. Schmidt. 28606.
Water cooled hollow shafts with water cooled stirring arms for mechanical furnaces for roasting ores. Aktieselskabet Dansk Svovlsyre & Superphosphat Fabrik. 28703.

1912.

Coal cutting machines. Anderson, Boyes, & Co., Anderson, and Shield. 1616.
Ball bearings. Sachs. 2356.

ELECTRICAL, 1910.

Time mechanism for operating electric switches. Reid. 25607.
Polyphase commutator dynamos. Allgemeine Elektricitats Ges. 27993.

1911.

Regulating electric tensions. Grob. 2719.
Combination electric radiator or heater and humidifier. Wilson. 2914.
Method and apparatus for the measurement of the specific resistance of electrical conductors. Evershed & Vignoles, Ltd., and Evershed. 5142.
Electric incandescent lamps. Richardson & Crowley. 6066.
Electric accumulators. Fuller, Fuller, & Fuller. 6545.
Di-electrics for contact breakers. Wright & Burnside. 8063.
Dynamos. Midgley & Vandervell. 9112.
Brake electro magnet for tramway vehicles. Shears. 9475.
Apparatus for producing electric ignition in internal combustion engines. Robert Bosch. 9840.
Electrodes for secondary galvanic cells. Pörscke & Achenbach. 10261.
Electric signal systems for railways. British Thomson Houston Company. 12580.
Fittings for electrical conduits. Barton & Sons, Ltd., and Harper. 12860.
Electromagnets. British Thomson Houston Company, and Weimore. 13571.
Vapour electric lamps. Kent, Lacell, and Silica Syndicate, Ltd. 14587.
Electric signalling apparatus. Ransford. 15052.
Electro dynamometers, watt meters, and watt hour meters. Moore, Gambrell, & Gambrell. 16095.
Control of alternating current electric motors. Barbour. 163 1.
Contact breakers for use in electric ignition systems of internal combustion engines. Brooks & Alston. 16875.
Arc lamps. Ges. fur Maschinen und Metall Industrie. 19002.
Safety device for electric cables. Siemens Schuckertwerke Ges. 20996.
Electric heating apparatus. Monnot. 22315.
Manufacture of electrical accumulators. Marino. 23265.
Alternating current commutator motors. Schrage. 25358.
Method and apparatus for localising faults in cables and circuits. Stephenson. 25683.
Electric condensers. Seibt. 25709.
Circuit systems for operating between manual and automatic telephone exchanges. Siemens Bros. & Co. 26830.
Electric ignition devices for internal combustion engines. Robert Bosch. 26928.
Protective devices for electric lamps. Perry & Davies. 28909.

1912.

Electric switches and circuits. Batley & Bem.
Electric influence machines. Partus. 128.
Fusible cut outs. Dorman, Smith, & Baggs. 315.
Single phase alternating current repulsion motors. Siemens Schuckertwerke Ges. 1250.
Electric surface resistances. Allison. 2028.

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Natural Sources of Energy.

ONE beneficial result emerging from the mass of trouble and misery that are at present the most prominent features of the coal dispute is the increasing attention being paid by power users to all questions relating to the economical transformation of energy into useful work, and for this reason the report just issued by the British Science Guild on "Natural Sources of Energy" is opportune. Although the report is not complete and the sections dealing with power derived from wind, waves, solar heat, and other sources are included, it nevertheless contains many contributions of interest at the present juncture. In a broad sense all sources of energy may be regarded as natural, inasmuch as energy can neither be created nor destroyed and the sum total in the universe is constant. Man's interest in it is limited to its various transformations and the extent to which in the course of these changes it may be made available to perform useful work. Hitherto this has been mainly limited to the processes by which the latent heat of fuel in the shape of coal, oil, peat, &c., has been chemically converted into an active form and utilised in heat engines of various kinds. Wind and water power, as we know, are used, though the manifestations of the latter, on which attention has been mainly confined, are the streams resulting from rainfall in mountainous countries flowing down to sea level. In the aggregate the rise and fall of tides presents a greater amount of energy, though the cost of any mechanical arrangement to harness this source has so far rendered it incapable of commercially competing with fuel. In fact, the value of any source of energy to man depends not so much on the total amount available as on the continuity of the supply and the cost and facility with which it may be transformed and transmitted in a usable form. Until the advent of electricity the possibility of transmission of the latent or potential energy of water was confined to an exceedingly limited radius, and as a practical proposition cannot even yet as regards distance of transmission compare with good fuel. A steamship, for instance, with a load of fuel,

whether oil or coal, in its bunkers, gradually transformed to meet requirements, could circumnavigate the globe, but it would be difficult to conceive in our present state of knowledge, of any central electric power station which would permit of an electrically-propelled vehicle or vessel to make a similar journey. A difficulty with water and wind as sources of energy is of course the irregularity in many cases of the supply and the difficulty of conservation to secure the continuity of output on which practical commercial application depends, apart from all questions of capital charges, which are equally as potent as the available energy itself in determining whether any particular source is or is not worth utilising. The question of the economic transformation and transmission of energy to meet man's wants, from a practical standpoint, is a complex one. Many other sources of energy beside the few enumerated are available in nature, but as commercial propositions they require only to be briefly glanced at to be dismissed. In the abstract the energy of radio-active substances appears stupendous; the ultimate amount in one ton of radium, for instance, is estimated by Sir William Ramsay in his report dealing with this section of the subject as 460,000 times that of a similar weight of coal. But this figure loses its impressiveness when we are informed that the liberation of this energy would have to be spread over 350 years and that the total amount of radium existing in the uranium ores of the entire globe does not probably exceed 5 cwts., or only about one hour's output of British coalfields alone. A slight study of other suggested sources of energy from atomic transformation prove them to be equally impracticable for power purposes, and a similar conclusion applies to the suggestion made by Sir Charles A. Parsons to the Engineering Section of the British Association in 1904 that the internal heat of the earth might be tapped by constructing bore holes 12 miles deep, at which point the normal temperature of the rocks, it is estimated, would reach 272° Fah. Scarcely a moment's consideration is necessary to show that the cost of such an undertaking, assuming even perfect efficiency, would be altogether incommensurate with the results attained. Solar energy poured down on the face of the earth would offer a better prospect, and working motors operated by this supply, which Sir J. J. Thomson has estimated to be equivalent, with a clear sky, to 7,000 h.p. per acre, have in certain places actually been constructed, but their performances have been of the most infinitesimal kind, not more, we believe, than 10 h.p. or 12 h.p., and at a cost altogether prohibitive. In fact, the more the possible sources of energy are considered the more certain it appears in the present state of our knowledge that economy can only be derived in the main from improvements in heat motors as we already know them, and of which the steam engine, the steam turbine, and the internal combustion motor, using oil or gas, may be taken as typical examples, coupled with such savings as may be effected by the better use of fuel used for domestic heating purposes. Dr. Beilby, discussing "the coal resources of Great Britain," estimates that about one fifth of the total British output of close on 300 million tons per annum is used in this way, and probably used with less efficiency than in almost any other application. It is, however, easier to recognise waste than to prevent it. The universal use of gas would no doubt afford many opportunities, and some of these are discussed by Prof. Vivian Lewes. As regards the steam engine and the steam turbine, it is not probable that much better results will be attained than those now secured in the larger units of these types of motors. Their heat efficiency is low, as compared with oil and gas engines, but they are the only motors available where large power units are required. In the best steam engine not more than 20 per cent. of the heat of the fuel burnt under boilers is converted into mechanical work, while in small power units it probably does not exceed half this. Sir C. A. Parsons states that with a steam turbine of 10,000 kw. a consumption of very little over 1 lb. of coal per shaft horse-power has been realised. The thermal efficiency of gas and oil engines leaves the steam engine a long way behind, and, moreover, they possess the advantage that a small power unit is nearly as economical as a large one, a 60 h.p. gas engine, for example, being practically as economical as one of 1,000 h.p., and yielding an overall efficiency of 25 to 30 per cent., while, in the opinion of Mr. Dugald Clerk, this still leaves a possible further improvement of 10 per cent. The difficulty with internal-combustion motors at present is the inability to construct them in large units to work satisfactorily, 1,000 h.p. being about the maximum at present attempted in a single cylinder. Looking at the question all round it would seem that greater efficiency in domestic heating and mechanical improvements in the construction of oil and gas motors, combined with concentration of power production in central stations, are the main avenues along which future economies in the transformation of energy for human needs will be found. There is a general agreement, however, amongst the various authors of the papers in the report that something should be done to secure the continuity of the enquiry of the Royal Commission on Coal Supply, and it is probable that representations will be made to the Government, some of the members of which, it is stated, view the proposal sympathetically, to secure this end.

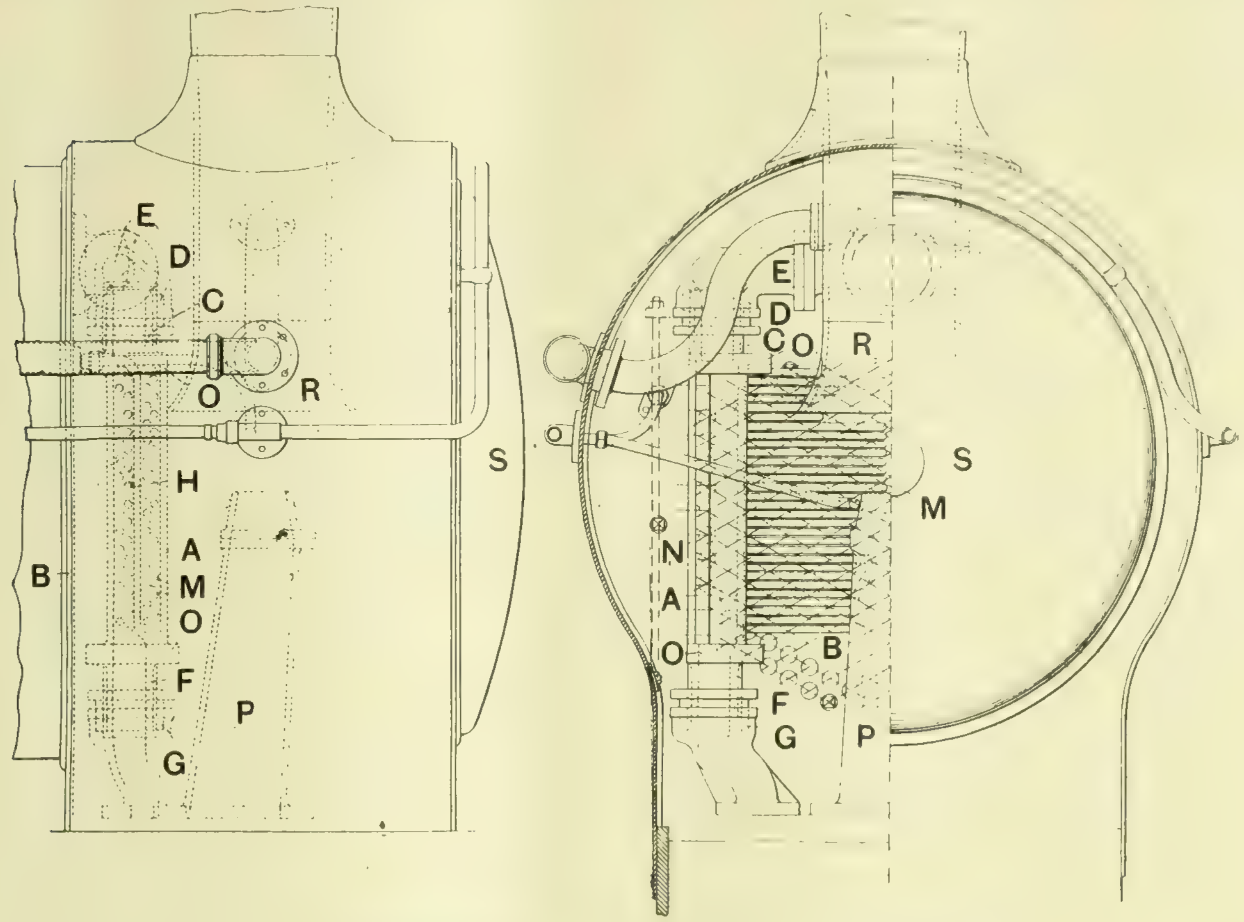
INSTITUTION OF MINING AND METALLURGY.

The 21st annual general meeting was held in London on the 21st ult., the retiring president, Mr. H. L. Sulman, being in the chair. The reports for last session's work were submitted, and showed that the membership had increased by over 200 during the session. The financial balance has also increased, and additional awards have been made by the council. Their gold medals were presented to three members for eminent services in the advancement of technological education and metallurgical practice, the recipients being Mr. Edward P. Mathewson, Sir Julius Wernher, and Mr. Walter McDermott. The Consolidated Goldfield Company's gold medal was awarded to Mr. W. R. Dowling for his paper on "The Amalgamation of Gold in Banket Ore," and the premium of 40 guineas went to Mr. A. M. Finlayson for his paper on the copper deposits of Huelva, Spain. The "Claudet" and the "Frecheville" prizes of 10 guineas each were awarded to student members, Mr. A. C. Hoare and Mr. F. P. Rolfe respectively, for papers by them which have been published in the transactions of the Institution. Two post graduate scholarships each of £50 were allocated to Messrs F. P. Lacy and S. J. Lock, both of the Royal School of Mines, and other eight students have been appointed to post graduate courses in mines and smelters abroad. During last session the equipment of the Bessemer Laboratory was completed by funds granted by the Institution and formally handed over to the governors in January of this year. The newly elected President, Mr. Edward Hooper, then delivered his presidential address, in which he reviewed the recent improvements in mining and metallurgical methods of dealing with various difficult problems.

New Electric Railway for Berlin.—It is announced by the A.E.G. that a contract has been arranged between them and the city council of Berlin whereby an electric railway will be constructed from Gesundbrunnen to Hermannplatz, in Neukolln (Rixdorf), two of the most densely populated parts of Berlin, at a cost of 90 million marks, of which 8[illegible] millions will be found by the A.E.G. The line will be 9·32 km. in length, mostly underground.

IVATT'S COMBINED SPARK ARRESTER AND SUPERHEATER FOR LOCOMOTIVES.

The combined spark arrester and steam superheater shown in the accompanying illustrations has been designed and patented by Mr. H. A. Ivatt, Avenue House, Doncaster. It comprises two vertically arranged headers A located one at each side of the smokebox near the tube plate B but clear of the tubes thereof. The upper end of each header is formed with a trunnion C mounted to rotate in a packed gland D secured to a steam supply branch E leading from the boiler. A similar trunnion F at the lower end of the header A is mounted to rotate in a packed gland G connected to the steam chest of the engine cylinder at the corresponding side of the smokebox. East header A is divided by a partition H into two longitudinal chambers, with one of which the upper trunnion C is in free communication, and with the other of which the lower trunnion F freely communicates. The inlet ends of a vertical row of horizontally extending U-shaped tubes M are connected to the header at one side of the partition, and the outlet ends thereof are connected thereto at the other side of the partition, so that steam from the boiler passes from the inlet chamber of the header to the outlet chamber thereof through the tubes M. Each header A is provided with a removable cover N whereby access can be obtained to the tubes. Adjacent to each trunnion the headers A are each provided with a flange O which is formed with holes for a tommy bar whereby the standard can be easily turned about its trunnions. The length of the superheater tubes M is such that when the apparatus is in operative position with the tubes extending across the smokebox parallel or nearly so and somewhat close to the tube plate B, the curved ends of the tubes of one standard are close to the curved ends of the tubes of the other standard so that the tubes together form a rectangular grid extending considerably below the mouth of the blast pipe P, and above the lower end of the petticoat or chimney R, which may be made removable from the main part thereof. The holes in the tube plates of the headers A are staggered to enable the tubes M to be arranged closely above one another, alternate tubes being in different vertical planes according to the staggering of the holes in the tube plate. When the apparatus is moved into inoperative position to enable free access to the fire tubes, the headers A are each turned about a quarter of a revolution so that the U-shaped tubes M extend outwardly towards the door S of the smokebox.

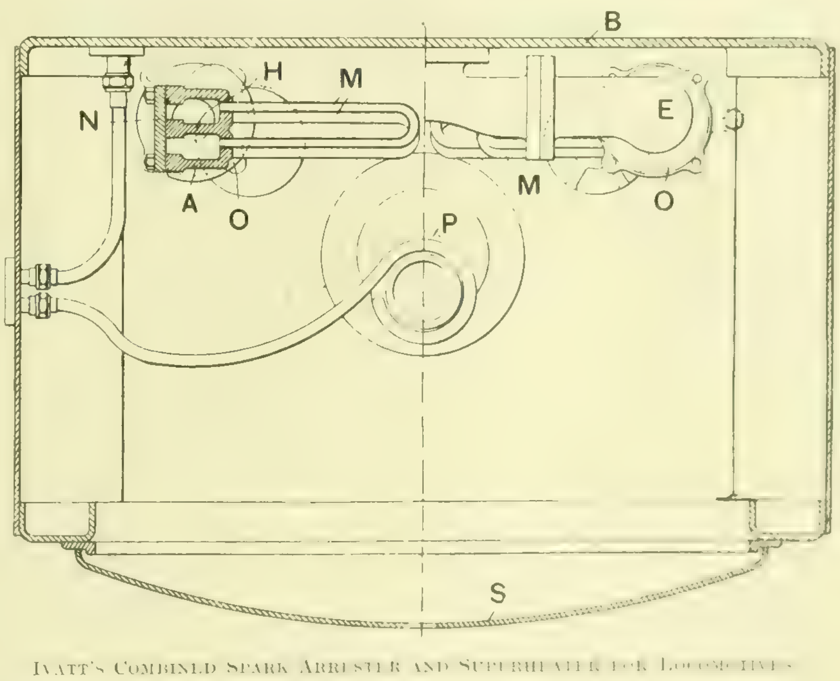


Ivatt's Combined Spark Arrester and Superheater for Locomotives.

A NEW WHITE, NON-CORROSIVE ALLOY.

A new white, non-corrosive, and malleable alloy of iron, nickel, and copper has, according to "The Brass World," been patented by G. H. Clamer, of the Ajax Metal Company, of Philadelphia, Pa. This alloy may be rolled into sheet, rods, or bars, or drawn into wire, and may also be cast in sand. It has a whitish colour, and can be made in the following range of percentages: Iron, 30 per cent. to 70 per cent.; nickel, 25 per cent. to 50 per cent.; copper, 5 per cent. to 20 per cent.

Pure copper and iron will alloy in all proportions and form a homogeneous mixture; but when carbon is present, as it is in steel or cast iron, the two metals do not alloy well and hard nodules separate, depending upon the quantity of carbon. When cast iron is used for alloying with copper there is almost a perfect separation. In the alloys patented, it is stated that carbon should not be present to any extent or there will be a separation of hard nodules in the metal. If, however, carbon is present, then the tensile strength of the alloy is increased but the quantity should not exceed 0·2 per cent. in order to have the best conditions. The strength of the alloy is high, and the inventor states that a mixture of iron 65 per cent., nickel 25 per cent., copper 10 per cent., and carbon 0·2 per cent. has the following physical properties: Tensile strength 96,100lbs. sq. in., elastic limit 51,750lbs. sq. in., elongation in 2in. 42 per cent., reduction in area 53·7 per cent.



Ivatt's Combined Spark Arrester and Superheater for Locomotives.

To make the alloy, the metals are melted so that carbon is kept low and a small amount of manganese or magnesium added for deoxidising purposes.

THE SMOKE ABATEMENT CONFERENCE.

At the International Smoke Abatement Conference held during the past week at the Agricultural Hall, London, a variety of matters bearing on the question of the smoke nuisance in large towns were discussed. The most important of these was the proposed Bill whose provisions were outlined on page 379 of our last issue, and which, it is announced, Mr. Gordon Harvey, M.P., has offered to introduce to Parliament. The scope of the measure, which was explained by Principal J. W. Graham, led to some discussion. Concerning the special difficulties of the steel industry, and respecting which a prolonged discussion took place recently in the "Sheffield Daily Telegraph," in the course of which Prof. Arnold, of the Metallurgical Department of the University of Sheffield, refused to grant that high grade steels could possibly be manufactured without producing smoke, he said there was a difference of opinion among experts, but as against Prof. Arnold's views he quoted experienced testimony from Coatbridge, near Glasgow, to the effect that it was being done there in two iron and steel works with smokelessness and economy, while a representative of Messrs. Siemens asserted that numerous firms in Sheffield used their furnaces, which were practically smokeless, for high class steel, and Mr. Victor Stobie, of Sheffield, claims to have re-heated high carbon steel without producing one-tenth of the usual quantity of smoke and with almost automatic certainty. Mr. Scott Anderson, a Sheffield consulting engineer, also denied that black smoke was essential in the making of any grade of steel.

In these circumstances the proposal of the Smoke Abatement League was to permit exemptions from the absolute rule to be made to particular chimneys for a limited period by the Smoke Department which they proposed to have created in the Local Government Board. They proposed that these should be renewable for two years, and that the power of exemption should for the present only be granted for ten years in all.

The introduction by Parliament of the word "black" in the Act as a necessary quality of smoke liable to prosecution had, he said, proved a fatal flaw, for no smoke was strictly black, whilst brown and yellow smoke were equally objectionable. They had, therefore, left the word "black" out of their Bill, but had left the words, "in such quantity as to be a nuisance, inconvenience, or annoyance." With regard to fines, they had put the penalty for the first offence between £5 and £1, for the second offence between £10 and £5, with power for the fine to be doubled on successive convictions within an interval of two years. By way of minimising undue local influence and establishing an authority which would find it difficult totally to neglect its duties, they proposed to divide the country into large districts, each managed by an *ad hoc* authority composed of members of the local sanitary authorities within its borders, with provisions for co-opting those who had specially studied the question. In order to meet the case of the few localities at present doing their duty, they proposed to exempt them from the operation of that clause after enquiry by the Local Government Board.

Mr. W. Nicholson, Chief Smoke Inspector, Sheffield, said he was not in favour of the proposed Bill, because it was to a large extent retrogressive. It limited the powers of local authorities, and it proposed the deletion of the words "black smoke." If those words were deleted it would make it very much more difficult to obtain a conviction, because so many convictions in the past had been obtained on the word "black," which, he urged, should be retained, with the addition of the words "or other smoke in such quantity as to be a nuisance." He was, however, in favour of certain amendments of the Public Health Act, which would be much more practicable than those proposed in the new Bill. Another objectionable feature of the Bill was that a manufacturer must make application for exemption for smoke emitted from furnaces the prevention of which was said by some to be impracticable, the applicant, even if successful, to pay the costs of the application. That he characterised as absurd and contrary to all the principles of equity.

Subsequently Mr. W. Nicholson submitted a paper on "Smoke Abatement from the Inspector's Point of View." After a reference to the wholesale destruction of public and private property, too great for tabulation, caused by smoke, he said that Sheffield in 1890 was called "a suburb of Hell." There were then 1,000 chimneys serving boilers and furnaces and over 3,800 serving almost every type of furnace, pouring out day and night dense volumes of black smoke up to 40 minutes in the hour. At length it dawned upon the minds of a few public spirited citizens that more smoke was made than was necessary, and as a consequence of their importunity the Corporation appointed a smoke inspector. As a result of the action of the authorities, he stated that in less than 10 years there was a marked improvement in the atmospheric conditions: boiler chimneys had ceased in general to emit over 40 minutes of black smoke in the hour, for the 8,000 hourly observations yearly on the worst offenders only averaged 2·2 minutes per hour.

As one result of this, Sheffield had, in 1907, 1,428 hours' sunshine: more sunshine, in fact, that year than any other large city or town from the North of Scotland to the South of England, the average excess being 273 hours.

Metallurgical furnace smoke was as much inside the Act as boiler smoke. Furnace smoke, like boiler smoke, was only exempt up to the point of practicability. Some metallurgical experts, however, said they must have an unlimited amount of smoke, as it was part of the process of steel-making. But how much was the necessary amount of smoke? Surely the metallurgist could fix it to 10 or 20 minutes in the hour. In furnaces where the normal temperature was above gas ignition point, there was little difficulty in preventing (with a profit) 70 per cent. or 80 per cent. of the smoke made. Many of the high-temperature furnaces were successfully worked by gas and electricity, the steel being either melted or re-heated for forging, pressing, or rolling, while similar satisfactory results were being obtained from coal-fired furnaces, with a sensible system of stoking. In conclusion, Mr. Nicholson suggested the creation of a "Smoke Department" to help the health authorities. It was not suggested that the Department should supersede the local authority, but supervise, advise, and co-operate, and he knew they would warmly welcome such Government help.

Prof. Hodgkinson read a paper on "The Smoke Abatement Problem," with special reference to domestic fires and the smokeless production of steel. Dealing with the pollution that comes from the domestic fire, Prof. Hodgkinson suggested a plan, which he admitted was most Utopian and not possible, excepting in the case of a garden city just commencing existence, or planned suburbs. The idea was to have each chimney of a house connected by a side flue conveniently arranged, with a main conduit laid under the roadway, this main leading to a central tower of considerable dimensions and height. With an artificial draught it could be arranged for the small fires to burn downwards, the ideal condition, for then on addition of fuel, the worst period of smoke production, the fumes of the decomposing coal must pass through the mass of red hot material, where it would become for the most part decomposed and burnt more completely than is now possible with an up-draught and contact with the excess cold air entering the chimney above the fire. Many steel works produced much smoke from heating furnaces, converters, and the like. Most of this was quite unnecessary and due to ignorance or laziness. A reducing, or at any rate a non-oxidising flame or fire was certainly essential in working steel to preserve its properties, but the smoke escaping from the tops of the chimneys was too far away from the steel to have any effect. The cementation or converting furnace could quite well, and much more cheaply, be worked by producer gas, and the same with most re-heating furnaces for larger articles. Indeed, most of the larger things made in Sheffield were now heated in producer gas furnaces, and that alone had made a great difference in the atmosphere of the place. The waste of coal, as smoke, in Sheffield through hurry and ignorance was still great, and the steel produced was no better therefor.

Amongst other papers read was one by Sir Arthur Church, dealing with the action of coal smoke on building stones and mural paintings. He stated that the sulphur products of combustion gave rise to an amount of oxidised sulphur compounds corresponding to half a million tons of sulphuric acid

poured every year into the London atmosphere. Putting aside the blackening of lead compounds, which should be excluded from the palette, it was, he said, sulphuric acid that was the chief culprit where paintings in true fresco are concerned. To protect pictures and objects of art wherever possible by means of glazing or by reclusion in glass cases was a sound precaution. He, however, uttered the caution that abatement of the smoke nuisance, or even its entire abolition, however great the advantages to health and comfort and the amenities of life which it would bring, could not get rid of the injury and pollution caused by sulphuric acid.

Mr. Noel Heaton dealt with "The influence of smoke on decorations." He said it was really the indirect action of smoke in acting as a collector and carrier for the destructive agencies that was its chief menace to decorative work. If all smoke were entirely abolished, the amount of sulphuric acid discharged into the air would be just as great as long as coal combustion continued, but the point which, in his opinion, thoroughly justified the agitation in favour of smoke prevention was that in the absence of smoke the effect of the presence of these impurities would be minimised. Every smut that lodged on a building, though harmless in itself, acted as a carrier for the moisture charged with the active products of combustion, which were the agents of destruction.

Dr. S. Rideal, who spoke of "The effects of town air on metal work," showed that tarnishing, disfigurement, and corrosion by coal smoke were phenomena, partly mechanical and partly chemical. Atmospheric corrosion effected constant damage, resulting sometimes in serious accidents by causing loosening or detachment of metallic fastenings. In this connection he recalled the accident which occurred at Charing Cross Station in 1905, when the roof girders collapsed through rusting. If the use of coal and coke could be abolished, and we depended exclusively on a gas supply, 90 per cent. of the sulphur impurity in the atmosphere would be removed.

The Hon. Rollo Russell, in a communication dealing with "Smoke and Fog," expressed the opinion that London fogs were less frequent and less dense than in the 'eighties, and that if it were practicable to revive the old law against the burning of slack and smoky coal without apparatus for smoke consumption the result would be a large economical gain to the community. The worst offenders, in his opinion, were domestic fires, and as evidence of this instanced that the darkest fogs had been on Sundays and Christmas Day.

In a lecture on "The Relation of the Gas Industry to Smoke Abatement" Prof. Vivian B. Lewes remarked that the coal strike had supplied the finest possible object-lesson as to the conditions which would exist a few generations hence, when the fuel supplies upon which the supremacy of the nation entirely depended began to fail from the extinction of the coal itself; and the country would never have a better opportunity for inaugurating those reforms which alone could purify the atmosphere and lengthen the period before the fatal day when the working-out of the main seams raised the price of coal to such a point as to be prohibitive for many of the purposes for which we had been in the habit of using it. It was a duty to posterity to do what we could to make up for the mistakes of the past by the most rigid economy in every branch of fuel consumption, more especially as by economising in the proper way better results could be obtained than ever before, and our town atmospheres purified from the blighting influence of smoke.

If after a coal fire had been replenished with fuel, the products that were passing up the cooler portion of the chimney above were examined, it would be found that until the fire had burnt clear there would be a mixture of steam, combustible gases, tar vapour, solid carbon particles on which tar was rapidly condensing, and particles of ash and dust drawn up by the draught, and it was this mixture to which was given the name of "smoke." If the same coal used in the fire had been destructively distilled in a gas-maker's retort, it would have yielded coke, coal gas, tar, and gas liquor. The coke would burn with little or no flame, giving none of the constituents of smoke with the exception of, perhaps, some steam and a little ash dust. The coal gas also could be burnt in atmospheric burners in a gas stove without the production of a trace of smoke, and thus it was clear that the constituents of the coal which gave the smoke were those which in gas-making were left in the liquid products. If, therefore, the gas manager were allowed to deal first with our fuel supplies, and after removing the tar were to supply the coke and gas as fuels, the problem of smoke abatement would be solved.

Referring to the objections that gas coke burnt without flame was difficult to ignite, gave off noxious fumes, and produced a dull and cheerless fire, while gas was much more expensive than coal, he said these objections had a modicum of foundation in fact. During the last 50 years the temperatures employed in the distillation of coal for the manufacture of gas had been pressed so high that everything that could be volatilised out of it had been given off. Now the ease with which any carbonaceous material ignited and the rapidity with which it burnt depended largely upon the presence in it of volatile matter, but the gas manager, desiring to make the largest volume of gas he could and looking upon coke as a by-product, pressed the heats to so high a point that the volatile matter left in the coke rarely exceeded 1 per cent. If the public could get coke which, like the old iron retort coke, contained 5 per cent. or 6 per cent. of volatile matter, it would be a perfect domestic fuel, which would not only give considerably more heat than bituminous coal, but would also do away with the pollution of the atmosphere. If only the gas companies would seize the present opportunity and start a crusade to demonstrate what could be done with good coke and coal gas, at the same time using their utmost endeavour to improve the burning quality of their coke to fit it for domestic requirements, it would be a revelation to the world of the relation of the gas industry to smoke abatement.

Gas fires, gas cookers, gas water heaters, and gas engines all had been developed to a point which left no valid excuse for overlooking their claims, and ever since Bunsen in the early fifties invented the atmospheric burner, in which non-luminous combustion was obtained and smoke rendered impossible, coal gas had progressed steadily in favour for heat and power as well as light.

In considering the cost of gas fires as compared with coal the usual method was to argue that as a pound of coal contained on an average about 14,000 B.Th.U. and it would take 25 cub. ft. of London coal gas to give this heat value, the cost of the gas stove would stand to the cost of the coal grate in the ratio of 1lb. of coal to 25 cub. ft. of gas. This was absurdly wrong, the reason being that only one-fifth of the effective heat of the coal was utilised. If gas was used in a flueless stove or radiator, which utilised the whole heat in the room, the cost would be equal as regards raw material. These forms of stove, however, should never be used except in a hall or large building where there was plenty of air space. In a dwelling-room the products of combustion must be taken up by a flue into the chimney, and under these conditions good gas stoves should give 35 per cent. of the calorific value of the gas as radiant heat and 25 per cent. as convected heat, so that 60 per cent. was utilised, or three times as much as with coal. If one took into consideration the labour expended in the use of coal and grate cleaning, and the economy of lighting the gas stove when it was wanted and turning it out when done with, it would be seen that the difference was very small.

Oil Fuel in the Navy.—In presenting his statement on the Navy Estimates in the House of Commons, Mr. W. Churchill referred to the use of oil fuel on war vessels. He said: "The adoption of oil as a motive power raised anxious and perplexing problems. They were among the most difficult that the Admiralty had ever been confronted with. Oil as a fuel offered enormous advantages to ships of all kinds, and particularly to the smallest kinds. If internal-combustion engines of sufficient power to drive warships could be perfected, as might, he thought, be hoped for within a very reasonable time, all the advantages of oil would be multiplied, and some of them would be multiplied three or four times over. On the other hand, could we make sure of obtaining full supplies of oil at reasonable prices in time of peace and without restriction or interference in time of war? Could we accumulate and store a sufficient reserve of oil to meet our growing requirements, and could we make that reserve properly protected against attack by aeroplane or sabotage? All these methods were receiving patient attention."

THE BALANCING OF LOCOMOTIVES.—VII.

BY JAS. DUNLOP.

Outside cylinder locomotives with medium or large-size coupled wheels present no special difficulties in the way of placing the necessary amount of balance weight in their wheels. There is not, unfortunately as it happens, any way of reducing the amount of balance weight used by altering the angle between the coupling cranks as in the case of inside cylinder engines, so that outside cylinder engines of ordinary construction will always require the maximum amount of balance weight.

Special constructions, of course, require special treatment, and Fig. 58, which illustrates the outside cylinder

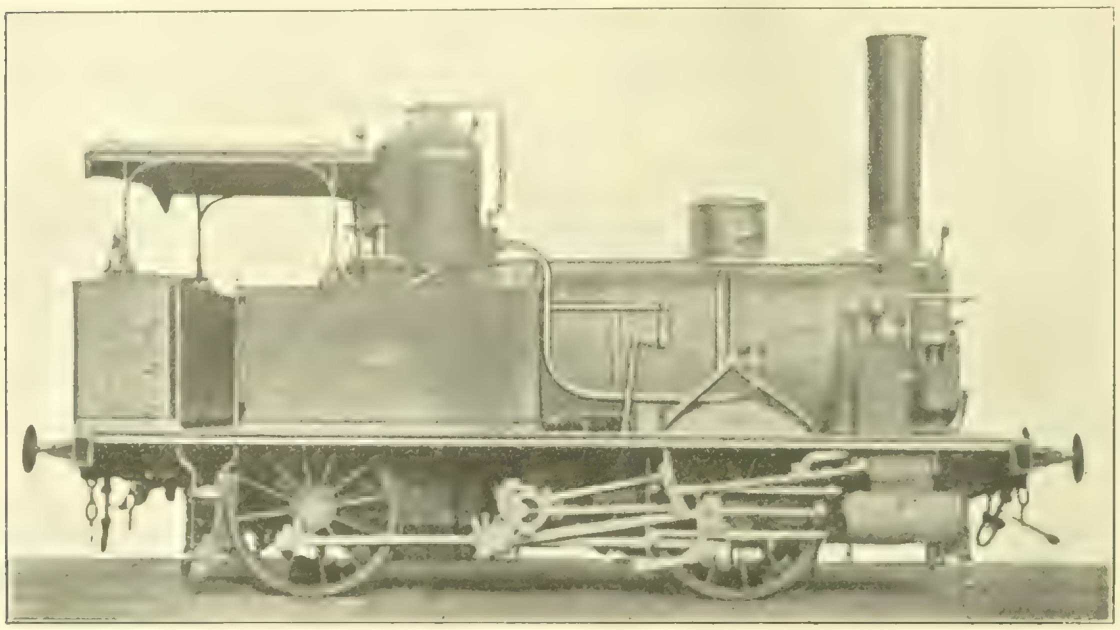


Fig. 58.—Outside Two-cylinder Four-coupled Driver Crampton Locomotive. Transmits its "hammer blow" through its springs.

equivalent of the engine illustrated in Fig. 47, is a case in point. As may be seen from the illustration, the connecting rods actuate outside cranks fixed on the ends of an intermediate crank shaft from which cranks, coupling rods are led forward and backward to actuate the leading and trailing coupled wheels. In these wheels the coupling cranks and the half of each coupling rod are the only parts for which balance weights are provided, the remaining parts of the coupling rods, along with the outside cranks, the connecting rods, and the reciprocating parts, in their due proportion, being balanced by the large sector tail weight on the outside cranks seen behind the eccentrics and rods. The result is that, as in the case of the equivalent inside cylinder engine, this engine transmits its hammer blow to the rails through its springs. In the longitudinal direction the engine is balanced in the same degree as an ordinary engine.

Fig. 59 illustrates an outside cylinder,. 8-coupled, driver engine with an intermediate crank shaft, the cylinders in this case being vertical. The placing of the cylinders vertically over an intermediate crank shaft at the centre of the engine enabled a very equable distribution of the weight on the coupled wheels to be made, especially as two boilers with their fireboxes towards the centre of the engine were used, and the combustion products led to a central chimney through return flues along the tops of the boilers. In other words, the centre of gravity coincides with the centre of the engine. It might be thought that placing the cylinders vertically would make the engine unsteady in its running, but such is not the case; in fact, it is equally as steady as an ordinary engine with horizontal cylinders, and requires somewhat less balance weight to make it so. There are no balance weights shown in the wheels, but had the engine been correctly balanced the revolving parts attached to each wheel should have had a corresponding balance weight. To make the engine equal in balance to an ordinary engine, with two-thirds of its reciprocating parts balanced, a weight equal to one-third of the reciprocating parts would require to be placed opposite the main crank, and in all likelihood such a weight actually was provided in the form of a sector cast on the back of the crank disc. The reduction in weight therefore corresponds to one-third of the weight of the reciprocating parts, but actually would be somewhat less owing to the lesser radius of the crank disc compared with the coupled wheels. Balanced in this way the engine would transmit its hammer blow to the rails through its springs, and, it may be noted, the fact of the connecting rods being threaded inside the coupling rods would be in favour of the steadiness of the engine. Had the balance weight on the crank disc been equal to two-thirds of the weight of the reciprocating parts, as in an ordinary engine, the hammer blow effect would be differently produced, but not altered in amount. This may be understood when it is remembered an ordinary engine is left with one-third of the reciprocating parts unbalanced in the longitudinal direction. As the amount of the balance weight in the crank disc is assumed to be equal to two-thirds and as this amount would be acting longitudinally and quite independent of the balance it was effecting vertically, the balance weights for the revolving parts in the wheels would require to be made less in weight so that half of the longitudinal effect of the balance weight in the crank disc would be counteracted by a corresponding deficiency in balance of the revolving parts attached to the wheels. As a result half of the hammer-blow effect would be transmitted to the rails direct and only half through the springs, as compared with the case of the crank disc weight being equal to one-third the weight of the reciprocating parts.

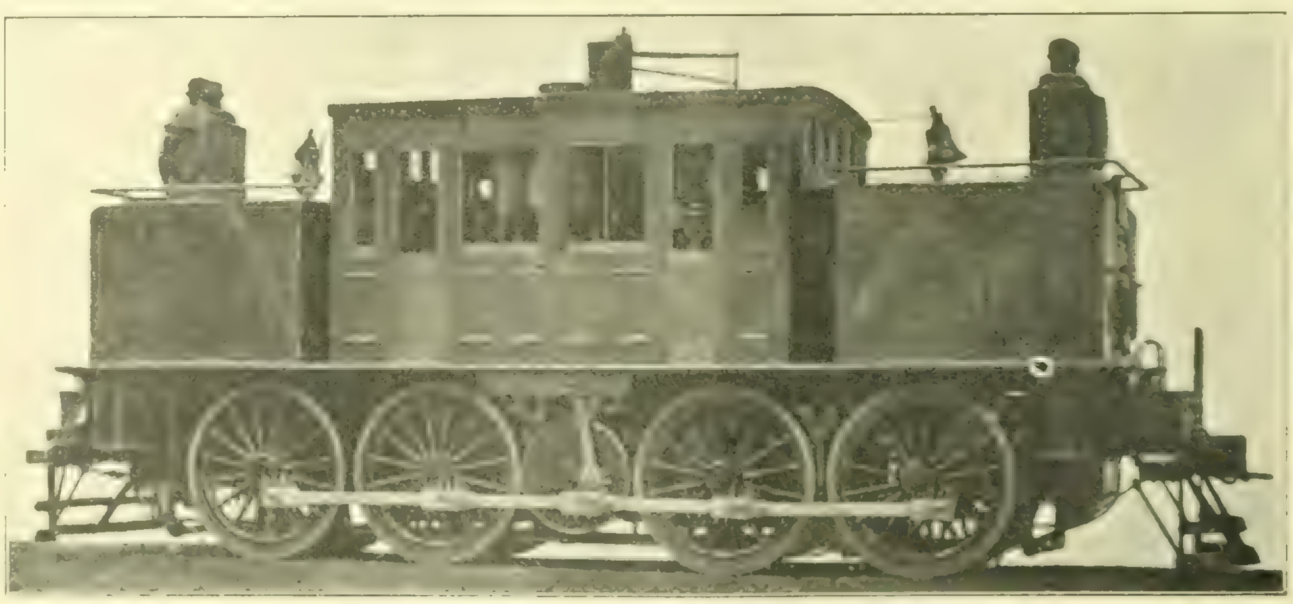


Fig. 59.—Outside Two-cylinder Vertical Eight-coupled Driver Locomotive.

This engine was known as the Raub Central Power Locomotive and was built in America some 16 years ago.

Although in the course of these articles some rather ancient specimens of locomotives have been illustrated, they have each served to illustrate some peculiar construction affecting the balance, but are not intended in any way to be taken as representing a connected record of the development of the locomotive even from a balancing point of view. Nevertheless, in view of the fact that the use of an inter

mediate crank shaft on a locomotive is in some quarters regarded as an original conception introduced on the Crampton locomotives, it may be desirable to illustrate here a locomotive of Mr. Timothy Hackworth's design built for the Stockton and Darlington Railway in 1832. This engine is illustrated in Fig. 60, and from the fact that no balance weights are evident it will be easily enough concluded that balance had nothing to do with the use of the intermediate crank shaft or the vertical cylinders. At the time this engine was built locomotive engineers were more concerned about the blow given to the rails by the dead weight of the engines than about any hammer-blow effect from unbalanced moving parts, most of the engines of that period having their cylinders either vertical or so much inclined that springs could not be used on the driving axles. The purpose of the intermediate crank shaft therefore on the Hackworth engine was to enable all the wheels to have springs and so obviate the shocks to the rails as well as to the engine itself from unevenness in the road.

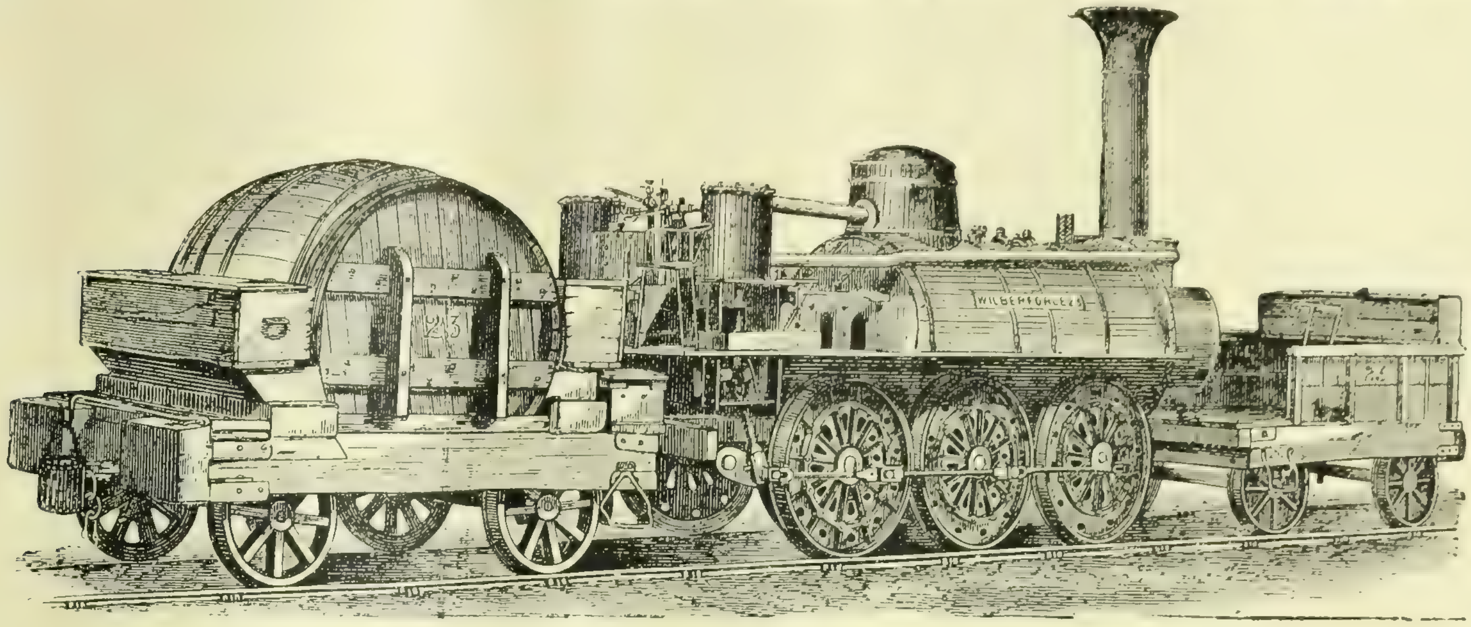


FIG. 60. HACKWORTH OUTSIDE TWO-CYLINDER (VERTICAL) SIX-COUPLED DRIVER LOCOMOTIVE "WILBERFORCE," Stockton and Darlington Railway, 1832.

In each of the cases of intermediate crank shaft engines so far illustrated the crank shafts revolve in bearings fixed on the frames of the engines. Fig. 61 illustrates a small engine in which an intermediate crank shaft is used, but in this case the crank shaft revolves in bearings sliding between hornblock guides similar to the axlebox guides. The purpose in using the intermediate crank shaft in this case is that of keeping the working parts well up out of the dust from the roadbed, the crank shaft being carried by strut rods from the axleboxes and the power transmitted to the driving axle by vertical transfer coupling rods. The construction in detail will be understood from Fig. 62, which illustrates the cross-section drawing of a small inside cylinder engine with a similarly-arranged intermediate crank shaft. The cylinders are placed between the frames above the boiler in this case, and in both cases outside cranks on the ends of the intermediate crank shaft are used. It will be noticed the intermediate crank shaft rises and falls along with the driving axle and that the driving strains imposed by the vertical coupling rods are taken up by the strut rods connecting the axleboxes and bearings. So far as balancing is concerned the vertical coupling rods are purely revolving parts and are balanced as usual by weights placed opposite the cranks. That is to say, no matter in which direction the coupling rods may be working, vertically, inclined, or horizontally, the position of the balance weight is the same in all cases.

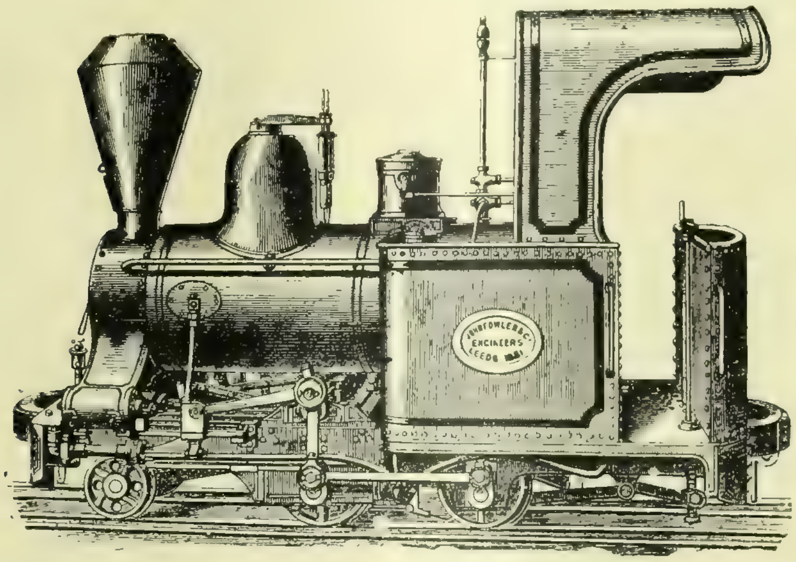


FIG. 61.—OUTSIDE TWO-CYLINDER LOCOMOTIVE WITH INTERMEDIATE FLOATING CRANK SHAFT AND VERTICAL TRANSFER COUPLING RODS.

The engine illustrated in Fig. 63 represents a type of which considerable numbers have been built for tramway and contractors' purposes on the Continent. Probably the first engine of this type was a passenger engine designed for the Belgian State Railways by M. Belpaire, the inventor of the square-topped firebox so extensively used in modern locomotive boilers. The engine in question was built in 1872 by Messrs. Carel Frères, of Ghent, and exhibited in the Vienna Exhibition of 1873. The distinguishing feature of the type is the use of a rocking beam between the piston rod crosshead and the connecting rod. This construction has a considerable influence on the amount of balance weight required to effectually balance the moving parts. To balance the

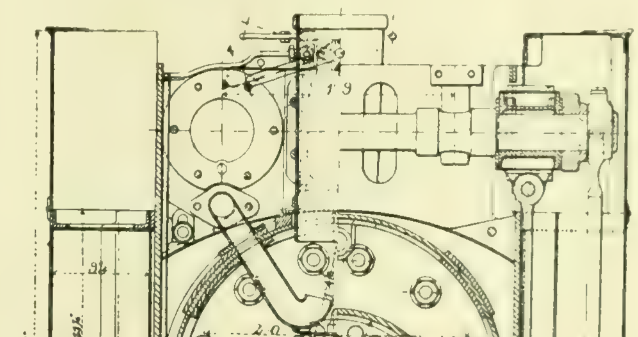


FIG. 62.—CROSS-SECTION OF INSIDE TWO-CYLINDER LOCOMOTIVE WITH INTERMEDIATE FLOATING CRANK SHAFT AND VERTICAL TRANSFER COUPLING RODS.

reciprocating parts it is only necessary to leave a corresponding amount of the revolving parts unbalanced, due regard being given to the fact that the rocking beam requires no balance. The remainder of the revolving parts is balanced in the usual manner. It will be seen therefore that only a minimum of balance weight is required for an engine of this type. The engine illustrated was built by the Swiss Locomotive Works of Winterthur to the design of the late Mr. Charles Brown, an English engineer in charge of these works and the inventor of the combination of radial valve gears usually known in this country as the Joy gear. Amongst other uses to which this type of engine has been put on the Continent is that of operating rack railways, and when a rack railway was made up Mount Snowdon in this country the English engineers obtained the engines for the railway from the Swiss Locomotive Works. Of course something distinctly original had to be imparted to the design of the engines. This feature is shown on the engine as illustrated in Fig. 64. The rocking beam, instead of providing for a mutual balance of parts in this case increases the weight to be balanced, and it may be understood from the relative size of the coupled wheels that to provide the necessary balance weights in the wheels was practically impossible. Considering the weight of reciprocating and revolving parts in motion on each side of the engine thus left unbalanced, it is not at all surprising to learn that these engines were very unsteady in their working, and that one of them ultimately threw itself off the road and rolled down the mountain. The succeeding engines had their parts arranged as in Fig. 63.

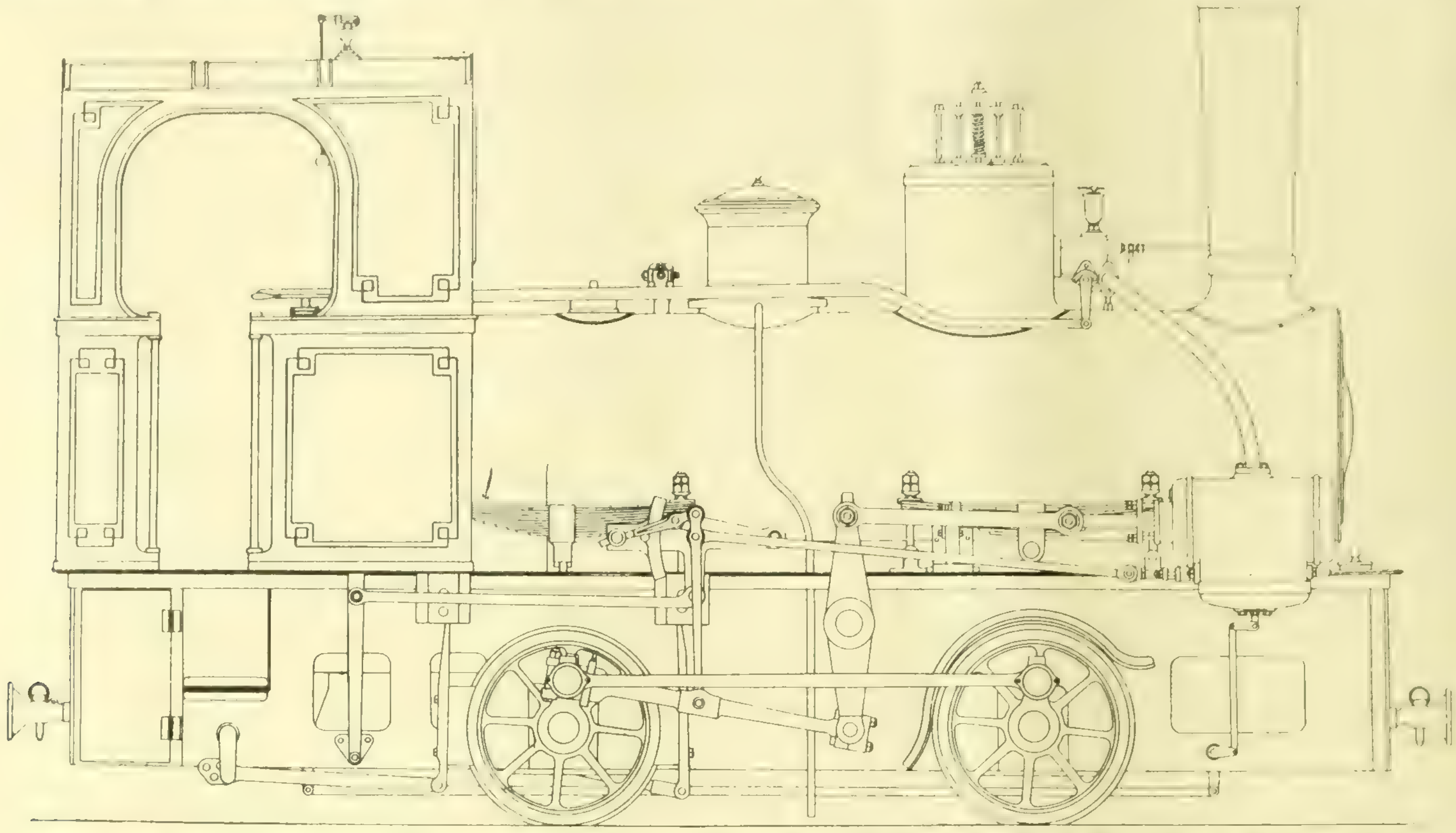


FIG. 63.—OUTSIDE TWO-CYLINDER LOCOMOTIVE WITH BALANCED ROCKING BEAM. Requires a minimum amount of Balance Weight.

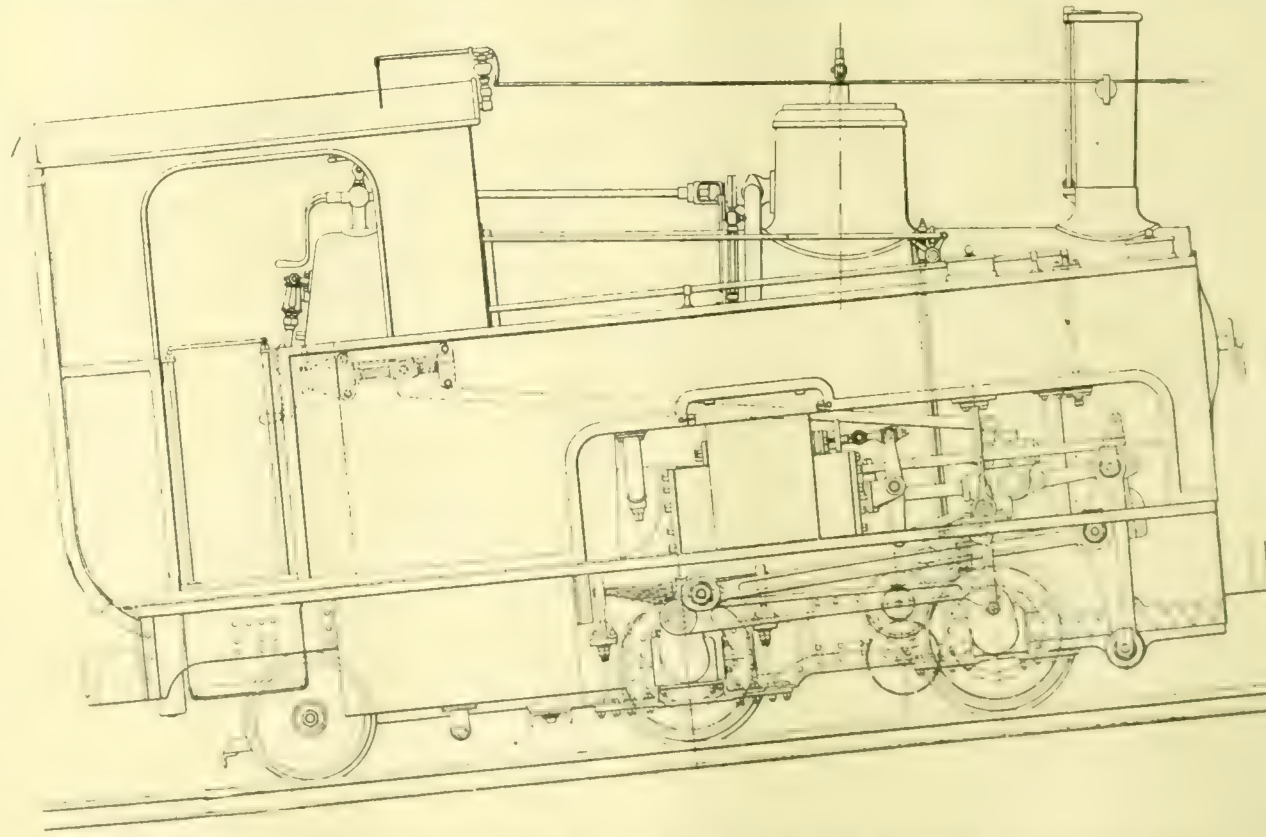


FIG. 64.—OUTSIDE TWO-CYLINDER LOCOMOTIVE, WITH NO BALANCE, AND WITH DEFECTIVE ARRANGEMENT OF ROCKING BEAM.

To make the series of illustrations accompanying these articles cover probably all the methods that have been used to connect the pistons of rigid frame engines with the wheels, the three engines following are given, although from a balancing point of view they are of comparatively little interest. Fig. 65 illustrates a cheap type of contractor's engine with a single cylinder and transmitting its power to the driving wheels by spur gearing. From the cross-section drawing illustrated in Fig. 66 it will be seen the pinion and spur wheel are maintained in correct meshing by struts between the driving axle and the crank shaft in the same manner as in Figs. 61 and 62. As regards balancing, the relative speeds of the crank shaft and the driving axle make it impossible to place balance weights in the driving wheels, consequently all that can be done is to provide tail weights on the crank webs to balance the crank arms and half the connecting rod. As regards reciprocating parts, these also can have tail balance weights and the corresponding secondary weight usually provided to maintain transverse balance would be placed in the flywheel, but it will be understood that the secondary weight will set up a longitudinal disturbance, although eliminating vertical disturbances.

Fig. 67 illustrates an outside 2-cylinder engine in which the power is transmitted by a combination of spur and chain gears. The driving wheel rims are made nearly semi-circular in section so that the engine can run on rails formed of wooden poles, this type of engine being used in large numbers in the timber regions of America.

Fig. 68 illustrates an outside 2-cylinder engine which is primarily a 4-coupled driver engine, but which by a combination of 4-wheeled and 6-wheeled trucks under each pair

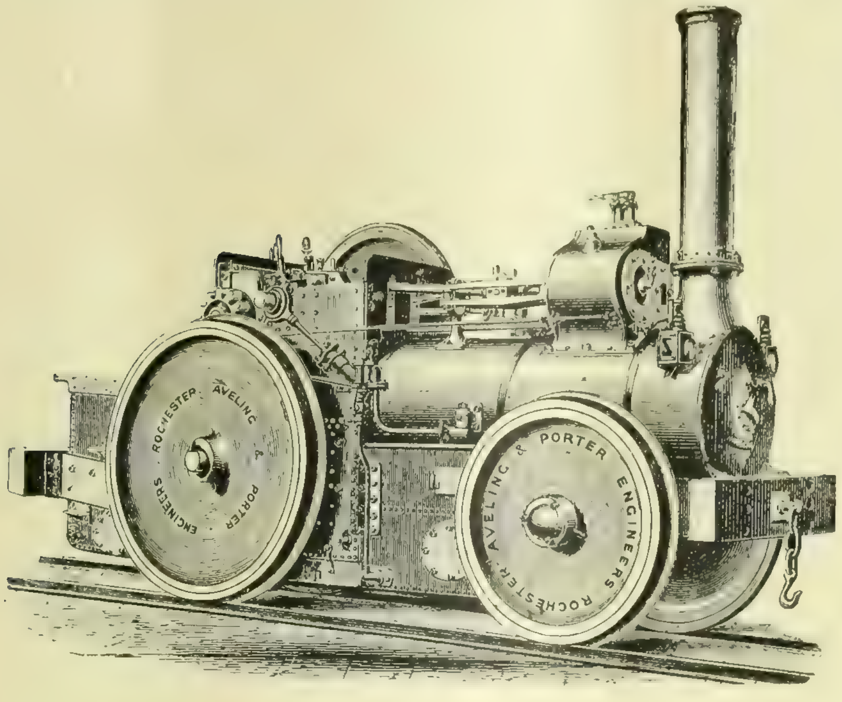


FIG. 65.—INSIDE SINGLE-CYLINDER LOCOMOTIVE WITH SPUR-GEAR TRANSMISSION.

of drivers becomes virtually equivalent to a 12-coupled driver engine. The truck wheels are in both cases of two diameters, the main driving wheels riding on the smaller diameters of the wheels of the 4-wheeled trucks, the larger diameters of

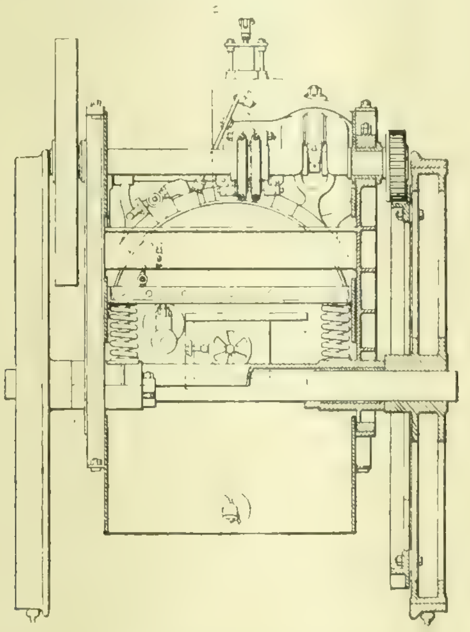


FIG. 66.—CROSS-SECTION OF SINGLE-CYLINDER SPUR-GEAR TRANSMISSION LOCOMOTIVE.

these wheels in their turn riding on the smaller diameters of the wheels of the 6-wheeled trucks. The larger diameters of the wheels of the 6-wheeled trucks ride on the rails and form the actual driving wheels. From this it will be seen the

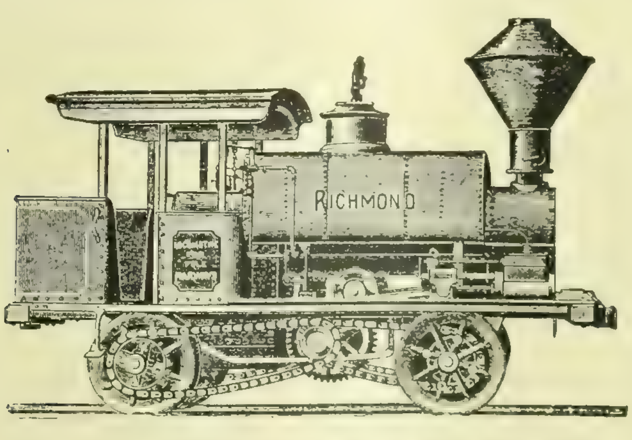
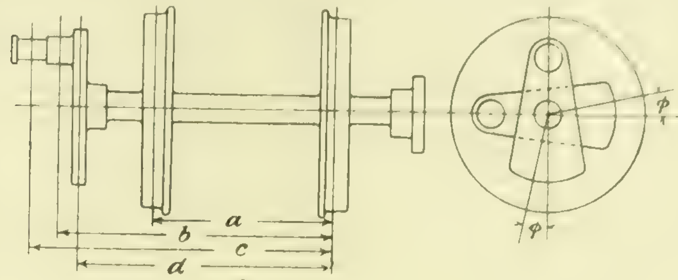


FIG. 67.—OUTSIDE TWO-CYLINDER LOCOMOTIVE WITH SPUR AND CHAIN GEAR TRANSMISSION.

power is transmitted by a compound friction gearing, the intensity of contact being increased by the wedging relation between the various wheels. At the rails of course the traction is determined by the total weight on the various wheels, but the mechanical efficiency of such an arrangement must in any case be extremely low, owing to the excessive friction set up on the various journals by the wedging action taking place between the various wheels.

Narrow-gauge engines are mostly small wheeled engines, and in most cases require to be built with outside cranks. The use of the outside cranks introduces extra factors into the balancing calculations. These take the following form:—

Form of Balance Weight Calculation (Outside Cranks).



Let a = distance between centres of gravity of balance weight.

b = distance between coupling rod centre and far balance weight.

c = distance between connecting rod centre and far balance weight.

d = distance between crank arm centre and far balance weight.

W_1 = weight of crank arm acting at distance d and balanced by tail on crank.

W_2 = weight of revolving masses, *i.e.*, part of coupling rod with included part of crank pin acting at distance b.

W_3^A = weight of revolving masses, *i.e.*, part of connecting rod with included part of crank pin acting at distance c and balanced by tail on crank.

NOTE.—No part of coupling rod or pin should be balanced by tail on crank, but as much as possible of half the connecting rod and pin.

W_3 = weight of revolving masses, *i.e.*, half connecting rod (less W_3^A) with included part of crank pin acting at distance c.

W = weight of reciprocating masses to be balanced in each wheel and acting at distance c in all cases.

W_P = primary balance weights.

W_S = secondary balance weights.

C = combined balance weights.

Driving Wheels (with tail on crank).

$$W_{P1} = W_1$$
$$W_{P2} = W_2 \frac{b}{a}$$
$$W_{S2} = W_{P2} - W_2$$
$$W_{P3}^A = W_3^A \frac{c}{d}$$
$$W_{S3}^A = W_{P3}^A - W_3^A$$
$$W_{P3} = W_3 \frac{c}{a}$$
$$W_{S3} = W_{P3} - W_3$$
$$W_{P4} = W_4 \frac{c}{a}$$
$$W_{S4} = W_{P4} - W_4$$
$$W_P = W_{P2} + W_{P3} + W_{P4}$$
$$W_S = W_{S2} + W_{S3}^A + W_{S3} + W_{S4}$$
$$C = \sqrt{(W_P)^2 + (W_S)^2}$$
$$\frac{W_S}{W_P} = \text{tan of angle of divergence } \phi$$

Leading or Trailing Wheels (no tail on crank).

$$W_{P1} = W_1 \frac{d}{a}$$
$$W_{S1} = W_{P1} - W_1$$
$$W_{P2} = W_2 \frac{b}{a}$$
$$W_{S2} = W_{P2} - W_2$$
$$W_{P4} = W_4 \frac{c}{a}$$
$$W_{S4} = W_{P4} - W_4$$
$$W_P = W_{P1} + W_{P2} + W_{P4}$$
$$W_S = W_{S1} + W_{S2} + W_{S4}$$
$$C = \sqrt{(W_P)^2 + (W_S)^2}$$
$$\frac{W_S}{W_P} = \text{tan of angle of divergence } \phi$$

Note.—All weights are taken at crank pin radius—*i.e.*, inch-pounds—and are to be reduced in ratio according to balancing moment of crescent found.

The reference above to tail weights on the driving cranks is due to the difficulty already commented upon of getting the necessary amount of balance weight into the driving wheels

of small-wheeled engines. Except in cases where it is impossible to get the necessary amount of balance weight for the revolving parts attached to the coupled wheels conveniently placed in these wheels, it is unnecessary and not at all desirable to have tail weights on the coupling cranks, as their use involves an extra amount of weight in comparison with the effect produced.

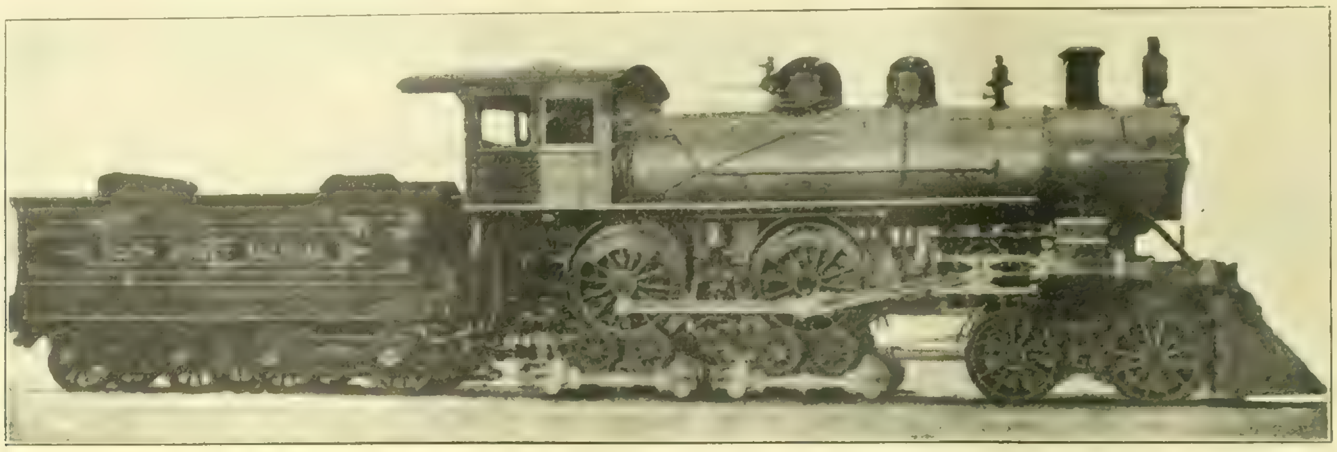


FIG. 68. OUTSIDE TWO-CYLINDER LOCOMOTIVE, WITH FRICTION GEAR. Transmission equivalent to 12-Coupled Drivers.

Fig. 69 illustrates an engine with outside cranks built for a 2ft. 6in. gauge, having six wheels coupled in the usual manner, *i.e.*, the coupling rods are threaded in a straight line and the connecting rods are placed outside the coupling rods. From the half-plan view, and more especially from the cross-section drawing illustrated in Fig. 70, it may be noticed how rapidly the amount of balance weight necessary increases as the cylinder and coupling rod centres are increased in relation to the balance weight centres in the wheels. Being coupled up in the usual manner, this engine requires only the number of primary and secondary balance weights given in the form of calculation above. The fact that the engine has a trailing wheel set well back as shown is an important factor so far as longitudinal stability is concerned, as it is very probable that the majority of narrow gauge small-wheeled engines with outside cranks are by no means completely balanced.

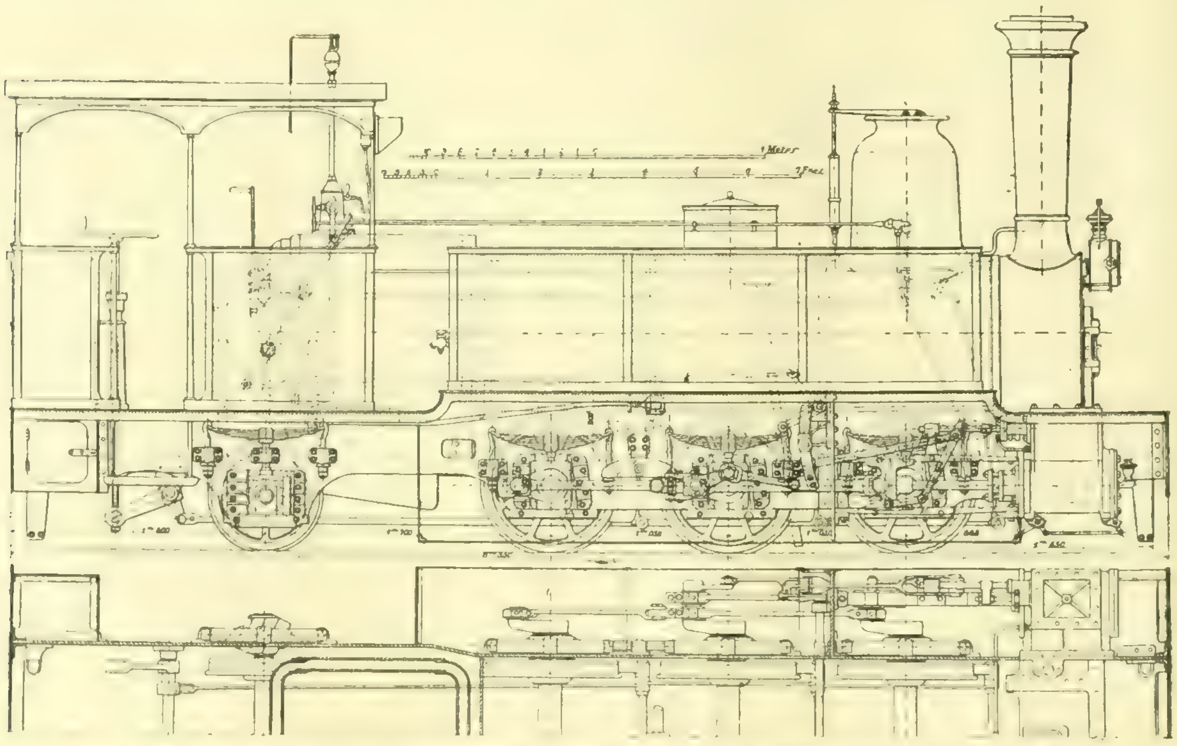


FIG. 69. OUTSIDE TWO-CYLINDER SIX COUPLED DRIVER LOCOMOTIVE, WITH SEPARATE OUTSIDE CRANKS

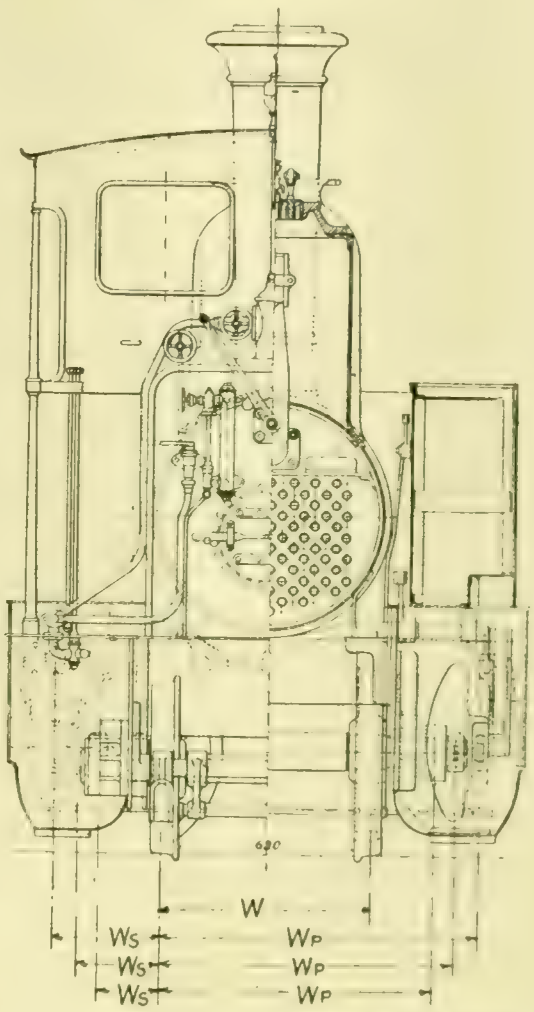


FIG. 70.—CROSS-SECTION OF LOCOMOTIVE WITH SEPARATE OUTSIDE CRANKS SHOWING HEAVY PRIMARY AND SECONDARY BALANCE WEIGHTS REQUIRED

Fig. 71 illustrates the half-plan section of a 6-coupled driver, metre gauge engine built for the Indian State Railways in which special efforts have been made to overcome the difficulties of balancing engines with outside cranks. It will be noticed the cylinders were placed as close as possible to the longitudinal centre plane of the engine, the connecting rods being placed inside the coupling rods. These latter are

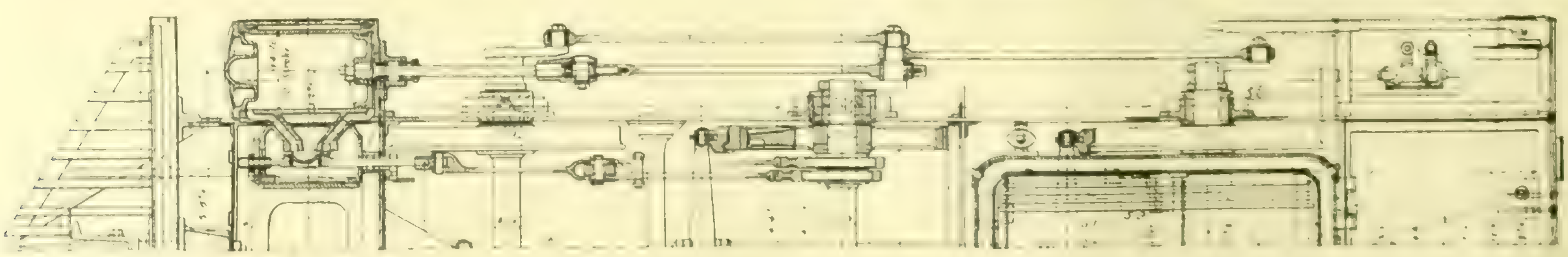


FIG. 71.—HALF PLAN SECTION OF SIX-COUPLED DRIVER LOCOMOTIVE WITH OUTSIDE CRANKS AND COUPLING RODS, THREADED IN PARALLEL LINES OUTSIDE THE CONNECTING RODS

threaded in parallel lines, so that the cranks of the leading coupled wheels may clear the piston rod crossheads. To enable the connecting rods to be placed inside the coupling rods it was necessary to set the cylinders at a considerable inclination so that the piston rod crossheads should clear the crank bosses on the leading coupled axle. In determining

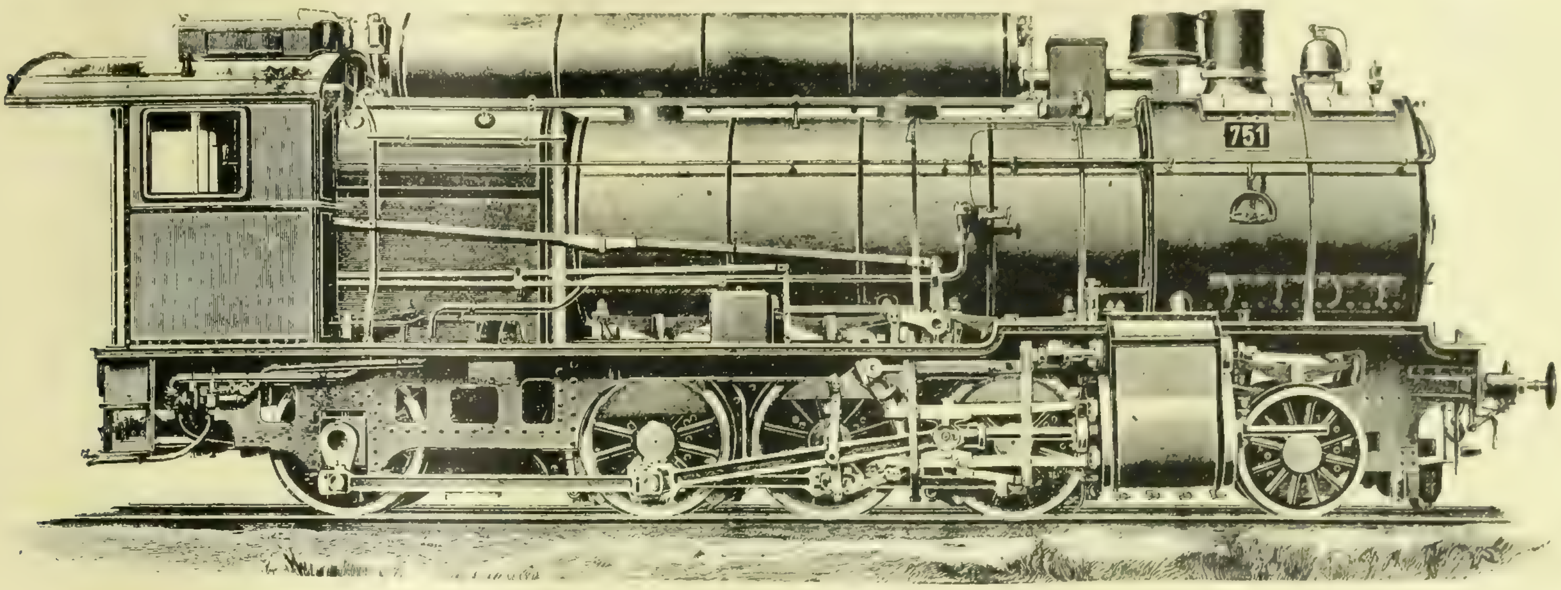


Fig. 72.—Outside Two-cylinder Eight-coupled Driver Locomotive with Cranks in Wheels as well at Separate Outside Cranks.

the balance weights to be placed in the driving wheels of this engine it may be noticed there would be no less than 10 separate weights to be combined in one in each wheel—5 primaries and 5 secondaries—and that the crank planes are different for all the wheels.

The 8-coupled driver engine illustrated in Fig. 72 is

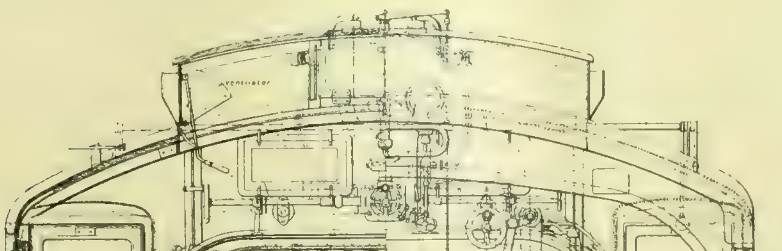


Fig. 73.—Cross-section of Eight-coupled Driver Locomotive Showing Coupled Wheels in which no Balance Weights should be Placed.

interesting from the fact that it shows a combination of coupling cranks in the wheels and separate outside cranks used on the same engine. The reason for the combination is that the trailing wheels are arranged to radiate on curves, while the axle on which they are mounted remains parallel to the other axles. The construction that enables this action to take place is illustrated in the cross section drawing given in Fig. 73. It will be noticed the trailing wheels are connected by a sleeve and driven from the centre of the axle by a universal joint which permits of lateral movement of the wheels under control of coiled springs. The lateral movement is made radial by controlling bars journalled on the outside of the sleeve as shown. From this it will be recognised that it would be extremely undesirable to place any balance weights in these wheels, as their motion planes and radii vary according to the radii and direction of the curves over which the engine is passing. As a matter of fact, the outside cranks on the axle should have had tail weights, but consideration of the amount of dead weight already concentrated on that axle probably accounts for their absence.

The Andrew Carnegie Gold Medal.—The Council of the Iron and Steel Institute have this year decided to award the Andrew Carnegie Gold Medal of the Institute to Dr. Paul Goerens, of Aachen. Dr. Goerens is a distinguished metallurgist, and is a member of the staff of the Royal Technical College at that city. In 1910 he was awarded one of the Carnegie Scholarships of the Iron and Steel Institute, to enable him to pursue his investigations on the influence of cold-working on the properties of iron and steel. The gold medal is now awarded to him in recognition of the highly meritorious character of his research work on this subject.

Oil Fuel for Locomotives.—An interesting experiment in the use of oil fuel for locomotives is being made by the Caledonian Railway Company. At their locomotive works at Glasgow an engine has been fitted up with oil-burning apparatus. The oil is stored in a cylindrical tank placed on the top of the tender, in a part of the space usually occupied by the coal. The oil flows from the tank to the engine injectors, which force it into the firebox at two separate points, about 18in. apart, where a current of steam from the boiler causes it to assume the form of fine spray spreading itself through the firebox. By means of a thin layer of wood or coal fire covering the firebars this spray is ignited, and so generates steam for the motive power as well as for the injecting and spraying. The extent of the flame is regulated by a controlling valve on each of the injectors. The firebox, in addition to the customary firebrick arch, is equipped with a firebrick wall to protect the copper front plate from the effects of the great heat produced by the oil fuel. The special fittings are of such a kind as permit of the engine using oil or coal as may be found desirable. On several non-stop runs made on Friday last with this engine, having a special carriage attached, the oil consumed was $1\frac{1}{2}$ galls. per mile. Drawing a full train it is estimated that the locomotive will require 3 galls., or 27lbs., per mile of the crude oil with which the furnace is fed. The tank which carries the supply contains 520 galls.—sufficient for a train run of 140 miles. The runs were thoroughly successful, and the locomotive, which is the first in Scotland so fitted, has now taken its place in the regular service of the company.

THE GEARED TURBINE CHANNEL STEAMERS "NORMANNIA" AND "HANTONIA."*

BY PROF. J. H. BILES, LL.D., D.SC.

THE fact that the turbine has to run a higher number of revolutions than the screw propeller, in order that both may develop their highest efficiency, has led to the consideration of means of transmitting the power through some reduction gear. Electrical transmission has been strongly advocated, and in cases where a great range of high efficiency is required it has some advantages. Its maximum efficiency cannot, however, be placed at more than 90 per cent. In some cases it may be an overall advantage to sacrifice maximum efficiency in order to gain a high mean efficiency over a large range of speed. In the case of a warship in which its circumstances called for a great radius of action at moderate speeds, it might be of more importance to have a high mean efficiency than a high maximum efficiency. This was the case, as a rule, in warships which had reciprocating engines. They were generally not so efficient at full speeds as were the mercantile steamers of the same period, but their mean efficiency over the varying lower speeds was higher than if they had been more efficient at full speeds. Hydraulic transmission has been used in some cases, and the system associated with the name of Dr. Föttinger is described in Mr. Holzapfel's paper.† Its efficiency is, however, below 90 per cent. at full speed. Both the electrical and hydraulic systems of transmission admit of very large powers astern without separate prime movers.

The system of transmission which is the most obvious one to adopt is that of mechanical gearing. It was adopted in the earlier days of the screw, when the engine was slower running than the propeller. The gear wheel was on the engine and the pinion on the shaft. Mechanical gearing was not popular in those days. The noise was objectionable. The wear of the teeth was considerable. Its efficiency must have been low. But the gradual increase in speed of engines rendered the gearing unnecessary. The engineers blessed the decease of mechanical gearing. Its suggested resurrection was looked upon with horror. But the advent of the motor-car has familiarised us with the possibility of quiet-running mechanical gearing. Machine-cut helical teeth have made it possible for us to look upon the reintroduction of gearing with some degree of hope that the most obvious method of mating the turbine with the propeller could become a practical possibility.

De Laval showed how gearing could be successfully applied in his turbine, which runs at many thousands of revolutions per minute. The Westinghouse Company have applied helical gearing to large powers on the Melville and Macalpine system. Sir Charles Parsons tried gearing in connection with his earliest turbines, but did not continue its use, preferring the disadvantages of the small screw in marine work to those of the gearing. There is, however, a limit of speed of ship, below which it does not seem to be economically desirable to go in the directly-coupled turbine and screw. With a view to applying gearing to a turbine-propelled vessel of low speed, the Parsons Company adapted the s.s. "Vespasian" for this purpose. Two papers have been read by Sir Charles Parsons describing his method of applying gearing to this vessel. The first described the results of comparison of steam trials between the old reciprocating engines of this ship and the new turbine geared engines. These trials showed that an increase of 20 per cent. of power was gained with 20 per cent. higher efficiency. The loss due to transforming the power from the high speed of revolution of the turbine to the low speed of the propeller was only 1½ per cent. The second paper gave the results of a year's work of this vessel and showed complete justification for the adoption of this method of transforming.

In the winter 1910-11 the London and South-western Railway Company had taken delivery of two 3-screw turbine-driven vessels, the "Cæsarea" and "Sarnia," built by Messrs. Cammell, Laird, & Co. for the Channel Islands service. The design and construction of these vessels was supervised by my firm. The trial speed of these two ships was 20 knots. The sea speed required was 18 to 19½ knots. This speed is not so advantageous as higher speeds for the application of the directly-coupled turbine. The company were considering building two similar vessels for the Havre and Southampton service. It was desired to get all the advantages of the "Cæsarea" and "Sarnia," but with a considerable reduction of fuel consumption.

The gradual increase in the requirements of the passengers in speed and accommodation could not be met without increased horse-power and consumption. To give some idea of the growth of horse-power which has been associated with the development of the cross-Channel services of the London and South-western Railway Company the following table has been prepared:—

	Built.	Displacement.	Passenger Accommodation.		Six Hours' Trial.		Remarks.
			1st.	2nd.	Speed.	H P	
"Alma"	1894	1,350	102	51	18·5	3,250	I.H.P.
"Alberta"	1900	1,530	135	50	19·0	4,500	I.H.P.
"Cæsarea" & "Sarnia"	1910	1,990	186	114	20·0	6,670	S.H.P.

To effect the object of reducing consumption without reducing the advantages of speed and accommodation to the travelling public which had been secured in the last two steamers did not appear at first sight to be an easy problem, because these vessels were very efficiently propelled.

Perhaps it may be permissible to refer to the results of the earlier turbine steamer "Londonderry," built in 1904 to my firm's designs for the Midland Railway by Messrs. Denny, in order to show how with higher speeds higher turbine efficiencies have been obtained. The "Londonderry" attained a speed of 21·6 knots on a 6-hours' trial. The machinery was of the ordinary 3-screw turbine type, and the water consumption on the 6-hours' trial was 15·7lbs. per shaft horse-power per hour. The "Cæsarea," the London and South-western Railway Company's 3-screw turbine steamer, already referred to, obtained a mean speed of 20 knots on the 6-hours' trial with a mean water consumption for all purposes of 17·1lbs. per horse-power hour. On service the "Cæsarea" was run at speeds which aimed at being about 18, 19, and 20 knots for each of a series of trips of two double runs across the Channel, and the coal used on these runs was carefully measured. The shaft horse-powers were not measured, but were carefully estimated from the revolutions and the receiver pressures. The results are given in the following table:—

TABLE A.

Proposed speed	18	19	20
Actual sea speed	18·22*	18·88	19·49
Shaft horse-power	5,060	5,830	6,460
Coal per S.H.P. lbs. ...	1·70*	1·48	1·71

* During one of the runs at this speed the engines were eased for 40 minutes in a snow-storm. If this pair of runs be omitted the coal per shaft horse-power is 1·54lbs.

The coal used on the builders' official trip at 20 knots of the "Sarnia" was carefully measured, and showed a consumption of 1·72lbs. per shaft horse-power. The results given in the table are those upon which it was desired to improve.

The dimensions of the "Cæsarea" and "Sarnia" are as follows:—

Length over all ...	296ft. 0in.
Length between perpendiculars ...	284ft. 0in.
Breadth moulded ...	39ft. 0in
Depth moulded to promenade deck	23ft. 10in

The boilers are two double ended ones of the following dimensions:—

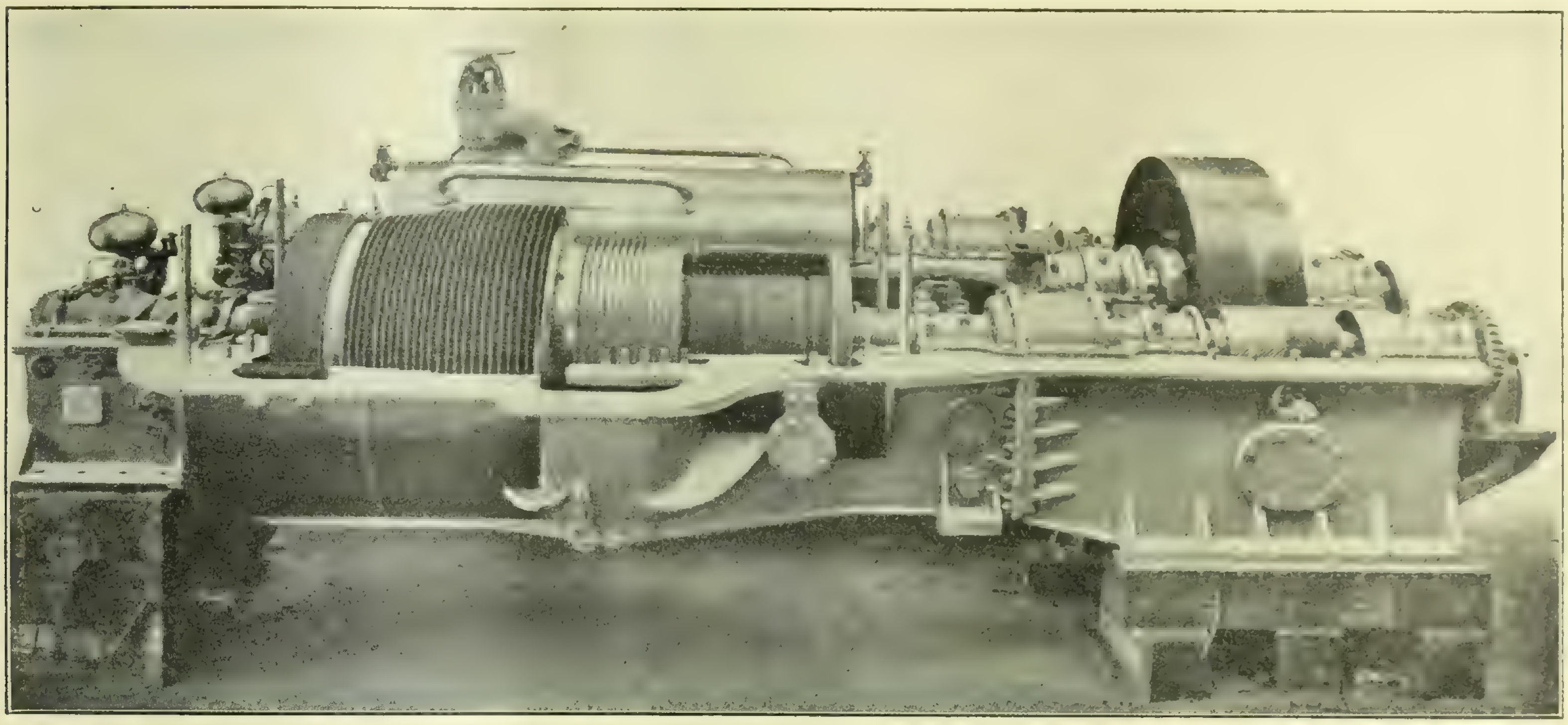
Length ...	23ft. 0in.
Diameter ...	16ft. 5in.
Grate surface ...	338 sq. ft.
Heating surface ...	12,985 sq. ft
Pressure ...	160lbs per square inch

The successful results of the Parsons Company's work in the "Vespasian" induced us to consider the adoption of geared turbines. The Parsons Company estimated that a

* Paper read at the spring meetings of the fifty third session of the Institution of Naval Architects, March 29th, 1912.

† This paper was reproduced in our issue of March 29th. See p. 386 ante.

water consumption of $12\frac{1}{2}$lbs. per shaft horse-power for the propelling engines could be obtained by the adoption of geared turbines. Allowing for the auxiliaries the amount consumed in the "Cæsarea" we were able to make a reduction of the boiler power, so that one double and one single-ended boiler could be adopted instead of two double-ended ones. By placing these with their axes at the middle line of the ship it was possible to reduce the beam of the vessel if a form could be found which would give the necessary stability. The principle enunciated by Dr. Froude that resistance depends on the beam of the ship, the curve of cross-sectional areas, and the form of the water-line forward enabled us to adopt a water-line on a reduced beam which had sufficient moment of inertia to give as much metacentric height as the wider form of the "Cæsarea." In fact, it was found possible to reduce the beam from 39ft. to 36ft. The 39ft. beam of the "Cæsarea" was necessary to properly contain the two double-ended boilers, and with this beam a fine water-line aft was full enough to give the necessary stability. The saving in weight of the reduced hull and boilers reduced the displacement and the horse-power necessary to drive the vessel. A further reduction in horse-power was made by reducing the 6-hours' speed from 20 to $19\frac{1}{2}$ knots. These figures are given to show one of the advantages of the 3-screw turbine in sea work is the great immersion of the screw tips and the consequent freedom from racing and loss of propulsive efficiency by the screws coming out of water. The diameter of the propellers in the 3-screw ships is only about $5\frac{1}{2}$ft. It is not generally possible with reciprocating engines in vessels of this size and power to increase the revolutions very much, and therefore the disadvantage of racing is accepted. In the geared turbine there is much more elasticity of choice of diameter of propeller, and it was decided to adopt a speed of revolution which would allow of a propeller of 8ft. diam. to be used. This propeller has a tip immersion of 3ft. more than in the reciprocating engines, while the loss of efficiency due to its smaller diameter is not serious. Judging from model experiments with screws the relative efficiencies of a $10\frac{1}{2}$ft., 8ft., and $5\frac{1}{2}$ft. diam. propeller may be taken as in the ratio of about 1·2, 1·1, and 1·0 respectively. There is reason, however, to believe that the efficiences of the full-sized screws are not so greatly different as appears from these figures, though it is extremely probable that there is a considerable difference between the 10ft. and the 5ft. screws. Taking the relative efficiencies in smooth water into account, and the fact that in sea work the greatly increased tip immersion would increase the average



GEARED TURBINES OF S.S. "NORMANNIA" AND "HANTONIA."

to what causes it was looked to reduce the horse-power and consumption in the proposed vessels.

The adoption of the geared turbine was recommended by us for two reasons—first, for the reduced consumption per shaft horse-power; second, for the adoption of two slower-running larger diameter propellers, in place of three small diameter propellers, of the earlier ordinary turbine type. The advantage of the present arrangement lies in the increased efficiency of the propellers both at full speed at sea and at manœuvring speeds when entering harbours. Before such advice as this could be adopted, the directors of the railway had to give the matter most careful consideration. The time-honoured objections to gearing had to be taken into account. The chairman of the railway, Mr. Hugh Drummond, and the marine manager, Mr. Williams, took a trip in the "Vespasian," and as a result of what they saw they took their courage in both hands and gave the order to the Fairfield Company to build two vessels with geared turbines. The first of these vessels, the "Normannia," has been recently tried, and it is with a view of placing the results of this trial before this Institution that this paper has been written.

The revolutions of the 3-screw turbine are about 500, while those of the 2-screw geared turbine are only about 300. At first sight it may appear that full advantage has not been taken of the reduction possible in gearing. In reciprocating engines of about the same power in similar cross-channel steamers the revolutions are 170 to 180 and the propellers are $10\frac{1}{2}$ft. to 11ft. diam. These propellers have a high efficiency in smooth water, but with the limited draughts of these vessels they have not much tip immersion. Undoubtedly, sea-going efficiency of the smaller propeller, it was decided to adopt 300 revs. instead of the lower number, which at first sight appeared to be the best for geared turbines.

The dimensions and particulars of the geared turbine vessels "Normannia" and "Hantonia" are as follows:—

Length over all	299ft. 0in	
Length between perpendiculars	290ft. 0in.	
Breadth moulded	36ft. 0in.	
Depth moulded to promenade deck	23ft. 6in.	
Boilers.	One double-ended.	One single-ended.
Length	21ft. 10in.	11ft. 4in.
Diameter	17ft. 0in.	17ft. 0in.
Total grate surface	303 sq. ft.	
Total heating surface	10,221 sq. ft.	
Pressure	160 lbs. per square inch.	

The weight carried on the trial of the "Normannia" was the same as on the "Cæsarea" and "Sarnia." The trial took place on the Firth of Clyde. The vessel was first tried progressively, and the relation between revolutions and speed was established on the measured mile. The maximum speed at which the vessel was run was 20·4 knots with 6,100 shaft horse-power. To do the contract speed of $19\frac{1}{2}$ knots it was shown that 4,750 shaft horse-power would be required. The vessel was run for 6 hours, and maintained an average of 5,000 shaft horse-power, which corresponds to a speed of 19·7 knots. The average air pressure in the stokeholds was less than $\frac{1}{2}$in. The maximum air pressure never exceeded [illegible]in.

The total coal burnt was carefully weighed out, and showed a consumption per shaft horse-power per hour of 1·34lbs. The water consumption for all purposes was 14·3lbs. per horse-

power hour. From the trials of the "Cæsarea" and "Sarnia" it was found that the water consumption for auxiliaries was 1·96lbs. per shaft horse-power per hour, when the total consumption was 17·1lbs., leaving 15·1lbs. for propulsion only. In this case the shaft horse-power was 6,600. In other cases it was measured with confirmatory results. The actual quantity of water used for auxiliaries was between 12,500lbs. and 13,000lbs. When running at 5,000 shaft horse-power the water consumption for auxiliaries in the "Normannia" would be 11,500lbs., which is 2·3lbs. per shaft horse-power hour. Hence the water consumption for the propelling engines was 14·3 – 2·3 = 12·0lbs., as compared with 15·1lbs. in the "Cæsarea." The total coal consumed in 6 hours in the two cases was 18 tons for the "Normannia" at 19·7 knots, and 29 tons in the "Cæsarea" at 20 knots.

In the run from the Clyde to Southampton the "Normannia" averaged 13½ knots, which would require about 1,250 shaft horse-power. The consumption of coal works out at 2½lbs. per shaft horse-power hour. The coal consumed on service in the "Cæsarea" at her highest speed is ·25 ton per nautical mile. A similar figure for the "Normannia" is not yet available. The arrangement of the gearing and turbines is shown on the accompanying illustration.

It is evident that the adoption of the geared turbine enabled us to produce an improved design of ship. The only element of doubt present to the minds of those who had the responsibility of the decision was the amount of noise which the gearing would make. Undoubtedly the running of turbine steamers has pleased the travelling public by their freedom from noise. The throb of the reciprocating engines has become a thing of the past, and to introduce a means of propulsion which is not as quiet as the turbine would not be looked on with favour by passengers. A careful consideration of the causes of what little noise there was in the "Vespasian" (the only geared turbine then in existence in a ship) led to the conclusion that the noise would be negligible. The trials of the "Normannia," and her passage from the Clyde to Southampton, have proved to those who were on board that the anticipation was a correct one. By listening carefully, when in the passenger quarters, a slight whistling sound, something like a small steam escape, can be heard. As to vibrations or trepidations, there is an absolute freedom from them, and the difference between even the ordinary 3-screw turbine and this vessel is very marked. Altogether, in the opinion of those who were on board the vessel, the geared turbine, as it is at present, has nothing to fear in comparison with any other method of propulsion, so far as comfort of passengers is concerned. Time only will show whether it maintains this position, but, at any rate, a stage has been reached where the installation can be judged on its merits, and not upon the opinion of optimistic or pessimistic prophets.

APPARATUS FOR GOVERNING AND OPERATING VALVES OF GAS ENGINES.

A TYPE of apparatus for governing and operating admission valves in such a manner that the opening of a valve will be inversely in proportion to the speed of the engine of which the valve is a part has recently been patented by Grices' Gas Engine Company, Ltd., and D. A. Willshaw, Taymouth Engineering Works, Carnoustie, Forfar. The apparatus is applicable to the gas and air admission valves of an internal-combustion engine or to any other valve of that type where it is desired to regulate the volume of fluid admitted to the cylinder. In gas engines the rate of rotation of the crank shaft is determined by the quantity of explosive mixture admitted to the cylinder in a stated period, by the richness of the mixture and by the amount of compression of such mixture before ignition. The quantity of mixture admitted is determined either by the "hit and miss" method, or by varying the amount required for each explosion. The apparatus under notice is applicable to the two methods of regulating the supply of explosive mixture for internal combustion engines, that is to say, the quantity of explosive mixture can be varied for each explosion, or the supply can be entirely cut off for one or more reciprocations of the piston.

Fig. 1 is a part sectional elevation showing the general arrangement of the apparatus as applied to a gas engine. Fig. 2 is a detail view of the cam roller lever, and Fig. 3 is an end view of Fig. 2. A rotatory ball governor A is employed which can cause a lever B to rise or fall. Suspended at the free end of this lever is a rod C and on its lower end is adjustably fixed a setter block D which can be made to move up or down on a vertical guide E within certain limits. On a rotatory shaft F is a single lift cam G in touch with a cam roller H on a finger lever J adjustably pivoted to the engine at K. At the free end of this lever is an adjustable spring plunger L whose adjustment can be effected by means of the nuts M. A second spring plunger O similar in design to that first mentioned is arranged on the lever J in the position shown. In front of the lever J is a similar lever P, its free end having on it a push knob R which can be made to come against the stem of the valve S and thus open the valve against the pressure of a spring. On the face of this lever P and opposite the path of the presser block D is an inclined plane T.

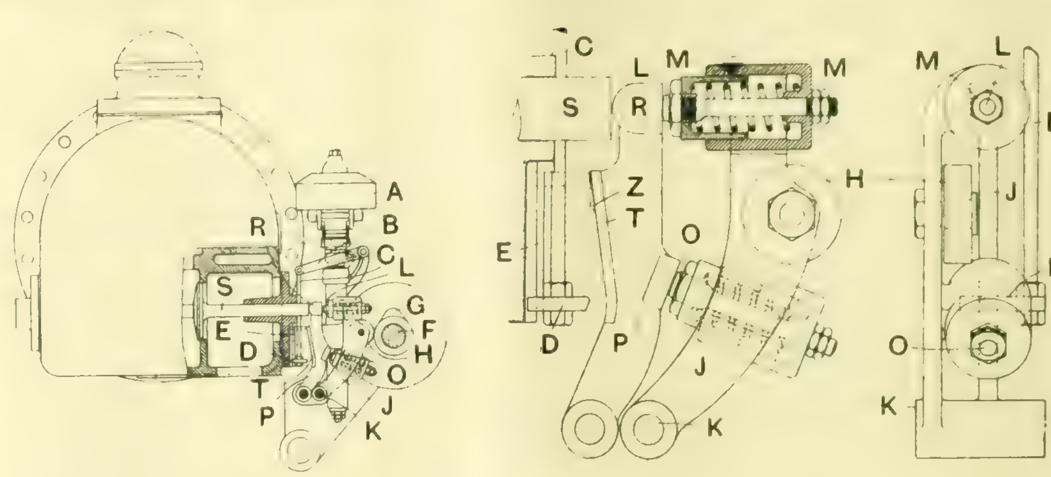


FIG. 1. FIG. 2. FIG. 3.

APPARATUS FOR GOVERNING AND OPERATING VALVES OF GAS ENGINES.

The apparatus operates as follows: The cam G when rotating moves forward the finger lever J, which movement is transmitted through the spring plungers L and O to the finger lever P, this lever in turn moving forward and lifting the admission valve S. The amount of valve lift is determined by the position of the setter block D relative to the inclined plane T on the lever P, the excess motion, if any, of the lever J being taken up by the spring plungers. The springs operating the plungers are more than strong enough to open the valve S. When the setter block D is at its lower position as shown by the full lines in Figs. 1 and 2 the engine is running below its normal speed, the inclined plane of the front lever does not come in contact with the block D and the two levers J and P can vibrate to the full extent, thus fully opening the valve S, and when the setter block is at the highest position it is in contact with the inclined plane of the lever P as shown by the dotted lines in Figs. 1 and 2 and the push knob R cannot operate the valve, the lever J at that time moving as before, the spring plungers also moving out and in due to the want of movement of the front lever. At intermediate positions of the setter block D the front lever can move accordingly and through it the valve.

Difficulty is sometimes experienced in throttle governing when rich gas is used as fuel, and the engine on very light load owing to what is termed "back firing," thus necessitating only a minimum lift of the valve. To overcome this difficulty the throttle system of governing is used from 50 per cent. upwards of the engine load and from 50 per cent. downwards to no load the hit-and-miss system. This combination is accomplished by the lever P having a parallel face for a short distance down the inclined plane. The action is as follows: At half load the setter block D is about the position Z. Immediately the setter block passes up beyond the point Z it is impossible for the lever P to move forward, thus shutting off the gas from the engine. As the speed of the engine decreases the setter block falls below Z, which allows the lever P to move sufficiently forward as to open the valve S wide enough to admit gas equal to approximately half engine power.

STEAM REGENERATIVE ACCUMULATORS.*

BY D. B. MORISON.

IT was in 1894 that Sir Charles Parsons recognised the possibilities of the exhaust steam turbine, by means of which

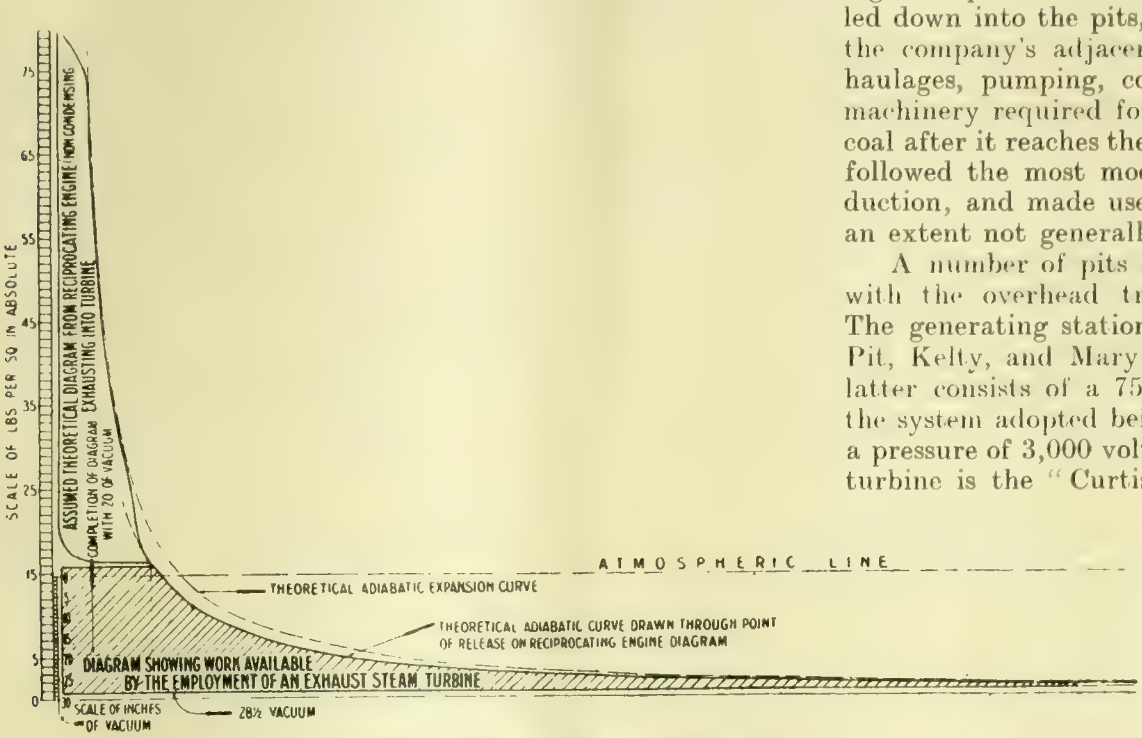


FIG. 1.—STEAM EXPANSION DIAGRAM.

exhaust steam from reciprocating engines could be utilised for the production of power to greater advantage than had been previously possible. In 1901, Prof. Rateau solved the problem of utilising exhaust steam from intermittently-running land engines. The practical result of the development of exhaust- and mixed-pressure turbines has been that, on land alone, nearly two million horse-power of electrical energy is being generated by means of exhaust steam which had been previously wasted.

Representative Plants.— At the works of the Dominion Iron and Steel Company, Sydney, Cape Breton, the exhaust steam from one cogging mill, one billet mill, and one rail mill is utilised to generate 8,000 kw. of electrical power. There

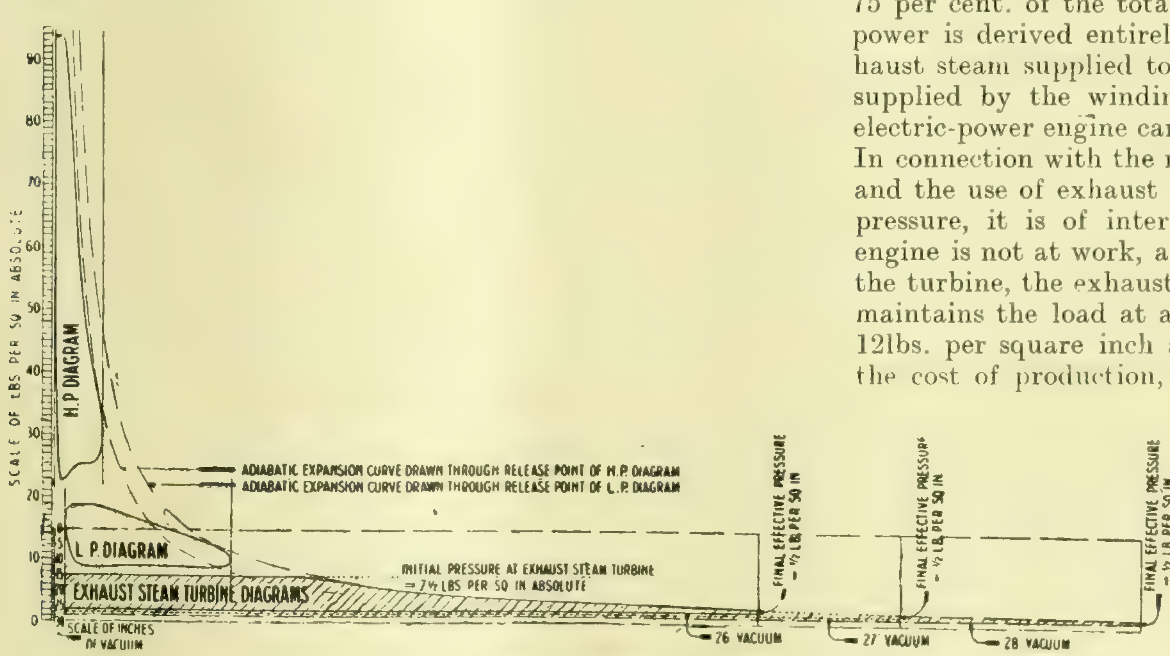


FIG. 2.—STEAM EXPANSION DIAGRAM.

are four accumulators employed, each 9ft. 6in. diam. and 40ft. long, designed to receive 300,000lbs. of exhaust steam per hour and to bridge periods of 30 seconds, other two of 140,000lbs. capacity being in course of erection.

The electrification of the Fife collieries has been carried out on a scale approaching the dimensions of a power supply system, and the number of generating units at work, the overhead transmission lines, and the number and size of motors installed, make this company's installation a very large and important one. There are four stations, each equipped with mixed pressure turbo-generating units of 750 kw. capacity, and one station having a 600 kw. unit: all these being in regular operation and delivering electrical power into cables led down into the pits, or into overhead lines connected with the company's adjacent collieries, to be used for operating haulages, pumping, coal-cutting plant, and the auxiliary machinery required for screening, washing, and handling the coal after it reaches the surface. This company has, therefore, followed the most modern lines with regard to power production, and made use of exhaust steam to provide power to an extent not generally realised outside colliery circles.

A number of pits are served in the West of Fife district with the overhead transmission lines connecting each pit. The generating stations for this area are situated at Aitken Pit, Kelty, and Mary Pit, Lochore. The equipment at the latter consists of a 750 kw. mixed-pressure turbo-alternator, the system adopted being 3-phase with alternating current at a pressure of 3,000 volts, and a periodicity of 50 cycles. The turbine is the "Curtis" Impulse type, and is supplied with live steam at an absolute pressure of 125lbs. per square inch at the turbine stop-valve, the exhaust steam being delivered at a pressure of 16lbs. absolute. This exhaust steam is derived principally from a pair of 38in. by 72in. winding engines, making 33 revs. per wind and about 500 winds in 16 hours. The diameter of the drum is 20ft., the depth of the shaft 340 fathoms, and about 2 tons of coal are raised at each wind. The engine makes 33 revs. per wind. The first six revolutions of the engine, during acceleration, are made on steam at a pressure of 125lbs. per square inch absolute without cut-off; the following 18 revolutions, at full speed, are made on one-third cut-off, and the remainder, during retardation, with no steam; therefore, approximately 322lbs. of steam are delivered during the first 7 secs. or 8 secs., and 323lbs. during the following 18 secs., making a total of 645lbs. of steam per wind. This quantity of steam is delivered into the accumulator about 31 times per hour, making an average of 20,000lbs. of steam per hour delivered into this apparatus, which is 9ft. diam. by 30ft. long. The turbine carries a steady average load of about 75 per cent. of the total, and during the winding period the power is derived entirely from exhaust steam. The only exhaust steam supplied to the accumulator in addition to that supplied by the winding engines is obtained from a small electric-power engine carrying an average load of about 80 kw. In connection with the regenerative effect of the accumulator, and the use of exhaust steam at the lower ranges of absolute pressure, it is of interest to note that, when the winding engine is not at work, and there is a load of about 100 kw. on the turbine, the exhaust steam from this reciprocating engine maintains the load at an inlet pressure of between 9lbs. and 12lbs. per square inch absolute. Experience has shown that the cost of production, including 12½ per cent. interest and depreciation on the capital outlay for the complete station equipment, has been as low as ·18d. per unit, and rarely exceeds ·2d. per unit.

In the North of England electrical energy from exhaust steam and waste gases is generated at various power stations, all of which are linked together and supply an area of 500 square miles. Within the area of the Cleveland and Durham Power Company on the North-East Coast alone there are, apart from rolling mills and collieries, about 70 blastfurnaces in operation, the blowing engines for which continuously discharge approximately 850,000lbs. of steam per hour. There is, in addition, the exhaust steam from rolling mills and collieries which will amount to at least as much, so that from 50,000 kw. to 60,000 kw. are available. Apart from privately-owned concerns, the Waste Heat Company has at present five

* Abstract of paper read before the Institution of Engineers and Shipbuilders in Scotland, March 19th, 1912.

exhaust-steam stations of a capacity ranging from 1,000 kw. to 5,000 kw., the total capacity being about 12,000 kw.

At Wingate Colliery the exhaust from the winding engines drives a mixed-pressure turbine, a heat accumulator forming part of the installation. Other interesting plants in the same district are two large exhaust-steam stations, one at Messrs. Bolckow, Vaughan & Co.'s South Bank works, where plant of a capacity of 11,000 h.p. is installed, and another at Messrs. Dorman, Long, & Co.'s rolling mills, which has a capacity of 4,000 kw. In both cases heat accumulators form part of the installation.

These examples are sufficient to show that the importance of the waste heat in exhaust steam is no longer ignored, and

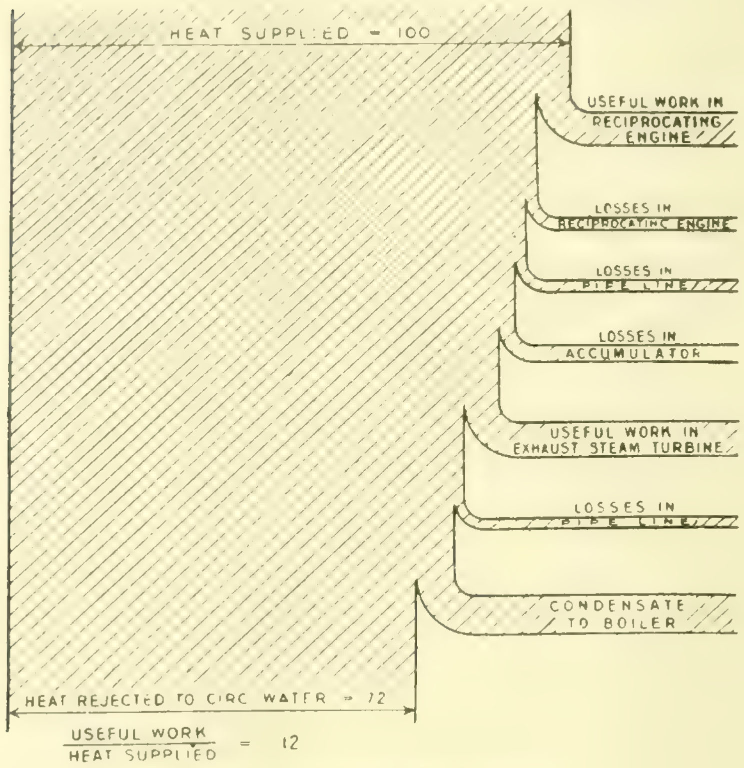


Fig. 3.—Heat Balance Diagram.

that its utilisation for the production of cheap electrical power is now recognised practice. Results may vary with the conditions prevailing, but in most cases the cost of the entire installation can be saved in from three to four years. The proposition is, therefore, very attractive from the commercial point of view.

Exhaust-steam Turbine.—The degree to which the expansion of steam can be carried in a reciprocating engine is governed by the limitations of design, but in a steam turbine an exhaust pressure can be utilised, limited only by the lowest

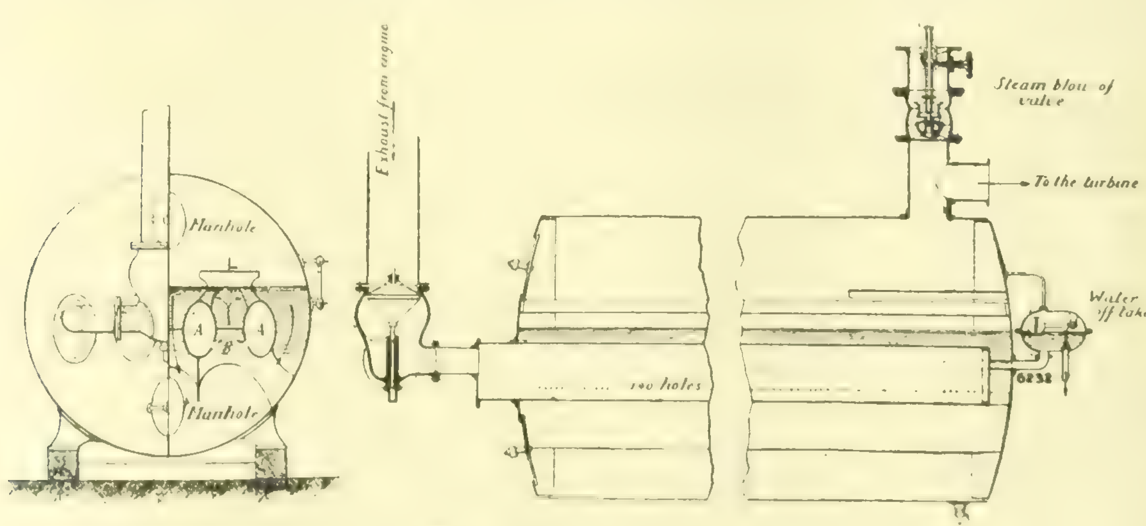


Fig. 4.—Rateau Accumulator.

temperature to which external factors allow the heat to be degraded. The simplicity of construction also permits of turbines being built which practically prevent air leakage, and enables the necessarily high vacuum to be obtained with condensing plant of normal size; it is this feature which has made the exhaust turbine so valuable when used in combination with a reciprocating engine. When an engine exhausts to the atmosphere, at least half of the available heat drop is rejected.

Fig. 1 shows the theoretical amount of work which can be obtained from the steam exhausted at atmospheric pressure

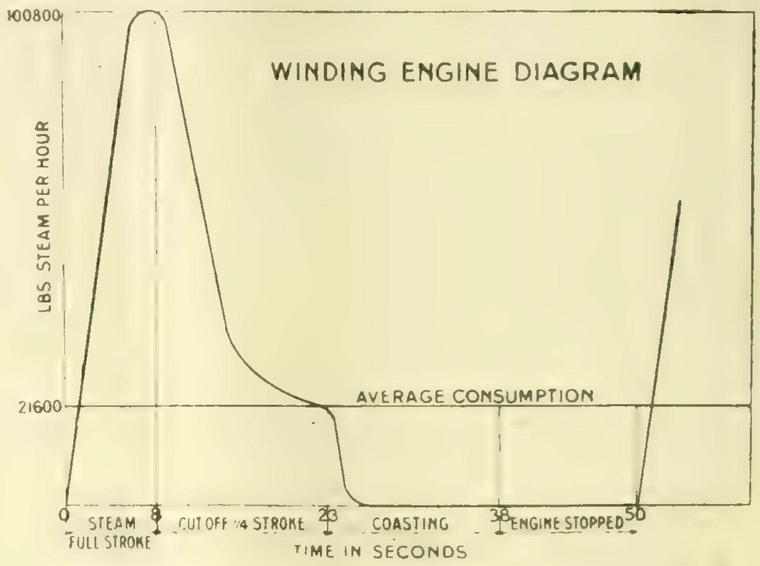


Fig. 5.

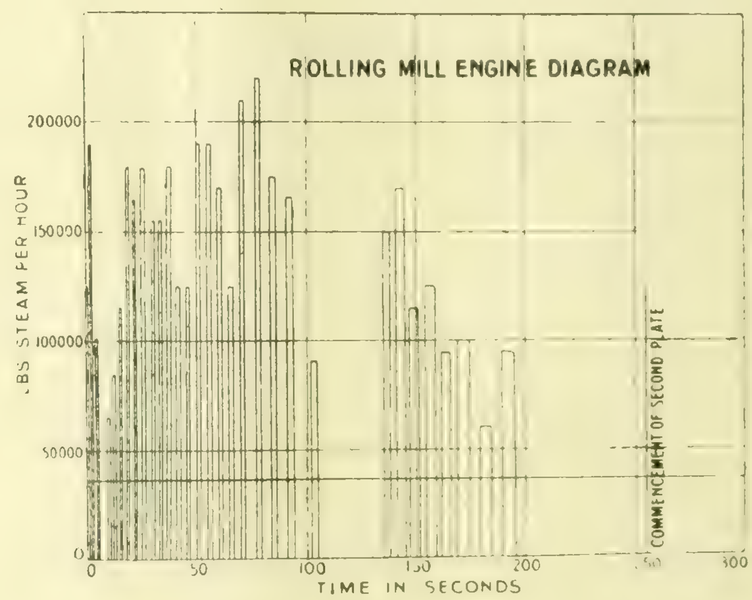


Fig. 6.

from a reciprocating engine working with an initial pressure of 75lbs. per square inch, the heat units available per pound of steam in the engine and in the turbine being 103 and 135 respectively. As the diagram neglects losses due to condensation, radiation, &c., the theoretical gain is 135 per cent. Fig. 2 shows a corresponding diagram for a compound-condensing engine. The shaded portion shows the work theoretically available in the steam turbine which, with a vacuum of 28½in., is approximately 60 per cent.

Fig. 3 is a heat-balance diagram showing the distribution in the various parts of an installation utilising exhaust steam from an intermittently running reciprocating engine. The heat supplied to the engine is for convenience taken as 100, and is represented by the distance between the lines indicated by the arrows. The branches to the right of the diagram represent the proportions of heat converted into useful work and absorbed by losses. After deducting the losses, the useful energy generated by the exhaust-steam turbine is equal to that of the reciprocating engine, or a gain of 100 per cent.

Intermittently-running Engines.—In engines of the type used at collieries and rolling mills the nature of the service demands an initial effort quite out of proportion to the average, and consequently the amount of exhaust steam at the

commencement of the working period is relatively very large. In order to utilise these irregular and intermittent supplies of steam and regularise the discharge to the turbine, it must of necessity be stored in some way. The use of a receiver for such a purpose involves proportions which are prohibitive except for very short periods of storage; moreover, experience has also shown that such a system has a prejudicial effect upon the working of the turbine, because it prevents the effective damping down of the rapid fluctuations of large amplitude which occur with winding or rolling mill engines.

Rateau Accumulator. — Prof. Rateau solved this important problem in a very simple yet effective manner by interposing, between an irregularly-working high-pressure steam engine and a continuously-running low-pressure turbine, a vessel which converts the irregular discharges of exhaust steam from the high-pressure engine into a regular and continuous supply for the turbine. The apparatus thus acts as a heat flywheel. Prof. Rateau's original conception consisted of a reservoir comprising a series of metal trays containing water placed vertically above one another, or as an alternative a large quantity of old rails piled together so as to provide space for the free circulation of the steam. This mass of metal had a certain calorific capacity and effectively regularised the steam-flow to the turbine, but although successful in practice it was very costly by reason of its size and weight. Prof. Rateau then employed water as the heat-absorbing medium and effected the condensation of the steam by passing it through submerged apertures.

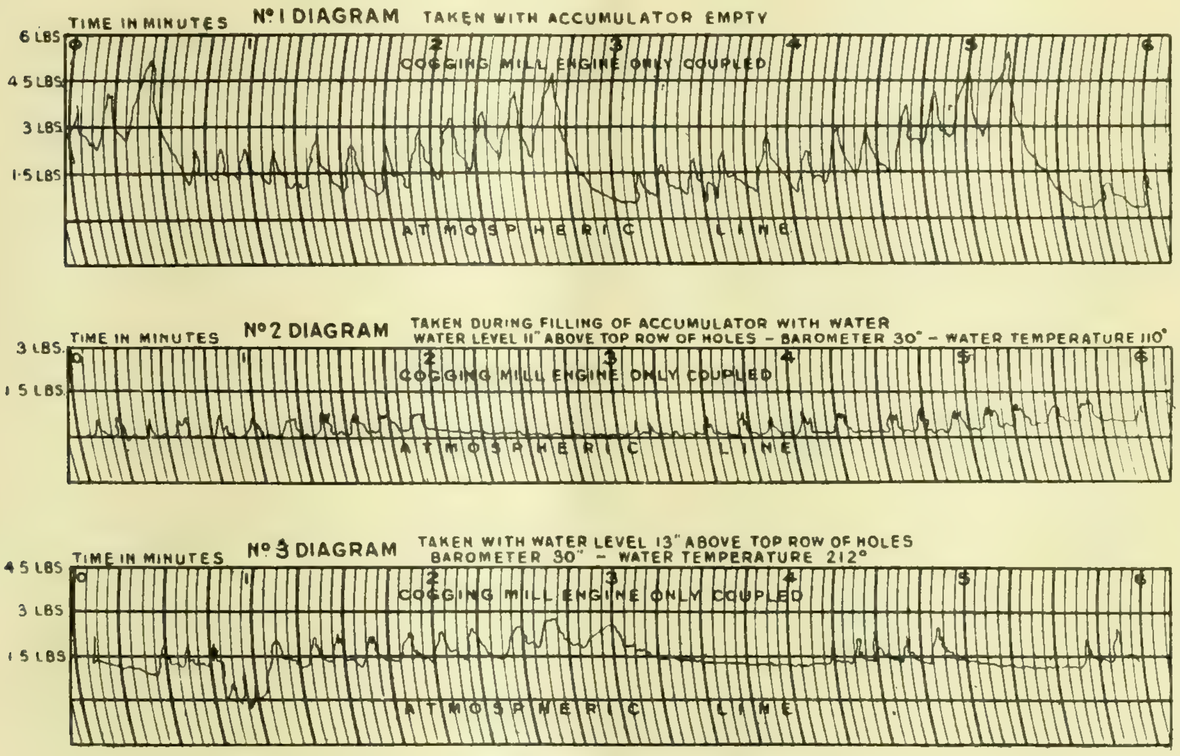


FIG. 7. ACCUMULATOR PRESSURE DIAGRAMS.

Fig. 4 illustrates an accumulator of this type. It consists of a cylindrical vessel about half-filled with water. Four oval tubes longitudinally disposed in pairs below the water level are perforated on their adjacent sides with rows of small holes. The tubes being connected to the steam supply pipe, the steam on entering passes through the holes into the water by which it is entirely or in part condensed, and the issuing streams by causing an active circulation of the water tend to equalise its temperature.

Heat Absorption. —The heat absorbing capacity of this type of accumulator depends on the quantity of water it contains and the temperature range through which it works. In practice the range varies according to particular conditions and requirements. As an illustrative example, suppose the safety-valve on the accumulator is loaded to 2lbs. above atmospheric pressure, and the exhaust-steam admission valve on the turbine shuts off when the pressure in the accumulator falls to 13lbs. absolute, or 3½in. of vacuum, then the temperature range is from 218° Fah. to 206° Fah., and the number of heat units which can be theoretically absorbed per ton of contained water is equal to 26,880. This is equivalent to 730 cub. ft. of steam at atmospheric pressure, and on this assumption one cubic foot of water can absorb 19·5 cub. ft. of steam. The action of the apparatus depends on the physical principle according to which a body of water having taken up heat will give off steam when the pressure is reduced. In the supposed example let it be assumed that, when the high-pressure engine stops after a period of working, the temperature of the water in the accumulator is 218° Fah., and the corresponding pressure in its steam space 2lbs. The turbine continues to draw from the steam space, and the pressure by falling causes the water to boil and give up its stored heat in the form of steam; this continues until the lower limit of the pressure and temperature range is reached. When the high-pressure engine restarts, the steam is condensed by the water in the accumulator, and heat is stored until the temperature and pressure again rise to the high limit of the range, the cycle being repeated for every variation of pressure within the range.

Winding Engines. — In the working of a colliery winding engine, the period of acceleration is about one-fifth of the total period, so that during acceleration the amount of exhaust steam may be many times the average and tail off to nothing before the wind is completed. In rolling mill work the effect is similar but the periods are shorter. Fig. 5 is a typical diagram from a winding engine showing the rate of exhaust during acceleration, uniform motion and coasting. The horizontal straight line indicates the average steam consumption of the turbine. During the first part of the wind the quantity of exhaust from the primary engine is in excess of that required by the turbine. This excess is represented by the area of the diagram above the turbine steam-consumption line and is available for storage in the accumulator. The quantity of steam regenerated is represented by the area of the diagram below the turbine steam-consumption line during the periods of coasting and rest. The period during coasting and rest is usually termed a bridge, and it is this gap that an accumulator is designed to span. Fig. 6 shows a similar diagram for a rolling mill engine. On examining individual cases it has been found, with small installations consisting of, say, a single engine with intermittent exhaust, that the peak load, *i.e.*, the maximum momentary rate of absorption by the accumulator, does, not, as a rule, exceed double the required rate of regeneration. In installations with a large number of engines it is safe to assume that the peak loads are considerably less, as it is only in exceptional cases that all the engines start at about the same moment and cause peaks to occur of double the normal regenerative load.

Bridge Periods. —The duration of the stops to be bridged varies for different services, but in the majority of cases may be taken at 60 secs. in colliery work, and from 30 secs. to 45 secs. in rolling-mill work. Exhaust-steam turbines are usually designed for an average admission pressure of 16·5lbs. per square inch absolute, and it has hitherto been customary to provide for a pressure range from 18lbs. to 15lbs. per square inch, or a corresponding temperature range of 10° Fah. There is, however, no reason why a lower range should not be adopted, and there are a number of plants at work in this country in which the back pressure never rises more than half a pound above atmospheric pressure, and in which the pressure in the accumulator drops to 12lbs. per square inch absolute, or 5½in. of vacuum. In such cases it is advisable to fit a self-acting valve in the exhaust main, between the accumulator and the exhaust of the engine, which closes as soon as the flow of exhaust steam stops and prevents a vacuum reaching the reciprocating engine. This is of importance in the case of winding engines as their regular manipulation is not interfered with, and air leakage into the system is avoided.

The effect of an accumulator on the exhaust pressure is shown in the diagrams, Fig. 7, which were taken from cogging-mill engines by a recording-pressure gauge. Diagram No. 1 was taken with the accumulator empty, and clearly shows the large amount of back pressure of the engine when coupled direct to a turbine, even with a large relief-valve the pressure amounting in one instance to about 6lbs. Diagram No. 2 was taken during the filling of the accumulator with water, and shows a marked reduction in the back pressure, although the cogging mill was doing the same work as in Diagram No. 1. Diagram No. 3 was taken with the turbine at work and with the accumulator full of water at 212° Fah., and although the pressure in the accumulator was slightly increased the reduction in its variation was very marked. At the point marked 3 on the diagram, the cogging mill was stopped for 75 secs., during which regeneration was in full operation.

(*To be continued.*)

UNDERFEED GAS PRODUCERS.

Two designs of gas producers, the invention of A. E. Pratt, B.Sc., "Glinton," Farnborough, Kent, are shown in the accompanying illustrations. They are of the type in which the fuel is fed continuously or intermittently in an upward direction to a fixed point within the producer, whence it passes more or less radially downwards over the grate to a peripheral discharge opening.

Referring to the design shown in Fig. 1, the producer is provided with an exit C for the gas, and poking holes D. The shell and lining are supported on flanged castings E, the upper parts of which form a seal with the water in the fixed tank F. The lower parts of the flanged castings E have open spaces at intervals to allow the water to circulate and to admit a shovel for removing the ashes or clinkers from time to time. The blast is delivered into the horizontal pipe H and passes upwards through an annular vertical passage to the

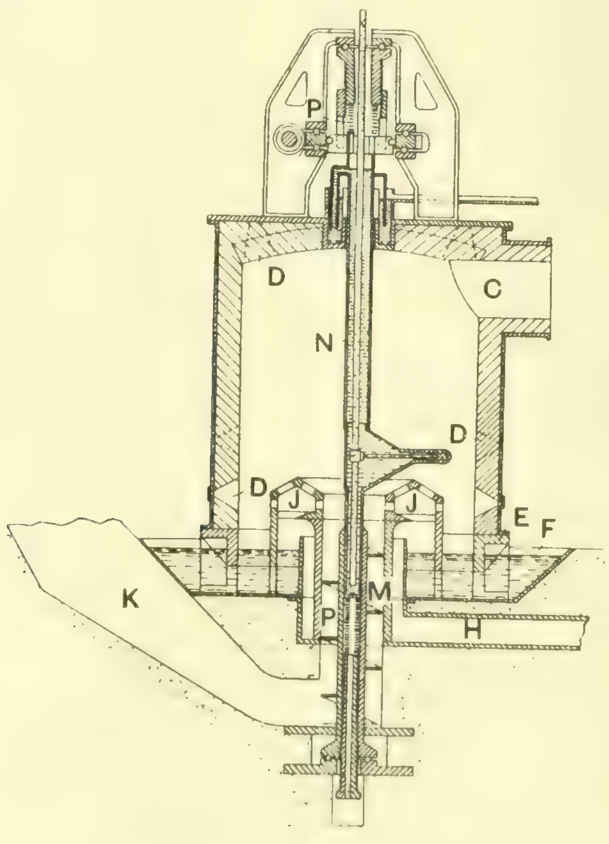


FIG. 1—UNDERFEED GAS PRODUCER.

inside of the annular grate J, having apertures through which the blast passes to the bed of fuel in the producer.

The fuel from the hopper K is raised upwards by means of the archimedean screw M. The screw receives its motion from gearing at the top of the producer by means of the revolving water-cooled shaft N. This shaft has one or more projections which serve as distributing or spreading arms for the fuel as it emerges from the vertical passage. The height of the projection above the grate may be adjusted to suit various kinds of fuel. The shaft N is so arranged that it has a certain amount of vertical play which takes place against the pressure of the springs P. When the vertical displacement of the shaft exceeds a certain amount in either an upward or downward direction it ceases to revolve. This prevents breakage of the shaft or distributing arm in the event of any obstruction (such as large masses of clinker) causing the shaft to rise above or sink below the limits of play provided by the adjustment. The shaft N is water cooled. Hoppers may be provided at the top of the producer for introducing live fuel at starting, or for charging fuel from above at any time when it is not desired to decompose the hydrocarbons.

In operation, for decomposing the hydrocarbons, the blast passes through the grate in the usual way, the fuel is fed upwards from the hopper K by the archimedean screw M and

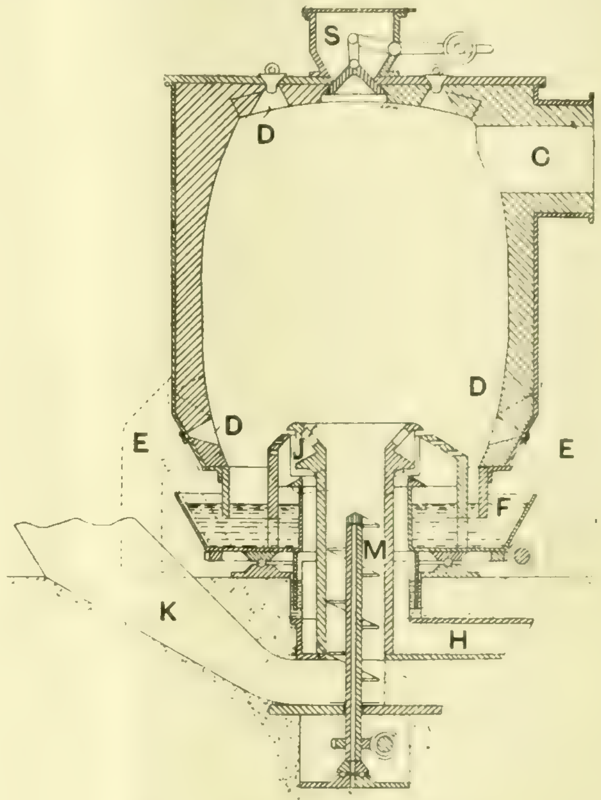


FIG. 2.—UNDERFEED GAS PRODUCER.

is distributed by the revolving arm, the gas which is produced passing out at C to the gas mains. The burnt ashes and clinkers pass downwards into the tank F around the circumference of the grate, and are removed at intervals. The clinkers are broken up as occasion requires by inserting a bar through the poking holes D.

Referring to the arrangement shown in Fig. 2, the producer is of the same general construction as in Fig. 1, and a hopper S, for charging fuel from above, when desired, is also shown. The supporting brackets of the producer are situated outside the tank F so as to permit the latter to revolve on a ball race. The grate consists of a fixed inner part J having apertures for the blast and also a revolving outer part which is attached to the tank F and has apertures for the blast. The fuel from the gas-tight hopper K is raised upwards through the vertical passage by means of the archimedean screw M. The screw receives its motion from the worm shown. The fuel emerging from the top of the vertical passage is distributed by the action of the revolving outer part of the grate, the top of which is constructed so as to slope downwards at different angles in different directions, thus acting like a screw and which also varies in width in different directions as shown in the figure on the right and left sides respectively. Owing to these irregularities in shape and to the revolution of this part of the grate, the fuel is distributed from the centre towards the circumference.

Fatal Crane Accident.—A serious accident occurred on the 20th ult. in the yard of the Forth Shipbreaking Company at Bridgeness, resulting in the death of one man and serious injury to another. A heavy load of wood was being slung ashore by means of a steam crane from a ship in course of demolition. The sling chain snapped, and the load fell upon and buried one of the men, who was unconscious when extricated, and subsequently died. The other worker was also badly injured.

RESULTS OF EXPERIMENTS WITH A WATER-TUBE BOILER, WITH SPECIAL REFERENCE TO SUPERHEATING.*

BY HAROLD E. YARROW.

OUR firm having recently tried some important experiments with a water-tube boiler, it was thought that the results would be of interest to the Institution, and I therefore venture to bring them before this meeting. Being convinced that superheating is one of the directions in which advances in marine engineering will be made, we constructed a water-

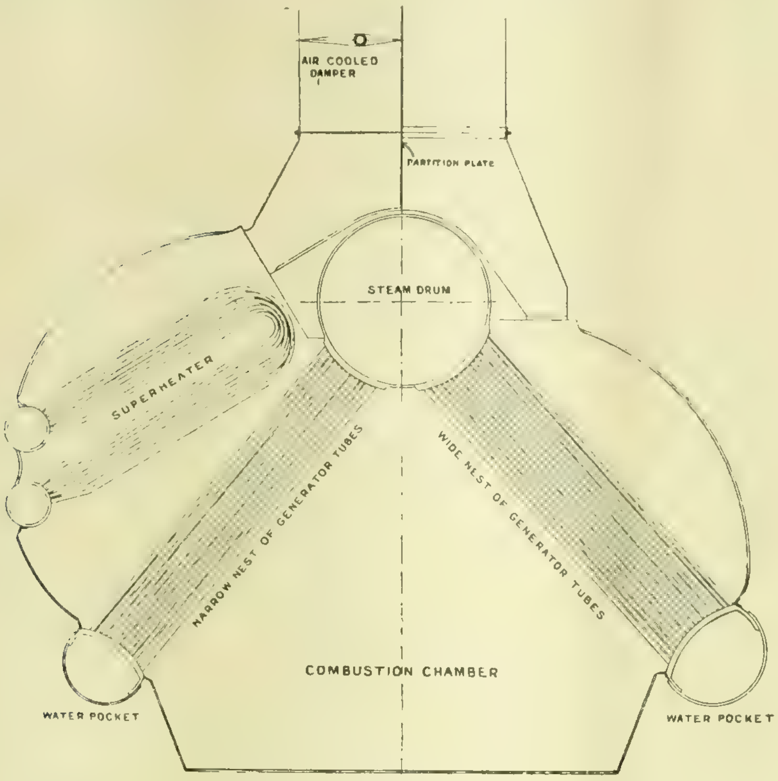


FIG. 1.

tube boiler which was fitted with a special form of superheater.

The objections which have hitherto been raised to superheating for marine work are: (1) Owing to the dryness of the steam, oil for the internal lubrication in reciprocating engines becomes a necessity, and the oil, finding its way into the boiler, leads to trouble. (2) The probability of burning the superheater when the passage of the steam through it is suddenly reduced or stopped.

By the introduction of turbines the difficulty of lubrication does not occur, and with regard to burning the superheater tubes, the arrangement we adopt avoids this risk. The boiler with which these tests were made was of the Yarrow type, and was fitted up in our experimental shop, which is equipped with the necessary plant for making very complete tests. Throughout the experiments oil fuel only was used, and as it is possible with oil to maintain steady and uniform working conditions, very accurate results were obtained, which would not have been possible with coal, in which case irregularity of stoking and other sources of discrepancy occur. During the experiments careful records were taken of the oil consumed, the water evaporated, steam pressure, temperature of the superheated steam, and the temperature of the gases at various points during their passage past the boiler tubes.

As is well known, superheating is very largely adopted in land installations, and in locomotives it is being rapidly introduced. From information kindly given us by the locomotive superintendents of the main railway lines in this country, it appears that the economy realised in locomotives due to superheating averages fully 20 per cent. in fuel consumption, and rather more in water consumption. It may, perhaps, surprise many marine engineers to know that on the Great Western Railway alone no fewer than 500 locomotives are now running fitted with superheaters. Taking the average of several land turbine installations, there is found by superheating to 100° Fah. to be a saving in consumption of fuel of from 8 to 10 per cent., and in steam consumption from 10 to 12 per cent. The reduction in steam consumption is specially important for marine work, as it enables a reduction to be made in the size and weight of the condensers, air pumps, circulating pumps, and feed pumps, and probably of the distilling plant. Independent of the gain directly due to superheating, the risk of water passing into the turbine

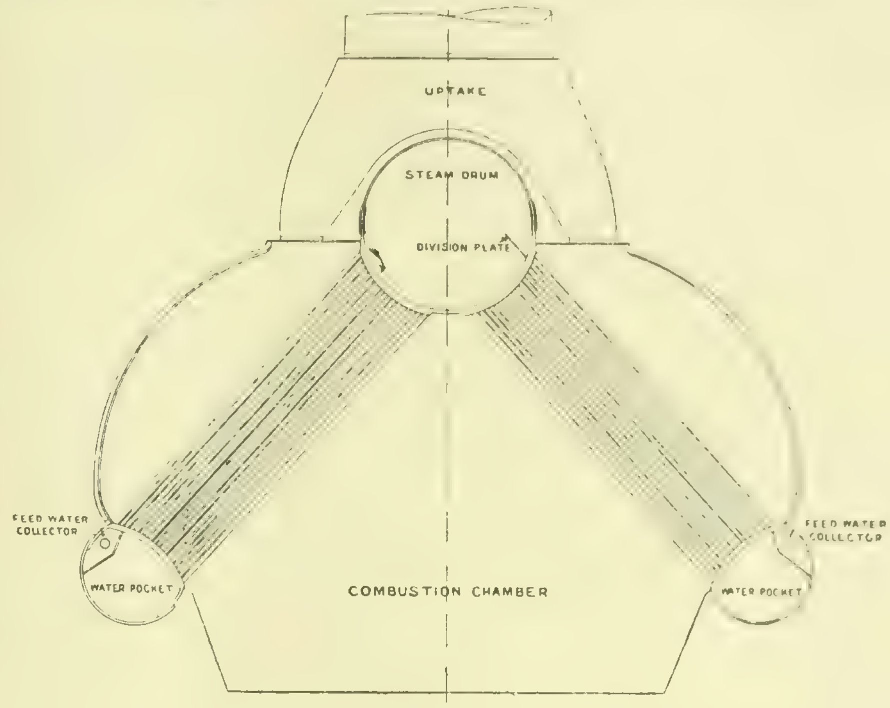


FIG. 2.

from any cause whatever is reduced, and the fear of damage in consequence of water causing the stripping or cutting of the blades is diminished, and any additional cost of upkeep of the superheater will, doubtless, be fully balanced by the diminished risk of injury to the turbine blades by the action of water when using saturated steam.

Turning now to the design of the boiler and superheater with which the various experiments were carried out, Fig. 1 shows a cross section of the boiler, and it will be seen that it consists of a top steam collector, as usual, and two lower water pockets. On the left-hand side the superheater is shown, and it will be observed that on this side of the boiler

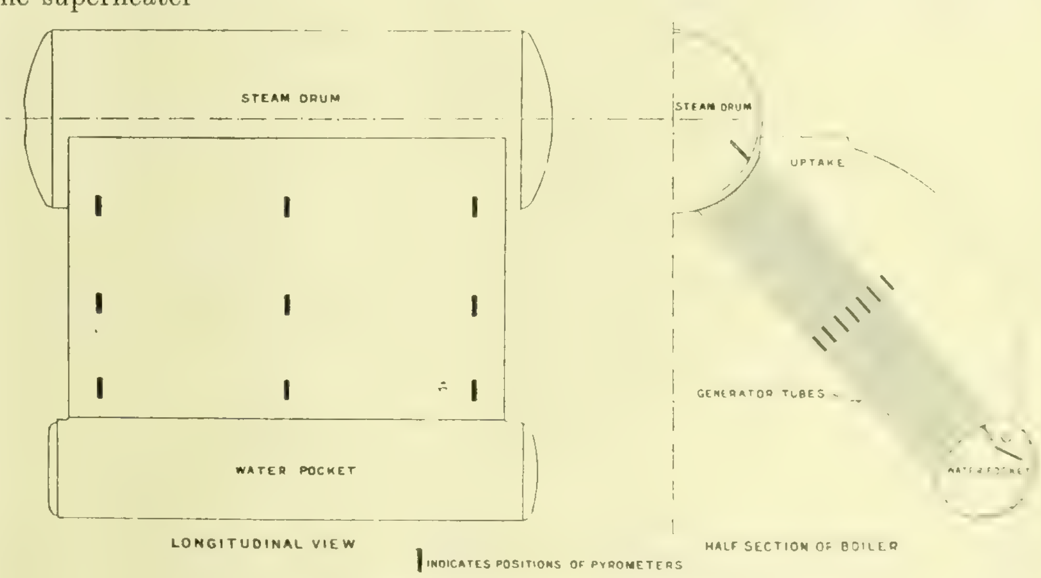


FIG 3.—SHOWING POSITION OF PYROMETERS.

there are fewer rows of generator tubes than on the other side, where there is no superheater, it being thought desirable that the total heating surface and the resistance to the gases on both sides of the boiler should be approximately the same. The total heating surface of the boiler was 6,700 sq. ft., of which 1,265 sq. ft. consisted of superheating surface; the total heating surface on the superheater side of the boiler was 3,453 sq. ft., and on the other side 3,247 sq. ft.

The superheater consisted of a number of "U" tubes

* Paper read at the spring meetings of the fifty-third session of the Institution of Naval Architects, March 28th, 1912.

expanded into two longitudinal collectors, small doors being fitted so that access could be obtained to the tubes when required. The leading feature of the arrangement is that the superheater is placed on one side of the boiler only, and a

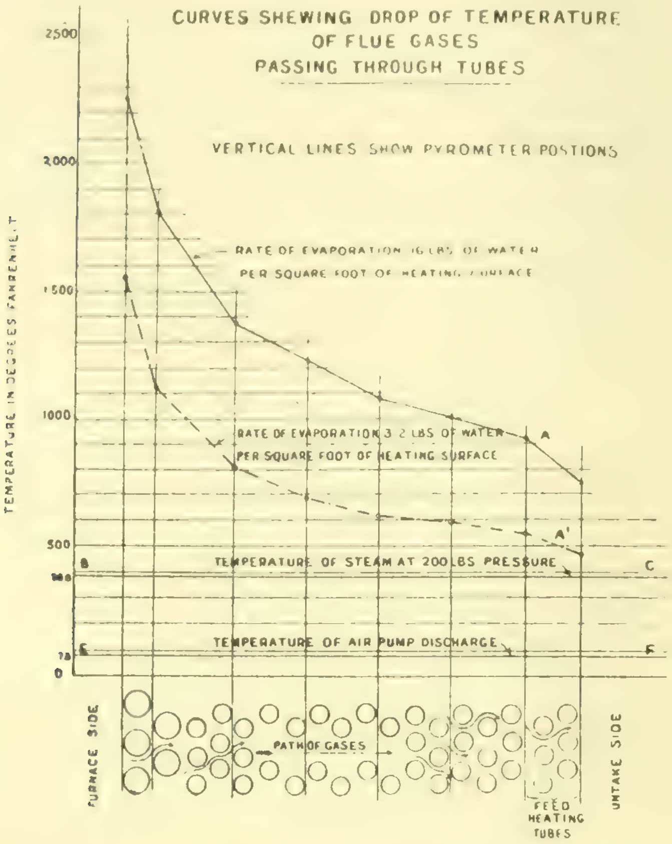


FIG. 3A.

damper is fitted in the up-take on the same side, as shown on the diagram. If this damper is closed the whole of the gases are deflected towards the opposite side of the boiler, and no heated gases pass the superheater, the object being that if the main engines should be suddenly eased or stopped, or when raising steam, the superheater may be shut off, so as to prevent the tubes being damaged, or the steam being superheated to an excessive extent, owing to there not being sufficient circulation of steam. In this way one objection to the introduction of superheating for marine installations is overcome.

A further advantage of this arrangement is that when the consumption of steam is suddenly reduced or stopped, not only does the damper prevent the superheater tubes from being burnt, but it also greatly diminishes the output of the boiler at the time when a reduced supply of steam is wanted, because only about one-half of the heating surface comes into contact with the hot gases. To avoid the possibility of the damper getting distorted through over-heating, it is provided with a hollow spindle, to which air is admitted and which passes from thence between the two plates of the damper, escaping at the edge, and thus keeping the damper cool. This arrangement of damper has proved thoroughly successful under the most trying conditions.

In order to carefully measure the temperature of the superheated steam and of the gases, a complete installation of thermometers and pyrometers was fitted to the boiler, and we have to thank the Director of the National Physical Laboratory, Dr. Glazebrook, and also Dr. Harker, for the assistance which they kindly afforded us in the selection of the most reliable instruments for this purpose.

Turning to Table I., giving particulars of one series of the trials with the damper open, it will be seen that the results are given for six rates of evaporation. It will be observed that at the maximum rate of evaporation, namely, when burning 1·237lbs. of oil per square foot of heating surface per hour, the degree of superheat was 93° Fah. Corresponding figures are given at the lower rates of evaporation. We now pass to similar trials with the damper closed, and on these the heating surface of the boiler is assumed to be that of the large nest of generator tubes only, as all the gases have to pass on that side of the boiler. The results of this series are shown on Table II.

TABLE I.—*Trials with Damper Open.*

Heating surface { Large Nest of Generator Tubes = 3,247 square feet; Small Nest of Generator Tubes = 2,188 square feet; Superheater = 1,265 square feet } 6,700 square feet total.

On these trials the heating surface is taken as the total heating surface of 6,700 square feet.

Steam Pressure. Lbs per sq. in.	Superheat in Deg. Fah.	Air Pressure. Inches of Water.	Lbs. of Water evaporated per hour.	Lbs. of Oil Fuel burnt per hour.	From and at 212° Fah. Lbs. of Water evaporated per lb. of Oil per hour.	From and at 212° Fah. Lbs. of Water evaporated per square foot of heating surface per hour.	Lbs. of Oil Fuel burnt per square foot of heating surface per hour.	Temperature of Feed Water. Deg. Fah.	Temperature between Small Nest of Generator Tubes and Superheater. Deg. Fah.	Temperature of Uptake, Deg. Fah. Above Superheater	Temperature of Uptake, Deg. Fah. Above Large Nest of Generator Tubes.
242	93·5	5·0	94,659	8,286	14·6	18·0	1·237	58·0	1,121	828	887
243	93·0	3·16	76,021	6,454	15·0	14·4	·9635	63·5	926	698	727
243·7	82·5	2·41	68,387	5,695	15·2	12·9	·850	63·5	903	685	688
242·8	61·1	1·7	46,041	3,630	15·9	8·6	·542	64·0	647	536	551
241·8	31·0	·998	20,059	1,540	16·1	3·7	·230	62·2	481	432	448
242·2	20·75	·625	8,478	649	16·1	1·55	·096	63·5	465	409	416

TABLE II.—*Trials with Damper Shut.*

Heating surface { Large Nest of Generator Tubes = 3,247 square feet; Small Nest of Generator Tubes = 2,188 square feet; Superheater = 1,265 square feet } 6,700 square feet total.

On these trials the heating surface of boiler is taken as heating surface of Large Nest of Generator tubes = 3,247 square feet.

Steam Pressure. Lbs. per sq. in.	Air Pressure Inches of Water.	Lbs. of Water Evaporated per hour.	Lbs. of Oil Fuel burnt per hour.	From and at 212° Fah. Lbs. of Water evaporated per lb. of Oil per hour	From and at 212° Fah. Lbs. of Water evaporated per square foot of heating surface per hour	Lbs. of Oil Fuel burnt per square foot of heating surface per hour	Temperature of Feed Water. Deg. Fah.	Temperature of Uptakes, Deg. Fah above Large Nest of Generator Tubes
242·0	4·85	68,618	6,287	13·25	25·66	1·936	61·0	913
242·25	3·97	57,693	5,065	13·84	21·6	1·56	60·0	843
242·4	2·491	44,050	3,501	15·3	16·5	1·09	60·3	673
242·5	1·46	31,481	2,473	15·4	11·75	·76	63·5	603

As one of the objects of the marine engineer is to obtain more and more steam out of a given weight of boiler, we thought it would give useful information to make tests burning oil fuel at a rate of consumption considerably greater than has hitherto been the custom, to ascertain if the boiler would, under such conditions, show any defects. It will be seen from Table II. that at the highest rates of evaporation nearly 2lbs. of oil per square foot of heating surface per hour were being consumed, if we disregard the heating surface on the superheater side of the boiler. Thus, the surface on the opposite side of the superheater was subject to the heating effect of all the gases plus half the radiation. Every part of the boiler

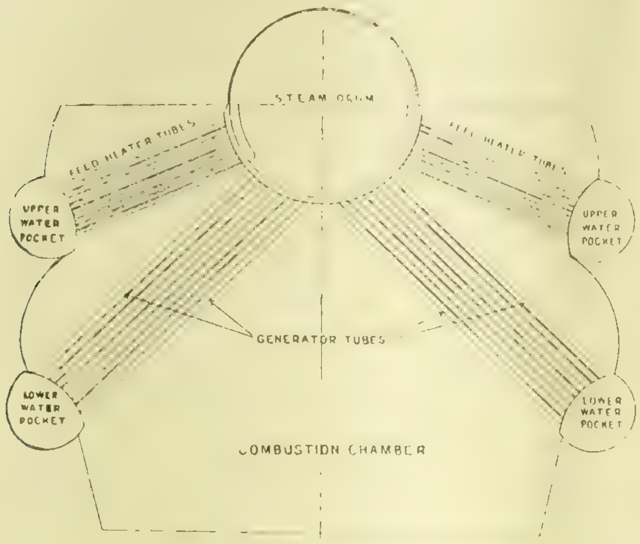


Fig. 4.

withstood the severe test, and trials burning this quantity of fuel were made on several occasions. The results of other experiments indicate that in a properly designed boiler of the type we are dealing with, it is possible to burn, without injury to the boiler, 2lbs. of oil per square foot of heating surface per hour.

Since these experiments were carried out the official trials have taken place with one of the destroyers built by us for the British Admiralty, H.M.S. "Archer," in which boilers fitted with superheaters were provided. The result of these trials showed that the gain we expected was fully realised,

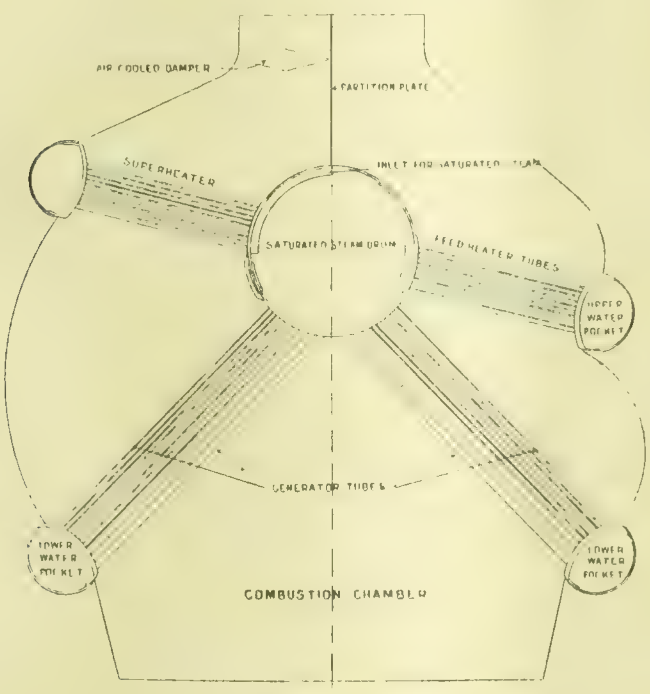


Fig. 5.

and on the full-speed trial the degree of superheat at the turbines was 94° Fah.; the shaft horse-power developed was slightly over 18,500, which compares with about 17,000, which is the shaft horse-power we should have expected had the boilers been of the usual type. The mean speed obtained on the six runs on the measured mile at Skelmorlie was 30·9 knots, and the mean speed for eight hours 30·3 knots, the contract speed being 28 knots.

One point to which Mr. Charles Merz (to whom I am greatly indebted for much valuable information) has drawn attention to the necessity, with the use of superheated steam, of efficiently covering the high pressure portions of the turbine cylinder with non conducting material, because the metal on the inside of the cylinder in contact with the steam becomes hotter than that on the outside, especially at the edges of flanges and ribs. The inside tends to expand, and this expansion is resisted by the colder metal on the outside; consequently, if the temperature difference is great enough, the metal will be distorted, and perhaps strained beyond its elastic limit. For this reason the design of the ribs should be carefully considered, the thickness of metal throughout the structure being kept as uniform as possible.

These experiments were also the means of pointing out to us another important improvement in the Yarrow boiler, and Fig. 2 has been prepared, which illustrates the ordinary type of boiler without superheater, from which it will be seen that the last two rows of tubes farthest from the fire are partitioned off for the feed water to ascend. When working the boiler at high rates of evaporation we found that notwithstanding all possible precautions, even with turned rivets and carefully reamered holes, we were unable to prevent the riveted seam of the water pockets from leaking. We found the pocket was sometimes hot and sometimes cool; indeed, in places sufficiently cool to be able to bear one's hand on it. These trials were frequently repeated with the same result, and we ultimately found out the cause. The fact was that the suction down the tubes which were in close proximity to

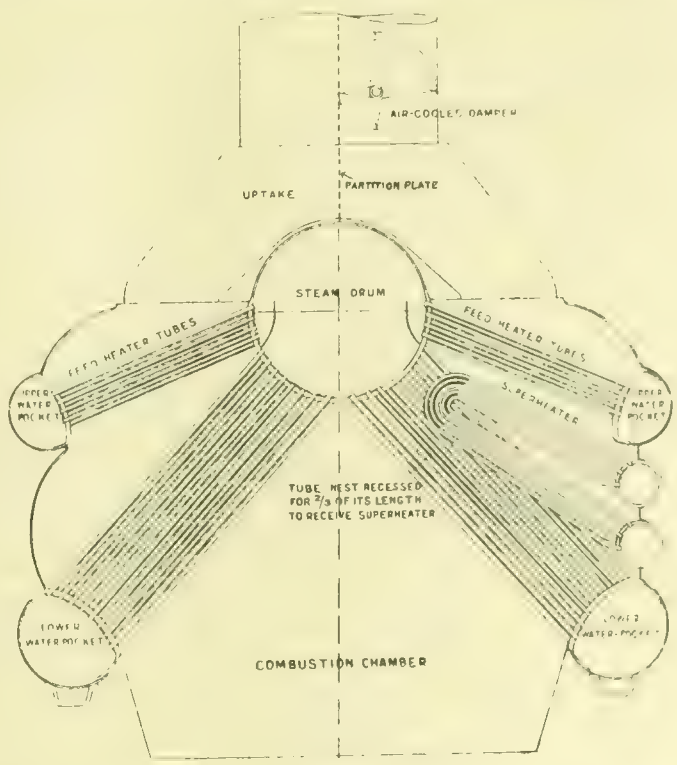


Fig. 6.

the feed-heating tubes was so great that the cool feed water which had passed up the feed heating tubes was instantly drawn down into the water pocket without having had time to mix with the hotter water in the upper chamber, as indicated by the arrow in Fig. 2. This action took place intermittently, and the water pockets locally changed their temperature, one portion of the water pocket being one minute hot and another minute comparatively cool, dependent upon the working of the feed pump. The strain thus thrown on the metal of the water pockets by this short circuiting of the feed was evidently severe, and resulted in the leakage of the seams. Having discovered the cause of our trouble, it was not difficult to find a remedy. It was found that by simply placing a longitudinal partition plate in the upper chamber, so as to avoid the short-circuiting of the feed, all difficulties disappeared. This plate is shown on the right-hand side of the diagram only, but in practice it would, of course, be fitted on both sides. The same trouble has before been met with, especially abroad, but the true cause was never suspected; it was generally put down to inferior workmanship. Even when no trouble is experienced, it is evident that serious and undesirable strains must at times be taking place, which may in the end lead to the failure of the metal, due to constant fatigue. By the fitting of this partition plate, however, all such strains are eliminated. Fig. 3 has been prepared to show the positions of the pyrometers.

Fig. 3A shows the temperature of the gases at various points in the boiler. The vertical lines correspond to the position of the pyrometers as shown in Fig. 3. The upper curve indicates the gas temperatures at a rate of evaporation of 16lbs. of water per square foot of heating surface, and the lower curve represents the gas temperatures at a rate of evaporation of slightly over 3lbs. per square foot of heating surface. The horizontal lines represent temperatures, and the line B C represents the temperature of the steam at 200lbs. pressure; and the line E F the temperature of the air pump discharge taken at 78° Fah.

It will be observed, the very great drop in temperature which takes place during the passage of the gases through the first rows of tubes, showing the large proportion of heat that is taken out of the gases by these tubes. Also, it will be observed that there is a sudden drop in the temperature at A and A′, that is, where the gases pass through the last rows of tubes. This is due to the fact that the cold feed water (which enters a portion of the water pocket) abstracts a greater amount of heat from the gases in ascending the two outside rows of tubes than would be the case if these tubes were full of water at the temperature of the steam.

Referring to Fig. 3A, it will be seen that the temperature of the gases at the point A′, *i.e.*, just prior to the gases passing the feed heating tubes, is about 550° Fah., and the temperature of the steam at 200lbs. pressure is 388° Fah., a difference of only 162°, whereas the temperature of the air

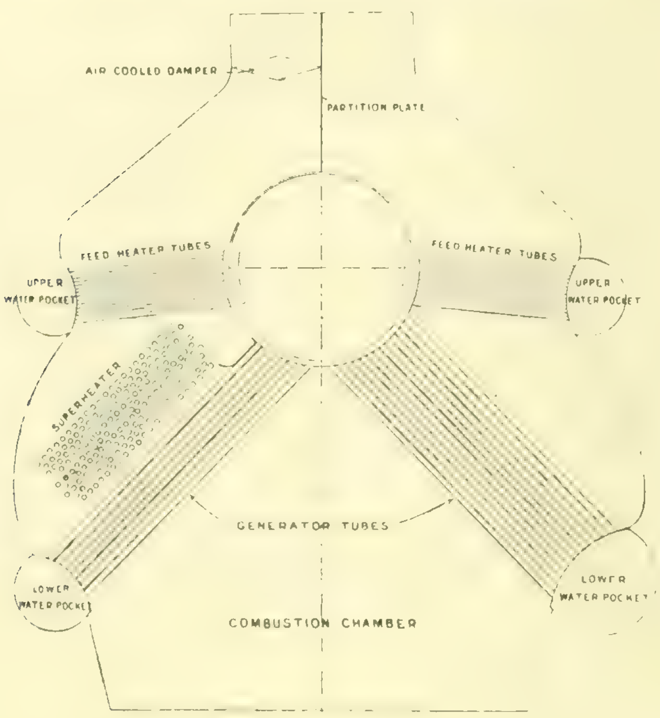


Fig. 7.

pump discharge of 78° Fah. gives a difference of 472°. This clearly shows the gain due to this system of feed-heating, and the desirability of extending it, which can be effected by having separate water collectors and feed-heating tubes apart from the main water collectors and main generator tubes, *i.e.*, there would be two water collectors on each side of the boiler, the tubes connected to the top one acting as a feed heater, and such a design of boiler is shown (Fig. 4).

It should also be pointed out that there is a supplementary and an important advantage in this feed-heating, namely, that any grease or sediment that comes over with the feed is deposited in these tubes which are not subject to fierce heat, rather than in those nearer the fire, which are exposed to the intense radiation of the furnace, and thus the life of the boiler is prolonged. With the introduction of oil fuel some such arrangement is the more necessary, because it has been found that the oil heaters leak, with the result that oil mixes with the steam and passes ultimately into the boiler.

As I thought it would interest the meeting to indicate some of the arrangements for superheating and feed-heating which may be adopted with a view to still further improving the results in connection with such a boiler as the one we are dealing with, I beg your reference to three illustrations.

Fig. 5, it will be seen, shows the superheating tubes united to the steam drum, and to a steam receiver sufficiently large for a man to enter, the tubes being expanded at both ends. In this arrangement all the tubes are straight, a condition much appreciated by many authorities, and also there is an additional advantage by this system, as the superheating tubes on the one side of the boiler and the feed-heating tubes on the other side of the boiler are of such a length that they can be withdrawn and replaced from inside the steam drum.

Fig. 6 shows a set of U-shaped tubes placed between the generator tubes and the nest of feed-heating tubes, the nest of generator tubes being recessed for about two-thirds of its length to receive the superheater. The ends of the superheater tubes are expanded into two longitudinal steam receivers. This arrangement will probably be the most efficient for a given quantity of heating surface.

Fig. 7 shows the superheater tubes placed at right angles to the generator tubes. This arrangement has the advantage that all the tubes are straight. I would mention that the arrangement of running the tubes at right angles to the generator tubes has already been adopted in boilers of certain warships constructed by Messrs. John Brown and also by ourselves, with the exception that a superheater was fitted on both sides of the boiler, and was, therefore, not under the same control as in the case of the superheater fitted only on one side in conjunction with a damper.

It is proposed in some cases to have an additional damper on the opposite side to the superheater, the two dampers being arranged so that either can be open, or both open, but under no condition can both be closed. This enables the superheater side of the boiler to be used to a greater or less extent as desired. When cruising at a slow speed, this arrangement may possibly lead to a more economical result than if both sides of the boiler are equally free for the passage of the hot gases.

Judging by the best practice in land installations, 100° Fah. superheat is by no means the limit that can be adopted with advantage. It is reasonable to suppose that the requisite condition to be desired is that the steam should remain in gaseous form as far as possible during its passage through the turbine, because any condensation that takes place must diminish the energy given out by the steam to the blades of the turbine, also the steam remains in gaseous form the steam friction is reduced.

I would submit, from the results of the accumulated experience of others, and from our own experiments, that there will be a certain gain by the use of superheated steam of from 8 to 10 per cent. in fuel economy when using 100° Fah. of superheat, and from 11 to 13 per cent. gain when using 150° Fah. of superheat in combination with a pressure of 200lbs. per square inch. Also, a further gain in fuel economy can be obtained by an efficient system of heating the feed from the gases after they have passed the generator tubes, so that some of the remaining heat should be absorbed which would otherwise be lost.

Although the experiments were made with an oil-burning boiler, the various arrangements as shown in the diagrams would be equally suitable if coal were used, and there is no reason to suppose that similar advantages could not be obtained.

With regard to the relative weights of boilers with and without superheaters, provided the total heating surface were the same, there would be no appreciable difference. If, however, the complete machinery installation is taken into account, there would probably be a small saving in weight in the case of the installation with superheated steam. I would therefore submit that in the propelling machinery of warships improved results can be obtained by superheating, without increased weight, cost, space, or upkeep, and a further extension of feed-heating by the waste gases.

In conclusion, I should like to thank those gentlemen who have assisted in carrying out the experiments I have had the privilege of describing, and also those who have assisted me in the preparation of this paper, especially my father, Mr. A. F. Yarrow, Mr. Crush, Mr. Marriner, Mr. Cotton, and Mr. Stone.

Lloyd's Register Scholarships in Naval Architecture.—The sixth of the scholarships given to Armstrong College, Newcastle, by the committee of Lloyd's Register of British and Foreign Shipping falls to be competed for in September next. The Scholarship is of the annual value of £50, and is tenable for three years. Full particulars of subjects of examination, &c., can be obtained on application to the secretary of the College.

ELECTRIC MOTOR AND GENERATOR BRUSHES.*

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THE object of this paper is to describe some experiments which are being carried out with the view of assisting in an improvement in the qualities of motor and generator brushes, and particularly of the carbon type. It is well known that, while there have been very many improvements in all sorts of electrical apparatus during the past 20 years, there has not been a corresponding improvement in the quality of brushes. It is a peculiar commercial or manufacturing condition – which all engineers will recognise when their attention is called to it—that an electrical manufacturing company usually puts upon its motors and generators all the legitimate accessories of its own make which are possible, excepting the brushes, and forces the users to purchase brushes from companies not necessarily in very close touch with electrical requirements.

If the brush were as simple an article of manufacture as the lag-screw with which the apparatus is attached to the floor, this would not be serious; but quite a different condition exists. In fact, I think it is safe to say that a poor carbon brush or brush of a wrong type may render inoperative any kind of electrical apparatus. When one considers the stoppage of a long line of electric cars or the temporary shut-down of a generating plant, because of defects in a brush, one wonders that the demands have not already made an art of brush-making. One finds, in fact, that the production of this very essential, unobtrusive little block of carbon has hardly had any study at all.

Every electrical machine is carefully designed in detail as to size and shape of copper, iron, and insulation, all of which vary with each machine, but as yet the important characteristics of a brush are not included in the design, although some one grade of brush is expected to operate satisfactorily over a great range of design. So long as this unfortunate condition exists the best that can be hoped for is a brush which will do fairly well for a large number of machines, very well on a few, and cause continuous trouble on a small balance, until investigation of the constants of the particular machine, or its operating condition, shows the need of a different type of brush.

The careful investigation now in progress leads us to hope that the various characteristics of carbon brushes will soon be sufficiently understood, so that before long the designers of dynamos and motors will be enabled to use a brush exactly fitted to a particular design of machine, rather than a brush which does fairly well on machines of that general size and character.

Apparently the carbon brush was first made from such stock as is used for arc lamp electrodes and dry cell carbons. It was mixed, moulded, and baked in practically the same way, and the prices fixed on that basis. We have experimented with the understanding that a product might be producible which could bear a tenfold greater cost of production than ordinary carbon brushes, and it is probable that our present methods are not far from this condition.

In what we call the early days, the motor or generator brush consisted of a brush of leaves of copper, and this had to be treated with the best of care. It was frequently cleaned and oiled, and on some types of machines gave much trouble. It was usually set at an angle, so that the ends of the laminæ bore upon the commutator. Any reversal of direction of rotation, as has frequently to take place in such apparatus as railway motors, was out of the question with this kind of brush. A block of solid copper bearing directly upon the commutator on such machines causes arcing and spattering of the metal, as there is a relatively high current passing from one commutator segment to the adjacent segment through that part of the brush which connects them. This was a reason for laminæ in the brush.

Our first experiments were taken up along the line of previous methods of manufacture, and attempts were made to get at some sort of life tests and standards of comparison. We tried to learn what a good brush had to do and how long it might be expected to do it. In lamp manufacture the testing is an art by itself. An incandescent lamp is made to burn a certain time at a prefixed efficiency. We questioned whether a carbon motor brush could be submitted to similar life and quality tests. We recognised the importance of learning, if possible, what physical properties or constants for brushes would help in determining quality for electrical uses. The art is undeveloped, so that there is no considerable agreement between engineers even on important points. For example, it would be made clear by one engineer that a brush must be much softer than copper, so as not to wear away the commutator, and must not contain any hard spots, because these might take up metal from the commutator. Against this was the equally powerful argument that the brush must be harder, so as to cut mica and prevent the insulation finally protruding above the copper, and for this reason carborundum, the hardest practical material, has been experimentally introduced into brush mixtures. That the contact resistance should be relatively high and the body resistance low were also practical suggestions. In order to operate systematically, we attempted to choose properties or tests to which numerical values could be attached. It was not assumed that all, or even any, of these factors could be interpreted strictly in terms of brush quality, but some such system of co-ordinating and comparing experimental products seemed necessary. There were finally adopted measurements of hardness, tensile strength, density, electrical resistivity, and such mechanical tests as a chip and fracture tests.

The hardness is determined by the Shore scleroscope, which consists essentially of a diamond-pointed weight which falls freely in a perpendicular glass tube and, striking upon the brush, rebounds to a height in the tube, which height is read from a scale. In general, the harder the material the higher will be this rebound. In the case of brushes it distinguishes qualities over a range of about 70 units, and is of considerable value in determining regularity of product.

A brush as made for railway motors, and containing coke, graphite, lampblack, and binder carbon, if properly baked and fired, would have a hardness about 50, while if the firing be interrupted at, say, 500° C., its hardness value would be about 20. If the coke and lampblack be omitted, while the binder carbon is 3 per cent., and natural graphite be used, the hardness value will fall to about 16, even after firing for maximum hardness. In other words, such brushes as find common use on electrical apparatus may vary in hardness, depending upon the desired use, from 15 to 75 units of hardness.

The tensile strength is determined by cutting from the brush, held between steel guide plates, a definite testing piece of the carbon which can be held in the grip of the strength-testing machine and which will break at a point where the cross-section is exactly one-quarter square inch. The break is produced by the addition of shot at a definite rate to a pan supported by the test sample. The strength is expressed in pounds per square inch section. The density compared to water is calculated from the weight of the brush and its physical dimensions.

The resistivity is determined by measuring the voltage drop across contact points 1½in. apart, which points bear heavily upon the brush when a current is sent through the brush. Separate contacts are used for the current. The accuracy of the measurement is about 3 per cent. of itself.

Some sort of chipping test seemed desirable, because brushes in use often deteriorate and wear away, due to flaking off of chips from the edges of the bearing surface. This would be expected from the nature of the impacts given a brush when it chatters on a rough armature revolving at high peripheral speed. The chip test we have used consists in a clamp for holding the brush firmly on a solid base or anvil, and in a weight guided by perpendicular rods, which weight falls from a fixed height and strikes the bearing face of the brush repeatedly at the same point, about a millimetre from the edge. The number of impacts necessary to force off a chip is called a chip test. This is quite surprisingly uniform for uniformly made brushes. It is usually weighted so that a brush of best quality will regularly chip after about 10 impacts of the weight when dropping from an increasing height in steps of one centimetre each.

Additional qualitative tests have resulted from comparison of product under different conditions. For example,

* Paper presented at a joint meeting of the Franklin Institute and Philadelphia section, American Institute of Electrical Engineers, January 17th, 1912.

the fracture or appearance of the fresh surface produced by breaking the brush across its longer dimensions discloses very effectively any irregularities produced by improper baking or pressing. This cross-section should be quite homogeneous and the fracture regularly conchoidal or square. No shelves, cracks, or angular markings will be disclosed on breaking a well-made brush. It is believed that such internal irregularities represent weakened structure, that even miniature cracks might take up and carry copper from the commutator, and that breaking of a brush in use may often be attributed to internal cracks produced in the manufacture. Undoubtedly a rough commutator or heavy pressure of the spring of the brush holder accounts for the breakage of many brushes in use, but in our tests on operating machines these variables are kept under control as much as possible.

The composition of the mixture from which the brush is moulded has been varied greatly to suit various requirements, but in general it is made up of two or more of the four elements: lampblack, finely-ground petroleum coke, graphite, and some kind of tar or petroleum pitch which serves as a binder. The effect produced by each of these ingredients is a different one, and a suitable balance seems necessary and varies with the use of the brush. A brush made mostly of lampblack, with suitable binder, would be dense and hard, but of poor conductivity, and would cut copper badly. One made mostly of graphite is usually too soft, and on ungrooved commutators wears away too rapidly. The mica between the bars gradually protrudes and wears away the brush. Its electrical resistance is very low. One made mostly of coke is hard and of high resistance. It usually cuts the copper badly. The petroleum coke is used because of its uniformity and freedom from mineral matter. It can readily be appreciated that for some special purposes it may be well to incorporate hard polishing material into a brush, as where much mica has to be cut and where high conductivity, and therefore much graphite, is desired. The accidental grains of sand or such mineral impurities as often occur in ordinary coke, on the other hand, are to be carefully excluded.

It might seem that by using the above four forms of carbon (for the pitch leaves a fourth form of carbon, after the heat treatment) a satisfactory product could be obtained, and it has become apparent that the qualities may be varied over a wide range by proper variation; but the requirements are continually advancing, so that all sorts of experiments in composition, such as adding sulphur, special oils, &c., have been carried out.

It may be stated as a general rule that, except for special conditions, the finer the state of sub-division of the brush ingredients, the better the quality of the finished brush. We have found it desirable to grind not only the coke but also the mixture of all the ingredients, to ensure thorough mixing and a dense brush.

The finely-divided materials, coke, lampblack, and graphite, are placed in a mechanical dough mixer and a solution of the pitch in benzol is added and the whole kneaded for several hours. The benzol is then driven off by heat and the dried product, which is then quite hard, is reground to about 200 mesh, and this powder is compressed into brush form in steel moulds.

It was first thought that the best way to form the brush was to squirt bars of the mixture by means of a hydraulic press. These bars could then be cut to desired length. So far as our work went along this line, the product was not as satisfactory as when the brushes were individually pressed. Experiments were made in which various proportions of pitch binder were used. The temperatures of the press, mould, and brush material were carefully controlled; special presses were built, &c., but irregularities often appeared in the product. The tendency of the material to flow unequally within itself during the passage through the die seemed to be responsible for cleavage planes and internal curved surfaces, which would often not develop until the brush was completed by baking, and even then could only be disclosed by breaking the brush. We do not mean to conclude that a satisfactory brush cannot be made by squirting the hot mixture through a die, as the reverse is probably true, but for our purposes we finally adopted the accurate weighing of the mixture for each individual brush, and the compression of this weighed material to an exact size in a mould under such a high pressure that additional pressure produces no further change. This pressure, for a standard railway motor brush, is about 25,000lbs. per square inch. Above this pressure the quality is not appreciably affected; much below it, inferior product, as shown by density, resistance, and strength, results. Marked effect is produced by variation in the temperature at which the mixture is pressed. For this reason care is taken to have the pressing done at about 25° C. The pressed brushes are then packed in cast-iron boxes, in lots of 100 to 200, and covered with a liberal layer of fine coke. A cast-iron cover which well fits the box is then inserted, and this, in turn, is covered with coke dust. This box fits snugly into an electrically-heated muffle.

Early in the investigation it became evident that a large part of the irregularity of product, the shrinkage cracks, &c., were to be attributed to a too rapid rate of rise of temperature during the early stages of heating the pressed brush. The pitch, or binder, which on its fractional distillation leaves the cementing carbon, which in turn largely determines the hardness and strength of the brush, is a mixture of organic compounds which liquefies at moderate temperature (100° C.) and rapidly evolves gases far below red heat. This led us to test methods of electric heating, and the rate of distillation of the volatile materials at gradually-rising temperature was determined. This work resulted finally in the adoption of a very small type of muffle, for commercial production, which had a capacity for not over 200 brushes. It was heated by a special resistance wire wound upon it, and the temperature was controlled by a thermo element and resistance, so that the rate of rise of the temperature on each lot of brushes was at the rate of about 5° C. per hour over a period of about 100 hours. The distillation of the binder under this treatment does not rupture or weaken the brush.

When larger volumes of brushes are heated or the heating of small containers in a large furnace of usual type is carried out, the brushes near the walls receive a very different heat treatment from those near the centre of the furnace. This causes much irregularity of product, so that we still give all brushes the first firing or baking in the small wire-wound and heat-insulated muffles. The control resistances enable the operator to gradually raise the temperature in each muffle. The rate of this rise is learned by means of pyrometer couples inserted into the muffles. In this, which is a preliminary heating only, the temperature rises after 100 hours to 500° C. In this process the volatile products of distillation have been so slowly eliminated from the brush that no striæ, laminations, splits, or blisters are produced. The brush is now bound together by a material largely carbon, but still capable of further shrinkage, hardening, and decomposition by higher temperature.

After the preliminary heating at 500° C. the brushes are unpacked and a series of tests would show relatively inferior qualities throughout, about as follows, for one type of railway motor brushes:-

Hardness.	Tensile strength.	Resistance.
20	9,000lbs. per square inch.	0·043 ohm per inch cube.

The material can still shrink greatly and be improved by a higher heat treatment. This is accomplished in an ordinary porcelain baking kiln at about 1,100° C., the brushes being packed as before, though not in iron, but in fireclay containers or saggers, the whole being covered with coke dust and the cover carefully luted on. The slightest carelessness in this protection process causes a softening of the outer surface of the brush, where a little combustion has removed the binder carbon. This binder carbon is easily combustible in the presence of an excess of coke powder.

Owing to the severe requirements for railway motor brushes, the work for a long time was devoted exclusively to this field, and there is probably still plenty of improvement possible. As the work has advanced, the refinements possible have become more and more apparent, and it is quite evident now that several different carbon brush types are necessary to satisfy the requirements for different types of machines. In case of this particular brush, however, it is worth attention that by slight modifications in the process, such as fineness of grinding, pressure on the hydraulic press, &c., the record of tests kept during the past two years shows the following changes. Attempts have been made to operate without change in the components, as weighed out. These qualities have all improved through small refinements

Year.	Hardness.	Resistance.	Tensile strength.
1909	52·3	·00135	1,800
1911	58-60	·00120	2,700

Development of the railway brush led to trying the same product on other types of electrical apparatus, and it was at once evident that the general brush requirements call for more than one kind of brush and more than a single composition. Generator brushes, while they do not meet the severe conditions met by railway motor brushes, and may therefore be softer and of lower physical tests, should have higher conductivity and should, in use, develop a polished commutator without cutting or smutting the metal. A fairly satisfactory type of generator brush may be made almost entirely of ash-free graphite and binder carbon, and will have approximately the following values on test: Hardness 35, resistance ·00078, tensile strength 2,500, chip test 6. It has been found that a brush needs some lubrication qualities which are difficult to quantitatively express. In the past it has even been customary to treat some brushes with oils, vaseline, &c., to give them this lubricating effect. It has also been found possible to improve operation of a commutator by using hard, strong, non-lubricating brushes and to interpose in several of the brush-holders a pure graphite brush, which serves to give desired lubrication for the other brushes. This has led to experiments on a combination brush. In this case, by a proper selection of proportions of binder or pitch and the mixture, it has become possible to gain the same shrinkage in the two widely different materials, a hard brush body and a body largely composed of graphite, so that the two are still firmly bound together after firing. A sort of laminated brush is thereby produced, and if there were service demands for such laminated brushes they could be produced.

A PECULIAR CASE OF SEASON CRACKS IN SHEET BRASS.

ONE of the peculiar obstacles frequently met with in the use of sheet brass is the formation of cracks in the surface after the article composed of the brass has been in use for some time. Many an article has been ruined on this account. Season cracks seem to be simply a sort of crystallisation in the metal, for the fracture of the brass shows a crystalline structure when examined and the metal is more or less brittle around it. The fact that brass will crystallise or season-crack under some conditions and not under others indicates that the brass itself is not always at fault. External influences, it is believed, have a much greater bearing on the subject than usually believed. In the current issue of "The Brass World" reference is made to a case of the season-cracking of an acetylene generator of drawn brass which occurred within a few months after use. A singular thing in connection with the cracking was that the dealers who sold the generator maintained that it had frozen and the expansion of the ice had caused the cracks! The fact was, the generator was used only for a short time during the summer months. There are, says our contemporary, a number of things that will bring about season-cracks in sheet brass, wire, or tubing, and among them are solutions which contain or evolve ammonia. For a reason not clear, ammoniacal compounds seem to affect the brass in this manner. One would naturally expect, however, that in the generating of acetylene gas from calcium carbide there would be no ammonia produced, but such is not the case. Impurities in the calcium carbide in the form of nitrogen compounds form ammonia when it comes in contact with water. It is believed that these compounds of ammonia are the cause of the cracking of many kinds of brass goods, as it was in the case of the acetylene generator. Other agencies which will cause the season-cracking of brass are mercury or mercurial compounds. This, as well as the ammonia, are external influences, but a very common internal one is the shape of the dies which are used for drawing the brass shell. It is now well known that in order to prevent season-cracking (or firecracking during the annealing) the brass shall actually be drawn out ("ironed" out, so to speak) by the punch so that the metal is really stretched. It will not suffice to merely form the brass, but it must be stretched. This fact is well known in the brass trade, but many outside, of course, are ignorant of it. It is not believed, however, that this was the cause of the cracking of the acetylene generator, as it had been in stock for a long time before being used, and had not cracked.

HIGH-SPEED ELECTRICAL MACHINERY.*

BY F. H. CLOUGH, A.M.INST.C.E.

THE development of high-speed electrical machinery has been very closely associated with development of the steam turbine. On account of the very high speed of rotation of this prime mover, the mechanical energy produced by it, except for ship propulsion, can only be made use of in special cases, such as driving high-speed pumps, &c. By coupling the turbine to a high-speed electrical generator, however, a very compact power unit is obtained at a very much lower cost per kilowatt of capacity than has been possible with slower speed generating units. It thus happens that the possibility of converting the mechanical power into electrical energy has enormously increased the field of utility for the steam turbine; and also the possibility of having a compact, cheap, and economical steam-electric generating unit has given a big impetus to the generation and distribution of electric power.

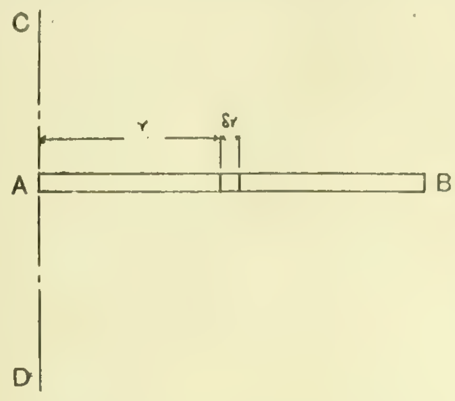

FIG. 1.

The most usual form of electric energy produced by turbo-generators is 3-phase, 50-cycle, alternating current. Two-phase machines can be built equally readily, and single-phase machines can also be made, although the design of these latter presents rather greater difficulties than that of the polyphase machines. The capacity of continuous-current generators is very much lower than that of alternators, due to the necessity of commutating the armature current and collecting it from a high-speed commutator. With a frequency of 50 cycles the possible speeds are 3,000, 1,500, 1,000, and 750 revs. per minute, with two, four, six, and eight poles respectively; and due to the greater economy and lesser cost of turbines which run at a high rotating speed, the majority of turbo sets run at the highest of these speeds. At the present time the usual capacity for 3-phase, 50-cycle generators running at 3,000 revs. per minute may be said to be about 1,000 kw. to 2,000 kw., although machines of 3,000 kw. or slightly higher ratings have been built. For 1,500 revs. per minute machines the capacity may be said to be from 2,000 kw. to 6,000 kw., although here again machines of considerably greater output have been built. For continuous-current machines, an output of about 300 kw. at 3,000 revs. per minute may be taken as representing the present position of the art of designing these machines. However, in all cases the tendency is towards greater outputs and higher speeds, and in the course of a year or two it will probably be quite usual to have a 3,000 kw. alternator running at a normal speed of 3,000 revs. per minute, and a 10,000 kw. to 12,000 kw. alternator with a speed of 1,500 revs. per minute.

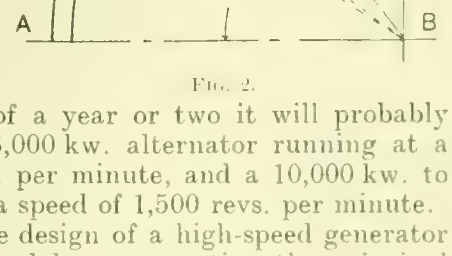

FIG. 2.

An understanding of the design of a high-speed generator may possibly best be obtained by enumerating the principal difficulties which are inherent to such a machine. These are: (1) Centrifugal force; (2) vibration; and (3) ventilation. These may be taken as the chief difficulties in the order given, though others, such as the enormous forces which come into play in case such a generator is accidentally short-circuited at full voltage, and the elimination of pulsations which occur in single-phase machines, are very serious difficulties; the more so as they probably come as a surprise to most designers when first encountered.

* Paper read before the Rugby Engineering Society, March 28th, 1912.

The amount of centrifugal force met with in a high-speed rotor may best be understood by quoting a few examples. To start with, it can easily be shown that a mass of 1lb., revolving at a radius of 1in. at 3,000 revs. per minute, exerts a force of 256lbs. There are two simple forms which a revolving body may have; firstly, it may consist of a series of spokes tied to a common centre, and secondly, it may be in the form of a ring. Let us consider the case of the spoke construction, which for simplicity we will assume to be made of steel and to have a section of 1 sq. in. If this spoke is represented by A B in Fig. 1, and be revolving about the axis C D, any small portion of it, δr, will exert a force equal to $\cdot 28 \times r \times \delta r$ ($\cdot 28$ being the weight of a cubic inch of steel). If we integrate this for the whole length of the spoke, which

FIG. 3.

we take as R, this force becomes $256 \times \cdot 28 \times \int_0^R r \times \delta r$, which is equal to $35 \cdot 8\ R^2$; and if we limit the total force to 15,000lbs. per square inch, it will be seen that this length R cannot be greater than about 20½in.

Similarly, if the structure takes the form of a ring, represented in Fig. 2, we assume that, as before, this ring is comparatively thin, and has a section of 1 sq. in. Further, consider a small portion of this which subtends an angle at the centre of $\delta\theta$. The weight of such a small portion will be $r \times \delta\theta \times \cdot 28$, and the centrifugal force of this will be $256 \times \cdot 28 \times r^2 \times \delta\theta$. This force acts radially from the centre, and its component tending to cause the ring to break across the axis A–B is $256 \times \cdot 28 \times r^2 \times \delta\theta \times \sin\theta$, and so the total force tending to cause a breakage across the axis A–B will be the sum of all such components contained in the quadrant A-D-C, which can be shown to be equal to $256 \times \cdot 28 \times r^2$. If, again, we limit our stress to 15,000lbs. to the square inch, it can be shown that the maximum radius of such a ring is approximately 14½in., that is, a diameter of 29in.

The above calculations are rather elementary, but they tend to bring out clearly the limits of such forms of construction. It is possible, by making the rotor in the form of a disc, to combine both these forms and so get a greater maximum diameter. This is made use of in the steam turbine, particularly of the impulse type; but in an electric rotor, the limits imposed by the ring form of construction usually come in, as although it may be possible to make the central portion of the rotor of discs or solid, it is usually necessary to have retaining rings to hold the end portions of the exciting windings in place. The diameter of the ring worked out in the example is practically the limiting value for a 3,000 revs. per minute rotor, for although it may be possible to use material which allows a higher stress than 15,000lbs. per square inch, still such rings are usually loaded, that is to say, they have to carry a considerable amount of material not capable of supporting itself, and so the stress is considerably increased.

Some of the earlier forms of high speed rotors were built with salient poles, but the difficulties of suitably holding the exciting windings in place on this type of rotor were such that nearly all rotors at the present time are built in a cylindrical form and carry the exciting windings in a number of slots round the outer periphery. This construction allows the exciting windings to be very much sub-divided, and so minimises the centrifugal forces by distributing them evenly throughout the steel portions of the rotor. Also, by subdividing the windings, a large cooling surface is provided, and so the heat is readily abstracted from the copper coils. Fig. 3 shows the stator and rotor punchings of a 3-phase alternator as made by the British Thomson Houston Company, and illustrates the considerations just given.

It will be noticed that a portion of the rotor disc is cut away between poles. This is necessary because, usually, the stator is made in one piece and the rotor is threaded through from one end, and as, of course, the retaining rings at one end must be smaller than the bore of the stator, and such rings have to be, for mechanical reasons, rather thicker than the air gap required, it becomes necessary to cut away some of the material in order to prevent excessive magnetic leakage from pole to pole.

Some makers use open slots on the rotors—in fact, in some cases the rotor consists of a solid steel forging, and these slots are planed or milled out. The coils are then laid in from the outside and held in place by bronze or steel keys. The method illustrated, however, offers some advantage, inasmuch as it gives greater possibilities for proper ventilation of the rotor, and also avoids the use of keys, which must always be considered as separate pieces and therefore liable to become displaced.

From what has already been said about the value of the centrifugal force associated with such high speed of rotation as 3,000 revs. per minute, it will easily be seen that if a heavy mass such as a rotor, which may weigh about 2 tons, is revolved about an axis other than its centre of gravity, very considerable vibration will occur. It is therefore necessary in all such machines to first of all take great care that all parts are perfectly symmetrical, and, in addition to that, make ample provision for balance weights, as a large proportion of an electrical rotor is composed of copper, cotton, mica, and other such unmechanical materials, and it is not always possible to get these parts exactly symmetrical. These balance weights must be provided at both ends of the rotor, and the rotor must invariably be balanced dynamically, that is to say, should be run up to full speed, or beyond full speed in suitable bearings, and balance weights added until it runs perfectly true. It is not sufficient to put such rotors on knife edges and balance them, because such a static balance can be produced by adding weights opposite to one another at different ends of the rotor, and when the machine is run these weights are not in the same plane, and can produce considerable vibration.

To repeat, it will be seen that a rotor must be built up as far as possible so that no displacement of any of the parts takes place, and ample provision must be made for supplementary balance weights. This is a more or less straightforward side of the question. The other side of the question is that which deals with the so-called "critical speed." This is a rather more complicated side of the balancing problem, but perhaps on that account a more interesting one, and is

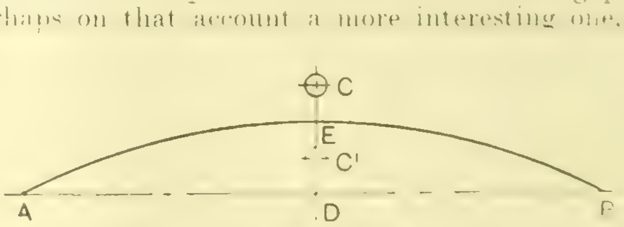

FIG. 4.

due to the elasticity of the shaft, which causes the vibration to be much more pronounced at one particular speed and to diminish again as the speed is increased.

This critical speed is one example of the phenomenon of resonance which occurs in so many cases in nature. It can probably be best understood by considering an elastic steel shaft supported at both ends in bearings and having a mass in the centre. If by some means this mass could be displaced and then released, it would spring back again, owing to the elasticity of the shaft, and oscillate about its proper centre. The frequency with which it will oscillate depends on the length and elasticity of the shaft and on the mass of the rotor. If, now, the rotor be revolved, it will be found that as the speed approaches the frequency at which the shaft naturally oscillates, the oscillation becomes enormously exaggerated until at this exact speed the vibration may become so great as to permanently strain the shaft or even break the bearings and wreck the whole machine. The problem of satisfactorily dealing with the critical speed

already mentioned gave a good deal of trouble before its proper solution was arrived at.

If a rotor is out of balance, its centre of mass may be considered to be displaced from its axis of rotation, and the following diagram (Fig. 4) shows this displacement: A D B represents the shaft straight; C E represents the initial displacement of the mass; D E the bending of the shaft under centrifugal forces; so that C D represents the total displacement of the centre of mass from its axis of rotation when the machine is revolving. The condition of equilibrium when the machine is revolving is that the centrifugal forces exerted by the mass of the rotor due to its eccentricity C D shall be counterbalanced by the elastic forces of the shaft due to its deflection D E.

In other words, let α be the initial eccentricity of the mass and δ the deflection of the shaft.

The centrifugal force exerted will be $M \times (\text{r.p.m.})^2 \times (\alpha + \delta) \times B$. (B is a constant depending on the units chosen.)

The elastic force of the shaft corresponding to the deflection $= A \times \delta$. (A is a constant depending on the dimensions and elasticity of the shaft.)

Equilibrium occurs when these two forces are equal, *i.e.*, $A \times \delta = B \times M \times (\text{r.p.m.})^2 \times (\alpha + \delta)$. $(\alpha + \delta)$ is the total eccentricity of the mass at any speed. Therefore, taking C

$$= \frac{A}{B \times M},$$

the total eccentricity $(\alpha + \delta)$ becomes

$$\frac{C\alpha}{C - (\text{r.p.m.})^2}$$

from which it will be noted that this eccentricity becomes infinite when $C - \text{r.p.m.}^2 = 0$ or $\text{r.p.m.} = \sqrt{C}$, which is the critical speed of the shaft.

It should further be noted that if the speed be increased above this particular value the eccentricity becomes finite again and has changed its sign, so that finally, at very high speeds, the centre of mass coincides almost exactly with the centre of rotation. This means that it is possible to run a machine perfectly satisfactorily above this critical speed if means are provided to ensure that no damage occurs while passing through this critical speed.

A diagram showing the eccentricity of the rotor at various speeds from standstill up to full speed of 3,000 revs. per minute is shown on Fig. 5. This shows that the critical speed is approximately 1,400 revs. per minute in this case, and that after passing through this critical value the machine settles down, and finally, at the normal speed of 3,000 revs. per minute, the total eccentricity is approximately one-third the original value at a standstill.

On account of the high speed of rotation the torsional forces in a shaft are low, which means that the diameter of the shaft can be comparatively small, and further, on account of the high velocity of the shaft the bearing is able to support a very high pressure per square inch. Both these factors mean that a small shaft can be used; a suitable diameter for a 1,000 kw., 3,000 revs. per minute machine would be about 3½in. to 4in. in the journals and possibly 5in. to 6in. in the centre. If we calculate the critical speed of such a shaft we should find that this is about 1,400 to 1,500 revs. per minute, so that if the normal speed of this machine is to be 3,000, either the critical speed has to be passed through or the shaft has to be radically changed so that this critical speed lies well above the normal running speed, *i.e.*, it has a value of about 4,000 to 4,500 revs. per minute. A shaft to fulfil these conditions has a diameter of approximately the full diameter of the machine, that is to say, either the rotor has to be a solid forging with slots milled on the outer periphery to take the windings, or else it is necessary to pass through the critical speed. In machines built by the British Thomson-Houston Company, this latter course is generally adopted, principally for the reason that by using a small shaft the ventilation of the machine can obviously be much better effected than when the rotor is practically a solid mass, and in order to ensure that no danger occurs when passing through this critical speed, a specially-designed bearing has been adopted which allows this to take place without danger. This bearing gives a small amount of freedom at one end of the shaft, and so allows the shaft to revolve about its centre of mass and prevent the excessive vibration that might otherwise occur. A somewhat similar device to this has been used by Messrs. Parsons, consisting of a number of rings around the journal, each of which has an oil film between it and the next. These oil films give a slight cushioning effect, and so, providing the balance of the rotor is good, allows the critical speed to be passed through without undue vibration.

Usually, if a rotor is carefully balanced, its centre of mass can be made to coincide with its axis of rotation within $\frac{2}{1000}$th or $\frac{1}{1000}$ths of an inch, and as the clearance usually allowed in the bearings is $\frac{10}{1000}$ths or $\frac{15}{1000}$ths of an inch, it is easily seen that it is not necessary to have much displacement of the oil film to allow the rotor to revolve about its true centre of mass, and thus, if a rotor be carefully balanced, it will usually pass through its critical speed with very slight vibration. However, the contingency that something may become displaced must always be provided for, and definite means should therefore be provided to allow the rotor to pass through its critical speed even when considerably out of balance. The bearing which has just been referred to has been tested with out-of-balance weights placed on the rotor; and has also been tested with the unbalanced magnetic pull caused by exciting one pole of the rotor only; and although under these conditions the vibration, when passing through the critical speed, is very considerable, still

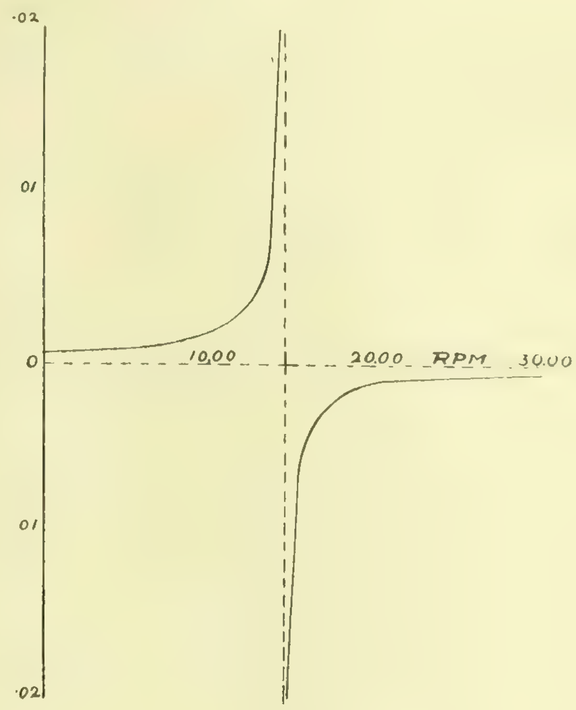

Fig. 5.

it is not enough to cause damage or permanent strain to the shaft.

The problem of ventilation is wrapped up very closely with the other two problems already described, as the subdivision of the windings into a large number of small slots not only minimises the centrifugal force, but also allows a large cooling surface to be presented to the coils, and so enables the heat from these to be transferred into the iron of the rotor. Suitable ducts in the rotor allow ventilating air to pass through, and in turn abstract this heat from the iron.

With regard to the stator punchings, many schemes have been devised for ensuring proper circulation of air among the core plates; but, generally speaking, these consist either of providing ducts between laminations and forcing the air through these ducts in a radial direction, or else punching a series of holes and forcing the air through in an axial direction; or, of course, combinations of both these schemes. In all these cases, however, it is necessary to provide adequate cooling surfaces to take care of the large quantity of heat developed in a very small volume.

Practically the only satisfactory way of cooling high speed generators is by means of blowing air through them, as, although water and oil cooling devices have been tried, these have generally been found to be unsatisfactory. Generally speaking, the rotor itself can be constructed so as to provide sufficient fanning action to force all the air neces-

sary for ventilating purposes through the machine; though in some cases external blowers have been provided. The advantage of the latter arrangement lies in the fact that a standard blower running at a low speed can be made a much more efficient blower than can the high-speed rotor. However, this problem has been studied very carefully during the last two or three years, and the tendency is to do away with the auxiliary blowers.

On account of the large volume of air passing through all high-speed machinery, and also the large number of small air ducts, there is a great tendency for dirt to accumulate inside the machine; and in nearly all cases filters are now installed which clean the air of suspended dust before it passes into the machine. The amount of air required will vary with the size, speed, and type of machine in question. To take a specific example, however, it will be found that about 6,000 cub. ft. per minute will be required for a 1,000 kw. alternator with an efficiency of 94 per cent., and the air passages both inside the machine and in the ducts which conduct the air to the machine must be proportioned to carry this quantity of air.

The output of an alternator (or, in fact, of any electrical machine) is proportional to the product of the total flux per pole, the armature reaction per pole, the number of poles, and the frequency. As the number of poles and the frequency are generally fixed beforehand, the design of an alternator resolves into a proper proportion of the first two quantities, and although a complete consideration of how these two quantities are related to one another is outside the scope of this paper, it may be interesting to consider roughly some of the features which influence the amount of flux and armature reaction which can be allowed for in any particular machine.

With reference to the flux, this is influenced by the permeability of the steel employed, as naturally the greater the permeability the greater the flux that will pass through a given section of steel, and consequently the greater the output that can be obtained from a given size of machine. Further, in connection with this, there is another consideration; that is, that high flux densities produce high iron losses, and the question of ventilation and efficiency has to be considered in determining what densities can be used. Roughly speaking, a density of approximately 100,000 lines per square inch is about the limit to which dynamo steel can be used.

As regards armature reaction, it may first be well to say that by armature reaction is meant the resultant magnetising force along any one axis, due to the instantaneous values of the currents flowing in all the phases of the machine. The determination of the permissible value of armature reaction depends very largely on the total amount of ampere conductors which can be carried in the slots of the stator and rotor of the machine; and here again a limit is imposed by the nature of the material used. If any material were available other than copper, which only produced, say, half the heating for a given amount of current, it would be possible to very much increase the armature reaction allowable. In the case of high-speed machines the limit usually comes in in the number of ampere turns or ampere conductors which can be carried on the rotor, on account of the difficulties of supporting a large mass of copper against the centrifugal force of rotation and abstracting the heat from it.

The relationship between the stator and rotor ampere turns is shown in diagram on Fig. 6. In this diagram these quantities are represented as revolving vectors; the direction of rotation is assumed to be clockwise, as shown by the arrow. The starting point is taken as the voltage vector A B. The magnetising force producing this voltage is ahead of this vector by 90°, as represented by the line A C. This is the state of affairs before any load comes on the machine. The magnetising force of the stator when the machine is carrying load is represented by the line A D. This magnetising force is in phase with the stator current, and has a phase displacement from the voltage vector, due to the power factor of the load, represented by the angle ϕ, or B A D. Now, in order that the voltage may remain at its original value, the resultant magnetising force of the stator and rotor must of course produce the original value A C, and in order to do this the original excitation A C on the rotor must be increased to C D. Suppose, now, that the machine is carrying load and the excitation on the rotor has a value represented by C D and the load is thrown off, that is to say, the de-magnetising force of the armature is entirely withdrawn, the diagram will now become a line A E = C D and the voltage in the machine will be considerably increased due to this large increase in excitation available. From this diagram it will be seen that in order that the alternator may have a reasonable regulation, *i.e.*, the voltage remain reasonably steady under variation of load, the armature reaction A D ought to be small compared with the initial value of the excitation A C, so that any variations in load do not materially affect the voltage of the machine. If, however, the total number of ampere turns carried on the rotor is limited by heating and centrifugal force to the value C D, it can easily be seen that the output of the machine is considerably reduced by making A C large and A D small and so obtaining close regulation; hence the tendency is for such high-speed machines to have a comparatively poor inherent regulation, and to obtain constant voltage by use of some supplementary device, which usually takes the form of a "Tirrill" regulator. This device automatically changes the excitation of the machine so as to keep the voltage constant under all conditions of load, and so allows a large armature reaction, and consequently a large output to be obtained with a limited rotor capacity.

In single-phase alternators a different form of rotor is necessary from that used in 3-phase machines. In the case of polyphase machines the armature reaction remains constant

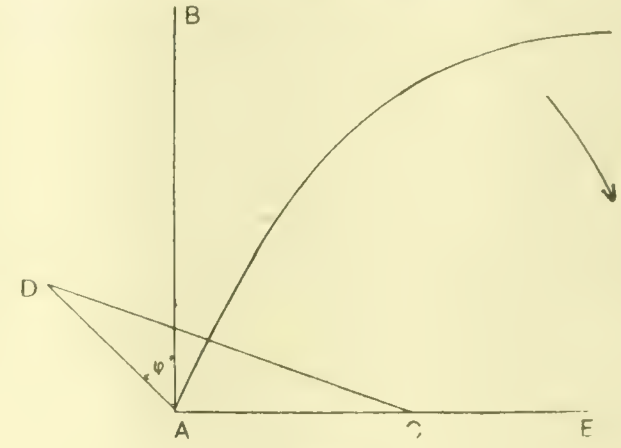

FIG. 6.

in value; for whilst the rotor revolves the current changes in the different stator phases so that the resultant magnetising force in any instant due to all the phases remains steady and revolves with the rotor. In a single-phase machine, the stator phases lie along one axis only, and consequently are incapable of producing any magnetising force along any other axis, hence the resultant magnetising force due to the ampere turns on the rotor and on the stator will vary according to whether the rotor is lying along the axis of the stator coils or at right-angles to it, and consequently a big pulsation takes place, which causes very largely increased losses throughout the machine.

The remedy for this trouble has been to provide the rotor with a series of short circuited copper bars lying along the outer periphery. Currents are induced in these bars by the rotation of the rotor in the magnetic field, and these produce a magnetising force along the axis at right angles to the axis of the stator coils: and thus in conjunction with the stator coils a continuously revolving uniform armature reaction is produced, which is equivalent to that which occurs in a polyphase machine.

Without such a short circuited winding on the rotor, the single phase output obtainable from a given size of machine is only about 30 per cent. to 40 per cent. of that possible if it were wound as a polyphase machine, whereas with this winding it only falls behind the 3 phase rating by the amount of the losses in the auxiliary short circuited winding, which generally makes the output about 80 per cent. to 85 per cent. of the 3 phase rating.

An interesting form of high speed generator which has the merit of extreme simplicity of rotor construction is the induction generator. Such a generator is simply an induc-

tion motor driven slightly above its synchronous speed, when, instead of acting as a motor, the direction of energy flow is reversed and the machine becomes a generator. It has the merit of extreme simplicity in rotor construction, as the rotor consists simply of a laminated core with short-circuited copper bars carried in slots on the outer periphery. This form of generator has been used in conjunction with exhaust steam turbines in order to increase the capacity of existing reciprocating electrical sets. It has the great disadvantage, however, that it is incapable of running by itself, and depends entirely on another generator to maintain the voltage, and further than that, not only is it incapable of supplying lagging current to magnetise induction motors, but it draws a certain amount of inductive current from the other generator; and thus its use is almost entirely limited to systems where synchronous machinery, or more particularly rotary converters, are used and where the power factor is inherently very high.

It may be of interest to briefly show what happens when an alternator is suddenly short-circuited when running at full voltage. To do this it is necessary to refer again to Fig. 3. Suppose now that the machine is generating full voltage; the flux comes out of the rotor at the centre of the pole and passes into the stator through the stator windings. If these stator windings are suddenly short-circuited, the flux can no longer flow into the stator, as currents will be induced in the stator windings which will prevent it. The tendency is, therefore, for the flux to disappear entirely, but in doing this it generates heavy currents in the rotor conductors, which are short-circuited by the exciter circuit, and these currents tend to maintain the flux at its original value. Thus currents are produced in the stator windings preventing the flux entering the stator, and the other currents are induced in the rotor winding which keep the flux at its original value; therefore the flux has to find a path along the air gap between the two windings. If the windings are close together, this path is a restricted one, and in order that the flux may flow along it, enormous magnetising forces are necessary, that is to say, the stator and rotor currents may rise to a value 20 or 30 times their original value. This state of affairs only lasts for a few cycles, *i.e.*, for a fraction of a second, but during the time it lasts enormous mechanical forces, due to the very heavy currents which are flowing, are produced, and these forces are in many instances sufficient to wrench the end windings of the stator from their supports and sometimes even to twist the shaft of the rotor or break the coupling bolts. As to the remedy for this trouble, we have seen that the output of the machine is proportional to the product of the flux and the armature reaction; so that if we increase the armature reaction and decrease the flux, firstly the amount of flux that has to pass between the two windings is less, and therefore takes a lesser force to send it along this path, and secondly, the magnetising force to send it along this path is initially greater, due to the greater armature reaction; so that by making such a change the severity of the shock can be considerably reduced. Such a modification as this, however, as has been seen earlier in the paper, tends to make the inherent regulation of the machine poorer, and this is another reason why it is generally necessary to use a "Tirrill" regulator in connection with high-speed machines; as of course it is of first importance that the machines should be safe under all conditions of operation.

In designing direct-current machinery to run at turbine speeds, the problem of commutation has to be considered far more thoroughly than is necessary for slower speed machines; and in addition to this, there is the problem of designing a suitable commutator and brush gear which will remain in contact with one another at the high speeds which are necessary. It is this latter portion of the problem which is really the more difficult of the two. Practically the only suitable material for brushes is carbon, or preferably graphite; and as such brushes are necessarily rigid, it is necessary that the commutator should remain perfectly true when running at full speed, and should not distort under the action of heat or centrifugal force. For this reason the form of commutator construction usual on slow-speed machines is unsuitable, and instead of this the shrink-ring type of commutator is used. This form of commutator consists of copper bars held in place by heavy steel rings shrunk on over mica bands.

The conditions necessary for proper commutation are, first of all, that there should be a well-defined neutral zone; that is to say, places on the commutator where there is no voltage between adjacent segments, at which places the brushes can bear on the commutator and cover several segments without producing any short-circuit current through the brush. Secondly, as the loads come on, the magnetic distorting effect of the armature should be neutralised by compensating windings, so that these neutral places remain, under all conditions of load, the same as at no-load; as, of course, if the armature reaction were to shift the flux so as to cause the brushes to be in a position where there was considerable voltage between segments, a big short-circuit current would be produced and bad sparking ensue. The third condition is that each coil of the armature during the time it is under the brushes must have a voltage induced in it sufficient to reverse the current it is carrying from the value on one side of the armature, to that on the other side of the armature. The force necessary to cause this reversal is proportional to the current to be reversed, and therefore the commutating poles or equivalent devices which are fitted to such direct-current machines are provided with windings connected in series with the armature, so that the reversing strength is proportional to the armature current.

The compensating windings referred to above consist of similar series coils embedded in the pole faces, connected so as to directly oppose the current flowing in the armature conductors. The strength of this compensating winding must be very nearly equal to that of the armature; as otherwise, as the load comes on, a considerable distortion of the flux takes place, and if the load is suddenly changed the flux distribution will suddenly change also and give an inductive voltage which may cause a flash-over on the commutator.

The consideration of critical speed already touched on applies more particularly to direct-current machines than to alternators, because in the case of alternators it is in most cases possible, at the sacrifice of a certain amount of ventilation, to make the rotor solid and so put the critical speed above the running speed, but in the case of direct-current machines, on account of the necessity of having laminations and also on account of the increased length of the armature due to the commutator, this becomes in nearly all cases impossible; therefore, high-speed direct-current machines must almost invariably run above the critical speed of the shaft.

Direct-current machines are usually protected from the danger of short-circuit by means of a circuit breaker, as this will usually open and interrupt the current before damage occurs. However, in case of failure of the breaker, the best way is to provide coupling bolts between the turbine and the generator, proportioned so that they will shear through before the shaft is twisted, and then, if such a short-circuit should occur, the worst that can happen is that new coupling bolts will have to be provided. Means have been discussed for installing a reactance in series with the armature and connecting the field leads on the far side of this reactance. In this case, if a short-circuit occurs, the voltage beyond the reactance momentarily drops to zero; and consequently the exciting current dies out and the reactance in the meantime prevents the armature current from suddenly attaining a high value. Such a reactance, however, would have to be large and expensive; and the means mentioned above is probably the simplest for dealing with the danger of short-circuit.

In concluding this paper, the author wishes to show a few slides illustrating various forms of high-speed machinery, and wishes to thank the British Thomson-Houston Company for the courtesy they have extended to him in the preparation of the paper and slides.

Railway Electrification.—The Lancashire and Yorkshire Railway Company have decided to electrify their Holcombe Brook branch, a short line about three miles long, running from Bury to Holcombe Brook. The work is being undertaken for experimental purposes by Messrs. Dick, Kerr, & Co., Ltd., and will probably be completed in a few months. The high-tension direct-current system will be used, in which current will be transmitted to the motors at 3,500 volts from an overhead conductor. The car equipment will consist of four 150 h.p. gear driven motors mounted on the trucks. The control will be series parallel multiple unit, enabling the cars to run singly or coupled up to form a train. The equipment of a line at this voltage has become possible only by the development of control apparatus fitted with Messrs. Dick, Kerr's metallic shield magnetic blow-out which permits this entire current of the equipment to be broken at a single contact.

INDUSTRIAL AND TRADE NOTES.

Locomotives for Argentine.—The North British Locomotive Company, of Glasgow, have secured an order to construct 20 powerful locomotive engines and tenders for the Central Railway Company of the Argentine Republic.

New Ocean-going Destroyers.—Messrs. Samuel White & Co., of Cowes, have received an order from the Admiralty for two ocean going destroyers, each 270ft. in length. They are to be built to the Admiralty design, and will consume oil fuel. This firm has already on hand an extensive order for ocean going destroyers for the Chilian Government.

Clyde Shipbuilding.—The output of new tonnage from the Clyde shipyards during March was 52,000 tons, which, notwithstanding the strike, is only about 8,000 tons less than in March of last year. The new shipbuilding launched in the first quarter of the year amounted to 135,140 tons, which is the greatest ever produced, and nearly 16,000 tons above the previous record output in the first three months of 1906. The new tonnage placed on the Clyde during March has been exceptionally large.

Trade Catalogues.—From the General Electric Company, 87, Queen Victoria Street, E.C., we have received a catalogue of their various types of electrical measuring instruments. Special attention is called to the fact that all switchboard instruments shown in the list are now calibrated in accordance with the British Engineering Standards Committee's specification of accuracy known as "first grade." Messrs. Cochran & Co., Annan, N.B., send us a brochure of photo views illustrating the accessibility for inspection and cleaning purposes of the Cochran boiler.

Scottish Tube Combine.—The Scottish tube combine has just been registered as a limited liability company with 300,000 preference and 450,000 ordinary shares of £1 each. It is to be known as the Scottish Tube Company, with offices at 5, Wellington Street, Glasgow, and the businesses it amalgamates are: The Caledonian Tube Company, Coatbridge; the Coats Tube Company, Coatbridge; J. Eadie & Sons, Rutherglen; Hendry Bros., Ltd.; John Marshall & Sons, Glasgow; D. Richmond & Co., Ltd.; the Tradeston Tube Company, Glasgow; and Wilsons and Union Tube Company, Ltd.

New Type of Furnace.—In the Cayley Robinson furnace, a demonstration of which was recently given at 14, Billiter Buildings, London, E.C., the gasification of the coal is brought about in one chamber and the combustion of the gas in another. The gasification process having been started by lighting the coal in the ordinary way, a small quantity of live coke is transferred from the fire into the adjacent combustion chamber in which the gases are made to circulate centrifugally by means of a jet of steam, and in which, it is claimed, they are completely consumed without ash, smoke, or clinker. The steam is generated from water in a coil of pipes placed in the combustion chamber. No actual tests have yet been carried out with the furnace, but it is claimed that over 75 per cent. of the calorific value of the fuel is utilised. Experiments are now being carried out with a view to adapting the principle for use in locomotives.

Mechanical Filters.—Messrs. Mather & Platt, Salford Ironworks, Manchester, send us a copy of a new issue of their booklet describing and illustrating their various open and pressure types of filters. These are designed to deal either with suspended or dissolved impurities. The importance of an abundant supply of water is common to most industries. It is frequently found, however, that the available water supply contains suspended and colouring matter which render it unsuitable—especially is this the case in the textile and paper making trades—with the result that town's water has to be purchased at considerable cost. During recent years a considerable number of manufacturers have recognised that there is no necessity to continue to incur the large yearly cost associated with the use of town's water, as it has been demonstrated, beyond doubt, that there are few natural waters which cannot be rendered suitable for manufacturing purposes by the adoption of an efficient mechanical filtration plant. For many years the firm have specialised in the construction of this kind of apparatus, and have installed a large number of plants, both at home and abroad.

Industrial Output.—A printed reply has been furnished to Mr. Amery, M.P., who asked the Secretary of the Board of Trade what was the value of the net output of the coal mining industry, the cotton industry, the iron and steel industry, and the engineering industry respectively; what number of workers were employed in each of these industries; and what profits or royalties had been returned for income tax in each of these industries. Mr. Robertson says the value of the net output and the average numbers employed, as shown in the preliminary tables summarising the returns received under the Census of Production Act, 1906, were as follows in 1907. Mines under the Coal Mines Regulation Act: Net output of £106,364,000; average number employed, 840,280. Cotton factories—£46,911,000; number employed, 572,869. Iron and steel factories (smelting, founding, and rolling) £30,918,000; number employed, 262,225. Engineering factories (including electrical engineering) £49,125,000; employés, 55,561. Marine engineering carried on in connection with shipbuilding, engineering work done by railway companies, and heating, ventilating, and sanitary engineering are not included in the last figures.

The Railways of Switzerland.—Switzerland, according to an American Consul at Zurich, takes eighth place among the European members of the International Railroad Convention in the length of its railways. Statistics for 1911 show that Russia is first with 40,612 miles, Germany second with 37,936, and other countries in the order named: Austria Hungary, 26,362 miles; France, 25,126 miles; Italy, 9,089 miles; Sweden, 5,695 miles; Belgium, 2,968 miles; and Switzerland, 2,848 miles. Switzerland has more railways than the Netherlands, Denmark, Servia, or Roumania. Of the Swiss mileage in 1911, 1,672 were State owned railways, and 1,176 miles private firms. Besides, there are 39 miles of foreign railways within the Confederation. There are at present about 41,000 persons employed on the railroads in Switzerland, 35,200 of whom are with the State lines, and 6,700 on the private roads. The rolling stock of the country consists of 1,615 locomotives, of which 1,224 are on the State lines; 3,662 passenger coaches, of which 3,237 are State property; and 1,287 baggage and mail cars, of which 730 are on the State railways. There are also in Switzerland 17,559 freight cars, of which number 14,449 are on the Government lines.

Power-Gas Corporation, Ltd.—The works of the Power Gas Corporation, Ltd., Stockton on Tees, are fully occupied at the present time, and the following is a list of the most important contracts recently secured by them: 1,500 kw. "Mond" bye-product gas plant, for Japan; 4,500 h.p. "Mond" bye product gas plant, for Australia; "Mond" bye product gas plant (capacity 69 tons of breeze per day), for steel melting; "Mond" coke breeze gas plant (capacity 15 tons of breeze per day), for retort heating; "Mond" bye product gas producers (capacity 46 tons per day), for cement works; 1,500 h.p. "Mond" bye product gas plant, for Spain, 2,000 h.p. "Mond" bye product gas plant, for electric generating station; 2,000 kw. "Mond" bye product gas plant, for electrolytic chemical works; 500 h.p. "Mond" power gas plant, for South America; "Mond" coke breeze gas plant (capacity 10 tons per day) for brick burning; 6,000 h.p. "Mond" bye product gas plant extension to the South Staffordshire Mond Gas Company's gas distributing station at Dudley port. In addition to the above, many smaller plants, to use bituminous coal, anthracite, coke, charcoal, and sawmill wood waste for power purposes, are on order.

Large Turbines for America.—The Commonwealth Edison Company, of Chicago, have decided to carry out some further extensions in connection with their Fisk Street station. This station at present contains ten turbo generators of 14,000 kw. each, and the proposed extensions will consist of four turbo units of 25,000 kw. maximum continuous load, and 20,000 kw. economical load. The order for the first machine has been placed with Messrs. C. A. Parsons & Co., and it will be built at their works at Heaton on Tyne. The machine will generate three phase current at 25 cycles and 9,000 volts, and will run at 750 revs. per minute. The turbine will be of the two cylinder type, the high pressure cylinder being a single flow turbine, and the low pressure cylinder a double flow turbine. The high pressure cylinder body will be of steel. The exciter will be direct coupled to the end of the alternator shaft. The current generated by the alternator will actually be at 4,500 volts, but will be stepped up to double that pressure by an auto transformer to be supplied by the General Electric Company in America. The specified steam conditions are 200lbs. steam pressure, 200 Fah. superheat, and 29in. vacuum. The supply company's extensions and the design of the turbo generators are being carried out by Messrs. Sergeant and Lundy, the engineers of the company, in conjunction with Messrs. Merz & McLellan, of Westminster.

Oil Production in New Zealand.—H.M. Trade Commissioner for New Zealand, adverting to the existence of oil in many parts of the Dominion, remarks that much money has been spent on boring operations in different places, but except at New Plymouth no oil has yet been produced. At Moturoa a third bore has just been brought into play, and oil to the extent of some 200,000 gallons has already been run into underground cisterns, pending the arrival of refining plant. Petroleum experts consider prospects favourable, and there appears to be only one serious problem, viz., that of a market for the oil. From the first bore oil has now been running for two years, which is taken as a very good sign. The oil is being obtained from a depth of only about 2,000ft., the strata through which the bores go presenting no technical difficulties. The oil contains an extraordinary per

centage of the most valuable of the bye products, viz., petroleum wax. So high is this percentage that it is found that costly prepared cisterns can be dispensed with and mere trenches dug; as soon as the pure petroleum touches the cold earth it solidifies and makes an impervious lining, inside which much of the oil also solidifies. There are these great natural advantages to outweigh the cost of labour, nevertheless the real question seems to be whether enough can be marketed locally to make a refinery pay. Outside the Dominion, and possibly the Commonwealth of Australia, it is hardly to be expected that New Zealand producers could compete with California and Burma, &c.

Railway and Canal Traffic.—Representatives of county, municipal, and local authorities, and chambers of commerce and agriculture and other kindred organisations, presided over by Sir Alfred Mond, M.P., assembled in London on the 26th ult. at a conference on the subject of railway and coal traffic. After a discussion, the following resolutions were unanimously adopted: (a) "That this conference is of opinion that the proposed Government legislation respecting the Railway and Canal Traffic Act, 1894, as explained by the President of the Board of Trade, would be prejudicial to trade and agricultural interests, and resolves therefore to oppose such legislation or any measure which may be calculated to destroy or diminish the protection afforded by the Act." (b) "That this conference is apprehensive that legislation giving effect to certain of the recommendations of the Departmental Committee on Railway Agreements and Amalgamations will be detrimental to traders and agriculturists, as the Committee, while expressing themselves in favour of 'the more complete elimination of competition' between railway companies and giving them greater freedom to enter into agreements with each other, fails to recommend any safeguards for traders and agriculturists under such new conditions, and resolves that no legislation will be satisfactory to traders and agriculturists that does not remedy their long standing grievances and in particular restore to them the right of appeal against any rate or charge." The gentlemen present at the conference were subsequently received as a deputation by Mr. J. M. Robertson, M.P., Parliamentary Secretary to the Board of Trade. Mr. Robertson informed the deputation that their views would be placed fully before the President of the Board of Trade.

Trend of Invention in 1911.—The twenty-ninth report of the Comptroller-General of Patents, Designs, and Trade Marks just issued states that the ever-increasing importance of means of locomotion to the community in general is demonstrated by the prominence this subject takes under an analysis of the whole field of inventive activity. The internal-combustion engine, an important factor in the science of locomotion, is greatly in evidence, particularly in connection with the revolving-cylinder type, and the so-called "valveless" engine, in which poppet valves are dispensed with. Wheels for vehicles are a still more prolific source of invention. Motor vehicles and motor cycles maintain their claim to attention, variable-speed gearing, clutches, and engine-starting devices being especially noteworthy. Aeronautics show a considerable diminution in comparison with the previous year, but the number of applications is still sufficiently great to make the subject one of the outstanding features of the year's invention. It is interesting to note that efforts are being made to utilise aeroplanes as auxiliaries in naval warfare by contriving means for launching them from the decks of battle-ships. In view of the recent dispute in the taxi-cab industry, it is significant that many applications were received dealing with the registration of "extras." In the textile industry the most noticeable feature of interest is the remarkable batch of inventions designed to obviate the objectionable habit known as "kissing the shuttle." Efforts are still being directed towards abating dust and improving ventilation in the carding-room of spinning mills. Chemical and fermentation processes for the extraction of fibre from flax, ramie, and other plants, both for spinning and paper making, are also worthy of remark. In the chemical industry considerable activity has been shown in connection with the synthetic production of india-rubber and of ammonia, the catalytic reduction of unsaturated fats, oils, and the like, and the production of vat dyes of the anthracene series. As a result of certain recent railway collisions that occurred towards the end of 1910 and early in 1911 (such as those at Hawes Junction and Pontypridd), caused in each case by a train being signalled into a section of the line already occupied by a standing train or engine, many applications were received dealing with the prevention of such accidents by automatic apparatus. Increasing attention is being given to the utilisation of the characteristic properties of the gyroscope, more particularly in its application as a substitute for the magnetic compass, and in its use as an anti-skidding device for vehicles and as a stabilising means for flying machines.

ELECTRICAL DRIVING IN COTTON MILLS.

A PAPER on "The Individual Electrical Drive for Looms" was read by Mr. J. F. Crowley at a meeting of the Lancashire Section of the British Association of Managers of Textile Works on Saturday night at the Victoria Hotel, Manchester.

Mr. Crowley, with the aid of lantern views, described an installation of 700 individually-operated looms established by Messrs. Siemens Brothers at the Wellfield Mill of Messrs. Frear, Lord, & Brothers, at Bradley Fold. A three months' competition between the individual and the group system at that shed, Mr. Crowley said, resulted in the individual system showing an increase of 10 per cent. in production. The outcome of 40 tests carried out by himself in Lancashire and Yorkshire was that he had never got less than this increase, but had obtained as much as 25 per cent. Five years ago, he said, it was doubtful whether a motor of the size used had an efficiency exceeding 67 or 70 per cent., whereas some of the individual motors in the shed referred to gave an efficiency of 88·5 per cent., and it was this advance that had made individual driving so important. The simplicity of the machine was one of its recommendations. If one broke down a spare one could be slipped into its place in a few minutes, though this had not once been necessary during the time the installation had been in operation. The starter supplied with each loom was of the simplest kind, and the motor was so designed as to give 1½ h.p. instead of the ½ h.p. ordinarily required.

The advantages claimed by electrical engineers for the individual drive were numerous. There was greater rapidity of erection, and a saving in capital expenditure on the building, due to the saving in cost of the main roof which had not to carry heavy shafting, and the design of which was of extreme lightness. While the weaving efficiency of the loom was increased from 75 per cent. to 88 per cent. without any special arrangements. There was also better lighting and atmosphere. Estimated with regard to profits, power consumption, wages, &c., he claimed that the 10 per cent. increased production meant to the textile manufacturer an increased profit of 34 per cent. and an improved material.

In the discussion which ensued, Mr. Pollit enquired why Mr. Crowley had compared the individual electric drive with the group drive instead of with the ordinary steam system. Mr. Crowley's reply was that in comparison with steam the individual drive came out even better, but he had chosen the comparison in which most doubt still lingered. Several further points were entered upon. Mr. Crowley said his use of the Board of Trade returns was to avoid the assumption that any shed was worked at a certain profit, an assumption which might be objected to. In the census returns the value of the output per operative is given at £82 per annum, while the average wage is given at £52 per annum. He therefore framed a formula equating profit, power consumed, maintenance, interest on capital, and depreciation, all expressed in terms of the number of operatives, against £30 (the difference between £52 and £82). Raw material plus 82 times the number of operatives equals the value of the output for the year. In the worsted trade the constant would be 79, and in the coal trade 129. Manufacturers sometimes miscalculated the power required for electric driving by basing it on the full-rated power of the motor. Where with steam driving there were three looms to the horse-power and with electric power three 0·5 h.p. motors are installed for three looms, it does not mean than 1·5 h.p. is being consumed. For manufacturing reasons no motors are made of a size between 0·33 h.p. and 0·5 h.p., and in reckoning three looms to the horse-power it must be remembered that the proportion of looms working at one moment is taken at only about 75 per cent. With electric driving when the loom stopped the motor stopped too, and when running normally absorbed a good deal less than its full-rated power. The proper calculation was to take the actual running horse-power and assume a loss in the motor of 14 per cent. and in transmission of 3 per cent. That is 17 per cent., against 25 per cent., which is usually assumed as the minimum loss in steam driving. With regard to the quick starting of the loom by the individual motor, it was erroneous to say that because this had ill effects on warp winding, breaking the threads, it would have the same disadvantage with a loom. The initial jerk was absorbed by the first pick of the shuttle, and the acceleration did not damage the warp.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1910.

Heat insulating material. Ferra. 28667.

1911.

Engine governors. Taylor & Evans. 3296.
Firing of boilers with pulverised fuel. Midgley. 3463.
Speed indicators. Bramley Moore. 4717.
Friction clutches. Godwin. 5497.
Variable compression device for internal combustion engines. Portway. 5630.
Power storing mechanism. Gilbert. 5785.
Water heating and purifying apparatus. Lake. 5951 and 5954.
Revolving cylinder internal combustion engines. Henry. 6111.
Pulleys. Alfred Steel & Sons, Ltd., and Steel. 6149.
Valve. Purser. 6269.
Valve gear for internal combustion engines. McCollum. 6289.
Pressure reducing, pressure controlling, and governor valves. David Auld & Sons, Ltd., Auld, and Graham. 6342.
Wheels and pulleys. Garside & Morgan. 6409.
Apparatus for removing boiler scale. Electric Safety Boiler Cleaner, Ltd., and Ardill. 6427.
Rotary pumps. Lehne. 6431.
Automatic screw cutting and finishing machines. Robertson. 6522.
Fuel injecting means for internal combustion engines. D'Harveng. 6533.
Acetylene gas lighting plants. Carmichael. 6680.
Regulating the fuel supply to internal combustion engines. Daimler Motoren Ges. 6760.
Ball bearings. Wingquist. 6765.
Steam generators. Aitken. 6832.
Smelting of ores containing tungsten and tin. Holloway and Wagner. 6837.
Generation of water gas. Stephenson. 6849.
Chucks for boring machines and lathes. Barnes. 7262.
Brakes of tramcars. Gleaves & Holliday. 7266.
Starting devices for motor vehicles. Demonte. 7760.
Shock absorber for chains, ropes, cranes, or tension members. Hiley. 7925.
Exhausting means of internal combustion engines. Martin. 8243.
Internal combustion engines. Carter & Carter. 8334.
Ejectors for exhausting or moving gaseous fluids. Hay & Buckley. 9187.
Apparatus for removing boiler scale. Electric Safety Boiler Cleaner, Ltd., and Ardill. 9567.
Ferro concrete railway sleepers. Wornda. 10734.
Change speed gearing for tramcars and locomotives driven by internal combustion engines. Clare, and Sidney Straker and Squire, Ltd. 11138.
Air supply and cooling devices applicable to coking stokers. Bennis. 11445.
Files for metal. Denley. 12560.
Coal cutting machines. Sutcliffe. 12592.
Screw gearing for steering ships and vehicles. Lord. 13855.
Friction clutches. Lucas & Jackson. 14026.
Change speed gearing for motor vehicles. Lord. 14307.
Sleeveless and valveless internal combustion engines. David Brown & Sons (Huddersfield), Ltd., and Burgess. 14540.
Smokeless boiler furnaces. Cook. 14626.
Metal couplings for connecting frames. Nees. 15449.
Combined double piston and double sleeve reciprocating and differential valve for use in connection with motors. Wilson. 15546.
Drill mountings. Newton. 16050.
Ball retainers for bearings. Wingquist. 17290.
Speed multiplying or reducing or varying gearing. Leistriz. 17592.
Sectional boilers. Reinartz. 17979.
Furnace for extracting zinc. Schneemilch. 18008.
Stocks and dies. Frey. 18034.
Die presses. Thompson. 18084.
Multiple wire drawing machines. Nacken. 18302
Apparatus for consuming smoke in steam boiler furnaces. Schneider. 18551.
Nut locks. Collier & Grove. 20009.
Shaft couplings. De Dion Bouton (1907), Ltd. 20696.
Recording mercury barometers. Agolini. 20881.
Superheater arrangements for vertical steam generators. Sugden. 21900.
Packing rings. Batty. 22669.
Case hardening processes for articles of iron, steel, and steel alloys. Soc. Anon. Italiana Gio. Ansaldo, Armstrong, & Co. 22778.
Process for the manufacture of formates of chromium, aluminium, and iron. Wolff. 23190.
Safety suspension devices for lifts. Smith. 23312.
Linkages for conveying rotary motion. Crary. 23935.
Means for operating tramway points or switches. Renner. 24531.
Ore concentrating tables. Pendray, Rodda, & Rodda. 24993.
Turrets for use in lathes and analogous machines. Willmund. 25346.
Fluid pressure braking apparatus. Hedendahl. 26155.
Railway rail joints. Harris. 26512.
Centrifugal pumps or compressors. Frame. 29089.

1912.

Ball bearing. Oheim. 348.

ELECTRICAL, 1911.

Ignition system for internal-combustion engines. Kettering. 5902
Apparatus for generating electricity on motor-driven vehicles. Joel & Taylor. 6257.
Control systems for electric hoisting apparatus. Allgemeine Elektricitäts-Ges. 6293.
Multiple telephony. Ruhmer. 6549.
Electrodes for flame arc lamps. Oliver Arc Lamp, Ltd., Oliver, and Pell. 6986.
Sparking plugs for internal combustion engines. Wallace and Green. 7787.
Electrostatic measuring instruments. Addenbrooke. 9077.
Remote control systems for electrically driven vehicles. Electro motoren-werke. Hermann Gradenwitz. 10550.
Method of feeding low voltage lamps and other low voltage electrical devices in a high voltage net. Neu. 10965.
Electrical accumulators. Bayley & Wood. 13266.
Electric relays. W. R. Sykes' Interlocking Signal Company, Sykes, and Tarrant. 14615.
Electric ignition fuses. Schaffler rekte Glössl & Weiss. 15219.
Circuits for telephone instruments. British Insulated and Helsby Cables, Ltd., and Redfern. 15502.
Electric motor control systems. British Thomson Houston Company. 15841
Telephone exchange circuits. Western Electric Company. 18649.
Impulse transmitters for automatic exchange telephone systems. Betulander. 19661.
Method and furnace for reduction or smelting of ore with electric current. Aktiebolaget Elektrometall. 25862.

1912.

Safety fuses for electrical installations. Appareillage Gardy (S.A.). 3121.

METAL QUOTATIONS.

TUESDAY, APRIL 2ND.

Aluminium ingot	67/- per cwt.
,, wire, according to sizes, &c. ......from	102/- ,,
,, sheets ,, ,, ... ,,	120/- ,,
Antimony ...... £27/-/- to	£27/10/- per ton
Brass, rolled	7⅞d. per lb.
,, tubes (brazed)	10⅜d. ,,
,, ,, (solid drawn)	8¼d. ,,
,, ,, wire	7⅞d. ,,
Copper, Standard	£70/12/6 per ton.
Iron, Cleveland	51/10½ ,,
,, Scotch	57/10½ ,,
Lead, English	£16/10/- ,,
,, Foreign (soft)	£16/3/9 ,,
Mica (in original cases), small	6d. to 2/- per lb.
,, ,, ,, medium	2/6 to 4/- ,,
,, ,, ,, large	4/6 to 8/6 ,,
Quicksilver	£8/12/6 per bottle.
Silver	26 $\frac{5}{16}$d. per oz.
Spelter	£26/-/- per ton.
Tin, block	£197/-/- ,,
Tin plates	13/10½ ,,
Zinc sheets (Silesian)	£28/12/6 ,,
,, (Stettin; Vieille Montagne)	£28/5/- ,,

The Institution of Civil Engineers.—It is announced that the 20th "James Forrest" lecture will be delivered at the Institution on Friday, the 19th April, at 9 p.m., by Mr. H. R. Arnulph Mallock, F.R.S., his subject being "Aerial Flight."

The Mechanical Engineer

AN ILLUSTRATED WEEKLY JOURNAL Vol. 29, No. 742

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The Inspection of Electrical Machinery.

ALTHOUGH the number of fatal accidents from the use of electricity is small having regard to its innumerable applications, investigation shows that most of those which do occur could be avoided by the adoption of precautions that any electrical expert would regard as reasonable. That they are not adopted is due largely to the belief of many power users that, once installed, an electric motor needs no care or attention beyond the lubrication of the journals, a belief to which support is afforded by their generally good behaviour under very adverse conditions. It is unfair, however, to presume too much on such conduct, and a section of power users seem to need educating on this point. This is the more surprising, as the same people would not, as a rule, dream of running their steam boilers or engines without first insuring them against explosion or breakdown to secure the benefit of supervision and periodical examination by engineering experts. Now similar supervision is just as valuable for electrical machinery and as easily obtained, for practically every boiler insurance company makes the inspection and insurance of electrical machinery a special branch of its business. In no industry are the conditions of working of electrical machinery more onerous than in coal mines, where it is so constantly assailed by its worst enemies in the shape of damp, dust, and ill-treatment, and, therefore, in no industry is there greater need for independent supervision. This is clearly brought out by Mr. Robert Nelson, H.M. Electrical Inspector of Mines, in a table appended to his last report setting forth the details and causes of the various electrical fatalities that occurred during 1910. While it may be admitted that much of the electrical plant below ground is not all it might be, and in some cases calls for replacement because actively or potentially dangerous from the point of view of risk of electric shock, a brief study of the statistics shows that a great proportion of the accidents which actually occurred [illegible]

he observes, "have been avoided by systematic and thorough inspection." It is not suggested that those responsible for the upkeep of electrical plants below ground are less conscientious than others occupying similar positions on the surface, but the risks of defects arising owing to the conditions of the service are undoubtedly greater, and the multifarious nature of the duties imposed on those in charge, coupled with the absence of evidence of the positive value of inspecting work when well performed—*i.e.*, when no accidents occur and nothing calls for remark—is apt to lead to lack of appreciation and its concomitant result, indifference. It is easier to assume that everything is right until something goes wrong than it is to be always on the alert against the latter possibility. As specific instances of the result of this attitude, Mr. Nelson mentions the accidents arising from the common failure to protect unarmoured cables during shot-firing operations, the casual and inefficient way in which earth connections are often made, and the neglect to periodically test the insulation of apparatus. Each of these causes is directly or indirectly responsible for some of the fatal accidents every year, and is the more to be regretted as it tends to damage electrical development by giving undue weight to the arguments of those who would prohibit its use below ground, notwithstanding its economic advantages and its benefits to the workman by saving him much arduous labour. When inspection, with its accompanying supervision, is exercised by outside independent authorities instead of by the owners' servants it is almost invariably carried out in a more efficient manner, for the inspector is free from any doubts as to the correct appraisement of his work, which he knows is most efficient when there is least reason for referring to it afterwards.

Diesel Engines.

It would be a pity if the recent development of the Diesel oil engine received a set-back through the extravagant expenditure of capital in schemes for the extensive construction of this type of motor, and yet we fear there is a serious risk of this. Two large companies, mainly of foreign origin, are already seeking floatation in this country. The basis of their appeals for public capital is that they have had a certain amount of experience in this type of motor for ships, and that the success met with will probably lead to their extensive adoption. Without wishing to discount in the slightest the merits of such success as has been attained, it appears desirable to point out to prospective investors that no master patent now controls the manufacture of Diesel engines. It is open to anyone to make them. Such patents as do exist relate only to details of the kind which cling by the score to the steam engine or any other prosperous industry, and which often stand more for novelty than for special excellence either in construction or workmanship. In the absence of any monopoly, and in face of the fact that orders for Diesel engines will be evolved rather from slow-growing confidence in them than from any boom demand, it is improbable that scope for any large outputs will be found for considerable time to come, besides which it should be remembered that most large builders of steamships already have their own engine shops, and it is very unlikely they will place orders outside their own works for propelling machinery simply because oil vapour replaces steam in the engine cylinder. The appliances suitable for manufacturing the one are equally suitable for the other, though it is true greater care in workmanship is essential in cylinder and valve construction when compression pressures of 600lbs. to 800lbs. on the inch are dealt with than is necessary with the pressures ordinarily used in steam engines. The constructional difficulties, however, are of the kind surmounted by the workmanship which soon springs out of experience and necessity. The firms who already make a speciality of Diesel engines are sufficient to cope with such orders as are now available, and in view of this it would seem a foolish policy, from a shareholder's point of view, to call more firms into being in this country. We do not want to see a repetition of the ruinous "cut-throat" policy that marked the entrance of one or two monster electrical enterprises engineered by Americans into the British industrial field some dozen years ago, and which in the long run proved disastrous to everybody except the original promoters. True progress with Diesel engines, as with other motors, will best come by "making haste slowly," and by recognising that in any new departure there is always much to learn. We are forcibly reminded of this by a reference to a destructive breakdown of a Diesel engine in the current issue of our contemporary "Vulcan," and which is worth noting at the present time, when the adoption of this type of engine is being considered by many central station engineers, and other power users. The engine in question was one of four identical engines, each driving alternators running in parallel, and of the 4-cylinder type having cylinders 12in. diam. by 1ft. $0\frac{1}{4}$in. stroke, running at 250 revs. per minute, and rated at 200 b.h.p. The primary cause of the breakdown was seizure of one of the pistons, following which the momentum of the flywheel, alternator, &c., proved sufficient to break the crosshead bolts after elongating them and reducing their diameter from 1in. to $\frac{5}{8}$in. The connecting rod which was then freed caused breakage of the piston and liner, and was itself badly bent, while one of the nuts of the crosshead bolts fouled the crank shaft and punched a hole in the bedplate. The crank shaft being then only held at the one end and rotated at the other by the flywheel and the alternator, was twisted through an angle of about 15° in its entire length. It will be evident from these details that the repairs would be extensive and costly. Our contemporary, in discussing the breakdown, says there was no evidence of failure of the piston lubrication, the seizure of the piston being apparently due to overheating consequent on the too onerous nature of the work. "Very little excess of temperature," it remarks, "would be required for this, as the diameter of the piston was only $\frac{8}{1000}$in. less than the bore of the liner." The engines, it is added, "were comparatively new by makers of repute, and the workmanship itself of the highest grade." The general conclusion drawn is that "Diesel engines—which, in order to keep up efficiency and obtain smooth running, must be built with very fine clearances and adjustments—should have a large capacity for overload, and receive the most careful supervision to ensure that the fuel and lubricating oils are of the right quality, the circulating water of the right temperature, and that the oil fuel jet and lubrication are properly regulated." The attendant, in fact, requires to be an expert mechanic and more than usually careful. Having regard to the source from whence this advice emanates, and the breakdown by which it is emphasized, and which we know does not stand alone, the lesson, it is to be hoped, will be taken to heart by both makers and users of this type of prime mover.

New Diesel Engine Works.—The Consolidated Diesel Engine Manufacturers, Ltd., are to erect works at Ipswich for building Diesel engines of both the stationary and the marine types. Some 40 acres of land have been acquired, conveniently situated for dock and railway communication

AN AUTOMATIC SELF-CONTAINED OPTICAL LOAD-EXTENSION INDICATOR.*

By Prof. W. E. Dalby, MA., B.Sc.

The object of the paper is to show a few load-extension diagrams of steel, copper, and iron obtained photographically by means of an instrument recently designed by the author in which the effects of inertia and pencil friction are eliminated. The instrument itself is shown in Fig. 1 supported on a tripod frame, but when it is used to obtain a diagram it is taken out of this frame and placed in the testing machine, the nut A of the frame being replaced by the upper shackle of the testing machine.

Fig. 1.

The instrument, in fact, hangs from the upper shackle with the lower end free. The upper end of the specimen to be tested is screwed into the coupling B, and the lower end is screwed into the lower shackle of the testing machine. The specimen and the "weigh-bar" C of the instrument are thus placed in series, and when the load is applied it is transmitted equally through the specimen and the "weigh-bar" C. The cross-sectional areas of the specimen and the weigh-bar are so related that the breaking load for the specimen produces a stress on the weigh-bar C well within the elastic limit. The extension of the weigh-bar is proportional to the load acting on it, and is therefore a measure of the load, not only on the weigh-bar, but on the specimen coupled to it. A mirror in the instrument is connected to the weigh-bar so that its angular displacement is proportional to the extension of the bar, hence its angular motion is a measure of the load applied to the specimen.

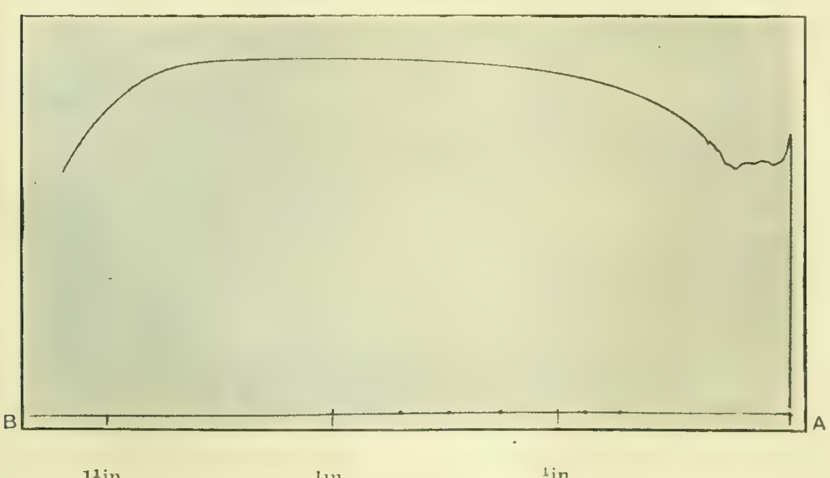
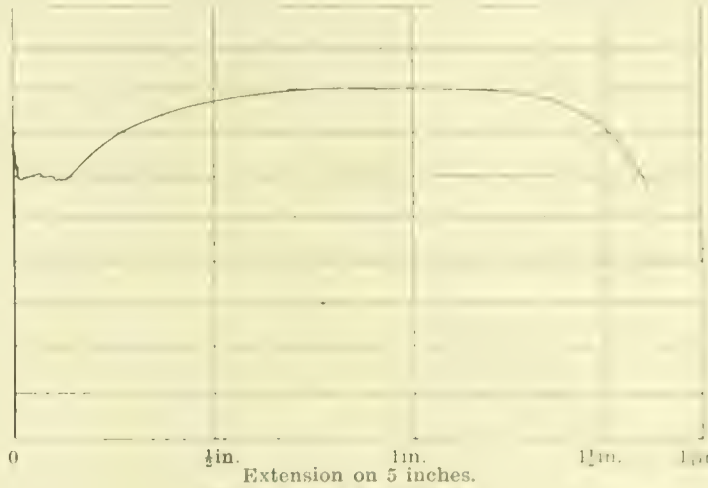


Fig. 2.

There is a second mirror in the instrument mounted on the axis D connected by linkage or by a steel wire attached by the arm E to the specimen in such a way that the extension of the specimen produces a corresponding angular displacement of the mirror. The two mirrors are placed in the instrument with their axes at right angles. A source of light is arranged in the head F, a beam from which is reflected from each mirror in succession to the focusing plane of the camera G. The whole instrument is self-contained, and is in contact with the testing machine only at the upper shackle.

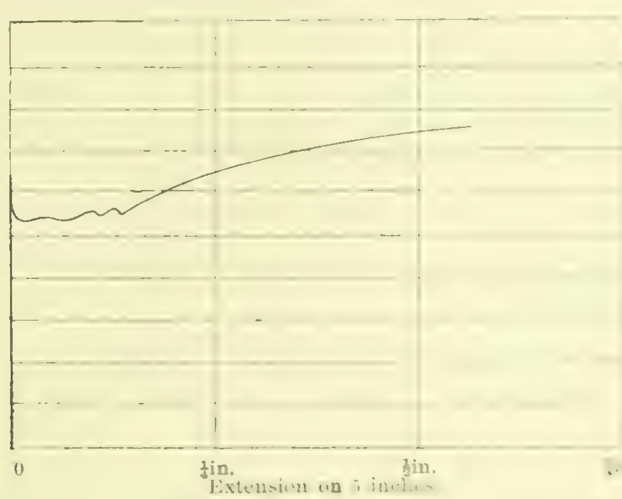


Extension on 5 inches.

Fig. 3.—Mild Steel 0·12 C.

The weigh-bar is calibrated by means of the steelyard of the testing machine in which the instrument is placed. For calibrating purposes the lower end of the weigh-bar is attached directly to the bottom shackle of the machine. The photographic scale of the weigh-bar is obtained by balancing the beam of the testing machine at a series of loads, and at each load giving a slight angular motion to the mirror attached to the axis D by slightly moving the arm E.

Figs. 3 to 7 and 9, 10 show (half full size) the load scale of the instrument illustrated in Fig. 1. It corresponds very nearly to 1 centimetre per ton, over a range of 10 tons. With this particular weigh-bar, the maximum load which can be applied to a specimen coupled to it is 10 tons. If, however, a larger maximum load is required, it is only necessary to replace the weigh-bar of Fig. 1 by another of larger cross-sectional area. For instance, if the bar were made 10 times the sectional area, the maximum load would be 100 tons, but the load scale would then be 1 mm. to the ton. A series of weigh-bars enables the instrument to be used over a wide range, just as a series of indicator springs extends the range of action of a steam engine indicator from the lowest to the highest pressures.



Extension on 5 inches

Fig. 4.—Mild Steel

There are several ways of connecting the specimen with the mirror on the axis D in order to ensure that its angular motion is proportional to the extension of the specimen. In any case, the extension scale is found by placing gauges of known size in the linkage in such a way that an angular movement of the mirror is produced corresponding to a known rotative linear displacement of the gauge points of the

* Paper read at the spring meetings of the fifty-third session of the Institution of Naval Architects, March 29th, 1912.

specimen. A slight load applied to the specimen then produces a small movement of the spot of light on the photographic plate, which serves afterwards as a point of known dimension in the extension scale.

Fig. 2 is a reproduction (half full size) of a negative obtained from a piece of mild steel, and shows the lines which appear when the negative is developed. The horizontal line

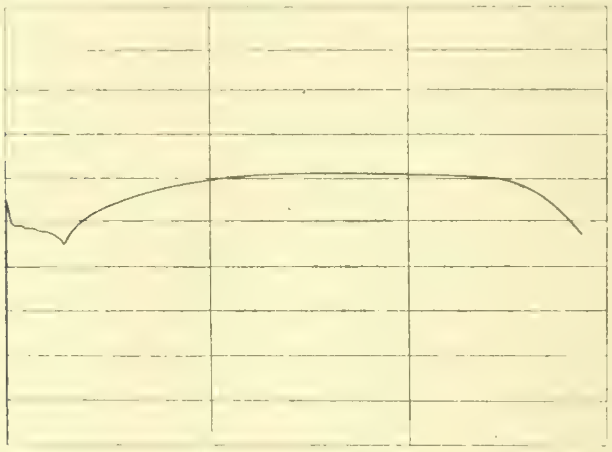


FIG. 5.—MILD STEEL 0·23 C.

A B corresponds to a load of 1 ton. It is obtained by balancing the beam of the testing machine at 1 ton and then slightly moving the arm E (Fig. 1). Three divisions are shown on the extension scale. These were obtained in the manner indicated above by means of three gauges inserted in the linkage. Each division represents ½in. extension of the specimen. The diagram itself is obtained quite automatically. Having obtained the 1-ton line and the scale divisions on the extension scale the jockey weight is run out on the beam to about 12 tons, so that the beam falls on the bottom stop, and the load is applied through the straining apparatus of the machine. The spot of light then moves over the plate and photographically records the load-extension diagram of the specimen.

The load corresponding to any point of the curve in Fig. 2 is found by placing over the negative a second negative, on which the load scale of the weigh-bar has been photographically produced in the way explained above, so that the 1-ton line of the load scale of the second or calibrating negative coincides with the 1-ton line on the negative on which the load extension diagram is taken. The scale of the calibrating negative may be divided as closely as desired, and if a large number of specimens are broken to the same exten-

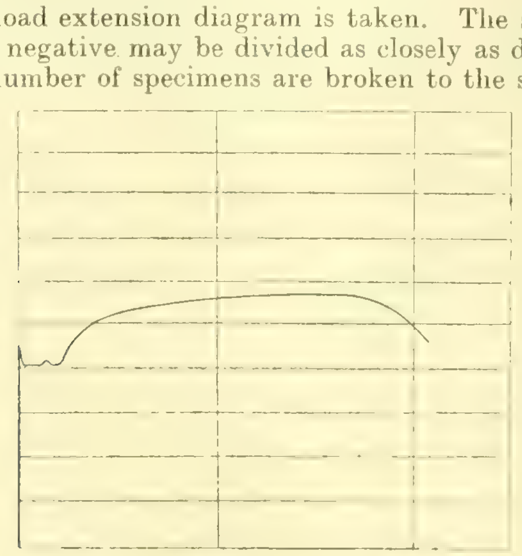


FIG. 6.—MILD STEEL 0·4 C

sion scale, it is convenient to draw on the calibrating negative a series of lines at right angles to the load lines to form an extension scale, the two sets of lines forming a network of small squares on the calibrating negative.

Figs. 3 to 7 and 9, 10 have been drawn in the following way. Prints were taken from the negatives, and the curves and lines were pricked through on to a sheet of drawing paper and the lines and figures completed from the points so obtained.

The point of interest is the way the apparatus brings out the peculiar relation between the load and the extension in the neighbourhood of the yield point. This peculiarity has been observed by Prof. Kennedy, who used a weigh-bar with mechanical multiplication to obtain both the load and the extension of the specimen, and also by Mr. Wicksteed, who uses the beam of the testing machine in connection with a spring and mechanical multiplication to obtain the curves. The results obtained optically and photographically with the consequent elimination of pencil friction and inertia, as will be seen from Fig. 2, and Figs. 3 to 9, bring out the peculiar

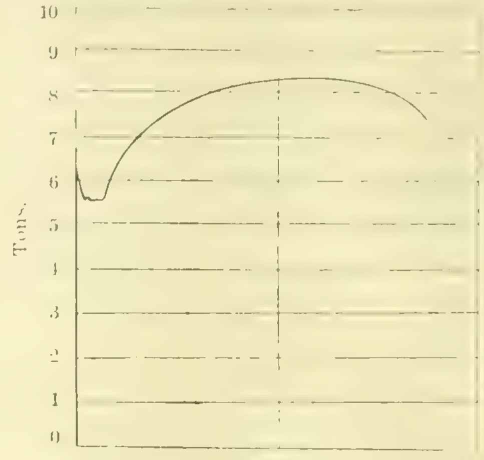


FIG. 7.—MILD STEEL 0·5 C.

phenomenon connected with the yield point with great clearness and accuracy. In the author's instrument the extension scale can be magnified to any desired extent. In Fig. 3 the extension of the specimen is magnified 3½ times.* In Fig. 4 a diagram is shown in which the extension is magnified 7 times, but, of course, in this case the whole of the load-extension curve cannot be shown on the plate. By magnifying the extension, the peculiarities in the region of the yield point may be specially studied. The magnification can easily be increased even to 200 times, and in this case the extensions of the specimen are brought within the elastic region, and the form of the line just before the yield point can be investigated.

Figs. 5, 6, and 7 are load-extension diagrams from steels containing increasing proportions of carbon, and form, together with the diagram of Fig. 3, a series of four. The

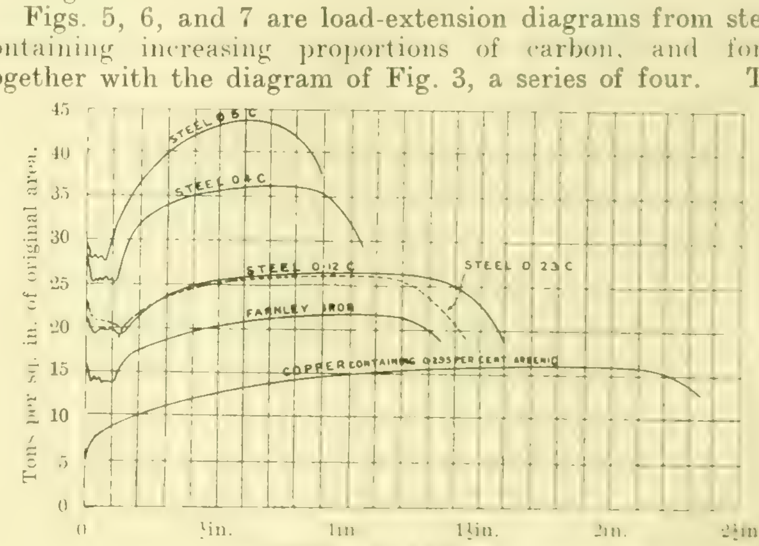


FIG. 8.

analyses of the specimens corresponding to these diagrams are given in the following table:—

TABLE I.

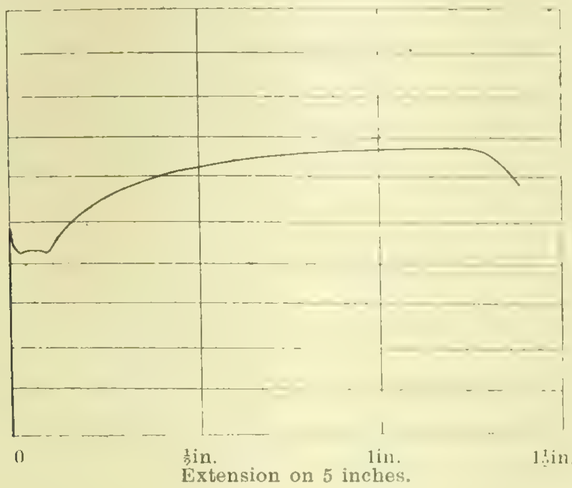
Load-extension Diagram shown in	Fig. 3.	Fig 5.	Fig. 6.	Fig. 7.
Carbon...	0·12	0·23	0·4	0·5
Silicon	0·03	0·07	0·016	0·036
Sulphur	0·031	0·046	0·075	0·032
Phosphorus	0·027	0·045	0·03	0·029
Manganese ...	0·56	1·01	0·64	0·52
Original diameter	0·625in.	0·55in.	0·447in.	0·5in.
Distance between gauge points	5in	5in	5in.	5in

These diagrams are reduced to a common stress extension scale in Fig. 8, the load now being given in tons per square inch reckoned on the original area of the bar.

It will be seen from this figure that the curves corresponding to the diagrams Figs. 3, 6, and 7 form a series in

* The figures here reproduced are half their original size.

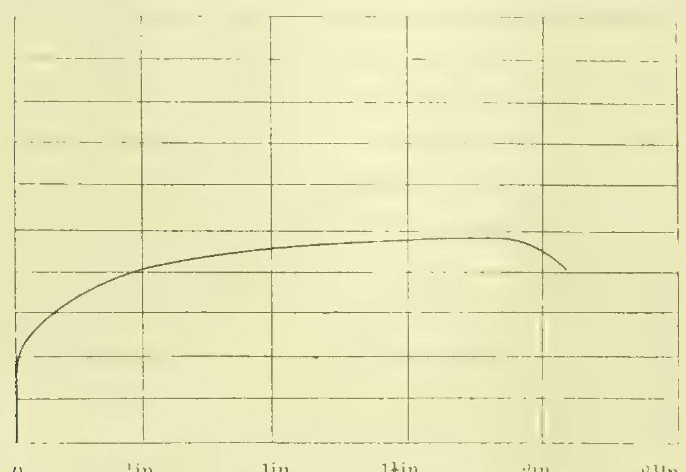
which the effect of the increasing percentage of carbon on the stress-extension diagram is well brought out. The curve corresponding to Fig. 5 is dotted in Fig. 8, and it does not appear to fall in the series at all. The peculiarity is due to the much larger proportion of manganese contained in this particular sample. In the case of Figs. 3, 5, and 6, the proportions of the constituents of the steel other than carbon remain fairly constant. Another point of interest in connection with these diagrams is that the load on the specimen at the instant of fracture can be read off without any ambiguity.



Extension on 5 inches.
FIG. 9.—FARNLEY IRON.

The load-extension diagram of a piece of Farnley iron is shown in Fig. 9. It presents the same general characteristics as the steel specimens in the region of the yield point. The original diameter of the specimen was 0·625, and the gauge point length was 5in. The diameter at the fracture was 0·42in.

The load-extension diagram of a piece of copper containing 0·295 per cent. of arsenic is shown in Fig. 10. Its original diameter was 0·625, and the gauge point length was 4·5in. There is with this material nothing approaching the complicated stress-strain relation at the yield point exhibited by the mild steels and the iron samples. The material simply gives way and draws out without discontinuities in the load-extension curve of any kind. This example shows that the irregularities in the yield point regions of the steel and iron diagrams are not due to any peculiarities of the instrument, otherwise the same irregularities would appear in the load-extension curve for the copper specimen.



Extension on 1½ inches.
FIG. 10.—COPPER.

In conclusion, I should like to record my thanks to Mr. Witchell, University Demonstrator in the City Guilds College, for his able assistance in connection with the work.

New Clyde-built Destroyer.—The destroyer "Attack," built for the British Admiralty by Messrs. Yarrow, of Glasgow, ran very successful official full-speed trials on Saturday, the 30th ult., on Skelmorlie deep-water measured mile, attaining a mean speed, during a continuous run of eight hours, of 30·6 knots, thus exceeding the contract speed of 28 knots by 2·6 knots. The vessel is 240ft. long by 25ft. 7in. beam, and is propelled by Brown-Curtis turbines driving twin screws. Steam is supplied by three Yarrow water-tube boilers, fitted with the firm's superheating and feed-heating appliances.

CURTIS MARINE STEAM TURBINES.

HERETOFORE in the construction of marine steam turbines having initial jet velocity stages, and built in two elements complete on one shaft, it has been the practice to employ in the high pressure element a number of velocity stages only, which, having the same steam pressure on opposite sides of the wheels, avoid the production in this element of excessive longitudinal thrusts which would have to be carried by the

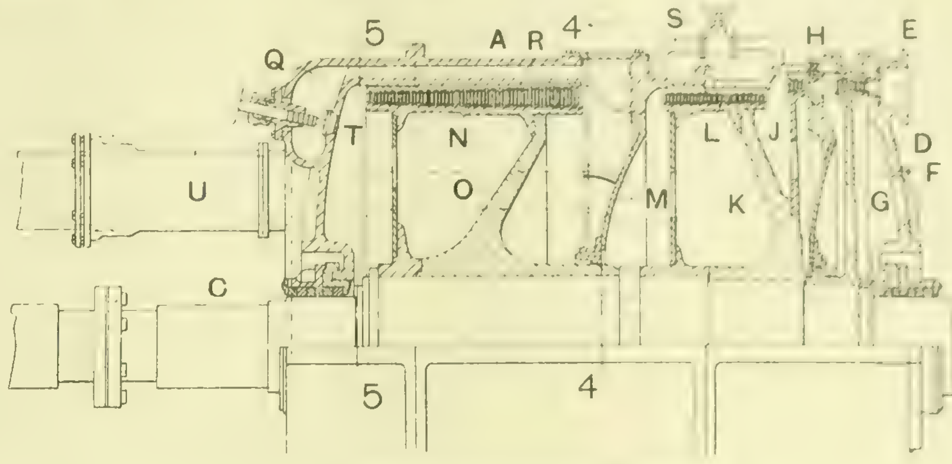


FIG. 1.—CURTIS MARINE TURBINE.
Longitudinal section of high pressure element on line 1—1 of Figs. 4 and 5.

thrust block and which reduce the steam pressure to the low pressure required to neutralise the propeller thrust; and to employ in the low-pressure element a drum-pressure stage, having a steam tight-pressure head closing the steam space between the drum and the shaft, and producing a thrust opposed to the propeller thrust. The construction indicated is open to the objection of using a considerable number of velocity stages with accompanying diaphragms and steam spaces which increase the cost and length of the turbine, and, on account of the inaccessibility of the diaphragm bushings, increase the difficulty and expense of repairs.

In the designs illustrated, the invention of Mr. C. G. Curtis, 2, Rector Street, New York, U.S.A., these objections are, it is claimed, overcome by replacing the velocity stages in the high-pressure element largely or partly by drum-pressure stages with steam tight pressure heads, which drum stages are reversed and are so proportioned relative to the steam pressures that the thrust produced by one drum stage is practically neutralised by the other drum stage, and the shaft thrust when present is also practically neutralised, at all substantial powers, so that the thrust carried by the thrust block for this element, if any, is small in amount. The propeller thrust is wholly or largely neutralised at all substantial powers in the low-pressure element by a single direct drum-pressure stage.

A further feature of the designs relate to means for adjusting the relative thrusts of the reversed drums in the high-pressure element so as to secure a more complete balance in this element under different conditions of steam flow and

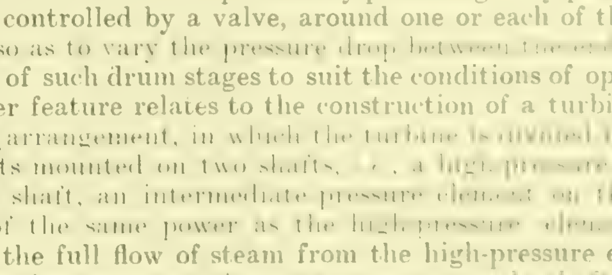


FIG. 2.—CURTIS MARINE TURBINE.
Longitudinal section of high-pressure element on line 2—2 of Figs. 4 and 5.

pressure. This is accomplished by providing a by-pass for the steam, controlled by a valve, around one or each of the drum stages so as to vary the pressure drop between the ends of one or each of such drum stages to suit the conditions of operation. Another feature relates to the construction of a turbine for a 4-shaft arrangement, in which the turbine is divided into four elements mounted on two shafts, i.e., a high pressure element on one shaft, an intermediate pressure element on the other shaft of the same power as the high-pressure element and taking the full flow of steam from the high-pressure element, and two low pressure elements (one on each shaft) which

receive the steam flow from the intermediate-pressure element in multiple. The high and intermediate pressure elements are balanced within themselves by the use of reversed drum-pressure stages, while the two low-pressure elements receive a low enough steam pressure to wholly or largely neutralise the thrust of the propellers at all substantial powers by the employment in each of a single direct drum-pressure stage.

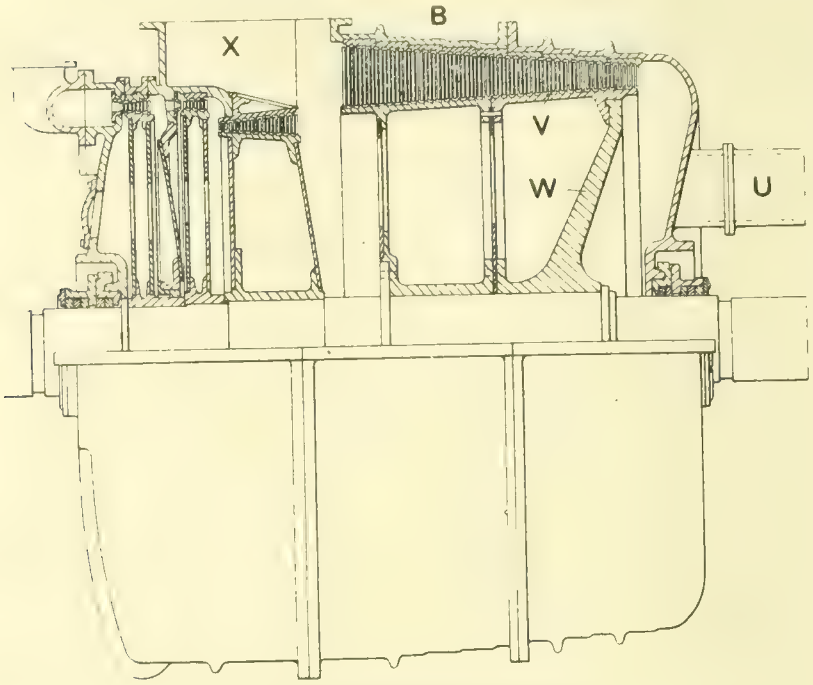


Fig. 3.—Curtis Marine Turbine.
Sectional elevation of low-pressure element.

Figs. 1 to 6 show the turbine composed of a high and low pressure element complete on one shaft. A and B are respectively the high and low pressure elements. Referring first to the high-pressure element, its shaft section C which carries the rotating parts is stepped down to smaller diameters where it passes through the stuffing-boxes, producing shaft thrust areas subject to the steam pressures at the ends of the shell. The high-pressure element is provided with two initial jet velocity stages. The nozzles E of the first stage are carried by the head D. The wheel F of the first stage carries a plurality of rows of moving buckets co-acting with stationary intermediate buckets carried by the shell. Following the wheel F is a diaphragm G supported by the shell and having a bushing or packing surrounding the shaft. The space in front of the diaphragm G is large enough to permit the removal and repair of the bushing or packing in segments, and access is given to this space by manholes and by openings in the web of the wheel F. The diaphragm G carries the second-stage nozzles H, and these deliver the steam to the buckets of the second jet velocity stage which are carried by the wheel J and by the shell. The wheel J is mounted upon the pressure head K of the first drum-pressure stage, which pressure head is formed and proportioned so as to withstand without change of shape the difference in pressure to which it is subjected. The drum L of the first drum stage is supported in part by the head K which closes steam tight the space between the drum and the shaft. The first drum stage carries the steam in the same direction as the initial velocity stages and receives it directly from the second velocity stage. The drum of the first drum stage carries a number of annular rows of buckets separated by annular rows of stationary buckets carried by the casing. These buckets operate on the impulse or on the reaction principle. In either case there is a difference in steam pressure between the admission and discharge ends of the drum stage which is effective on the head K to produce an aft thrust on the shaft. The admission of steam to the buckets of the first drum stage is a complete peripheral one, while at the velocity stages the nozzles occupy only a part of the peripheries of the wheels. In passing through the velocity stages the steam is reduced in pressure and increased in volume so that a complete peripheral admission can be had at the first drum stage with buckets of a sufficient radial depth to keep the tip clearance leakage within permissible limits. The radial depth of the buckets of the velocity stages can be made as great as desired because of the fact that a partial peripheral admission (*i.e.*, "jet" admission) is employed in these stages. The use of the initial jet velocity stages also results in a reduction in pressure within the casing head to that which can be practically controlled by the shaft stuffing-box.

Following the first drum stage, the steam space between the shell and the shaft is closed by a diaphragm M having a bushing surrounding the shaft. A working space is provided in which this bushing or packing may be repaired or replaced in segments, which space is accessible through a covered manhole in the casing. The diaphragm M is made necessary because the steam flow is reversed through the second drum stage. The second drum stage has a drum N carrying a number of annular rows of buckets co-acting with annular rows of intermediate buckets carried by the casing, and operating on the impulse or reaction principle. In either case, as with the first drum stage, there is a difference in steam pressure between the admission and discharge ends of the stage which is effective on a steam tight pressure head O closing the space between the drum and the shaft and formed and proportioned to withstand the pressure difference to which it is subjected without change of shape. The steam is admitted to the aft end of the second velocity stage by channels P in the casing (Figs. 2, 4, and 5) connecting the space in front of the diaphragm M with the space aft of the pressure head O, while the steam discharged from this stage into the space forward of the head O is carried back to the chamber Q in the aft head of the high-pressure element by channels R (Figs. 1, 4, and 5). The difference in pressure on the shaft thrust areas and the difference in pressure on the first drum stage produce an aft thrust on the shaft, while the difference in pressure on the second drum stage produces a forward thrust on the shaft. By properly proportioning the steam passage areas through the drums, so as to secure the proper pressure drop between the two ends of each drum, and by having each drum of the proper relative area, these thrusts in opposite directions will be practically neutralised or balanced or reduced to a practicable amount at all powers, so that the unbalanced thrust, if any, will be small. In order to secure a more complete balance of the thrusts under different conditions of operation, a controllable by-pass may be provided around one or each of the drum stages so as to enable the adjustment of the differences in pressure carried by the pressure heads K and O. A pipe S having a valve performs this office for the first drum stage,

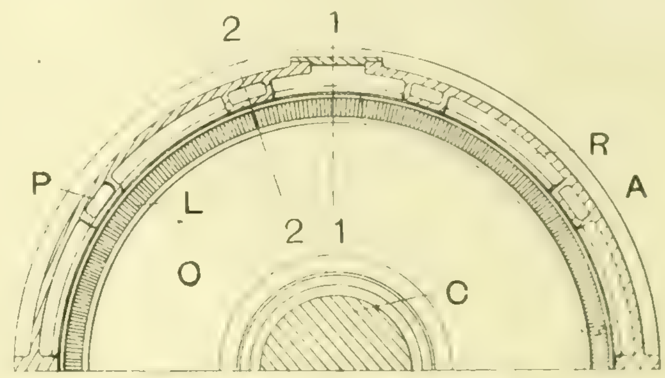


Fig. 4.—Curtis Marine Turbine.
Cross-section on line 4–4 of Fig. 1.

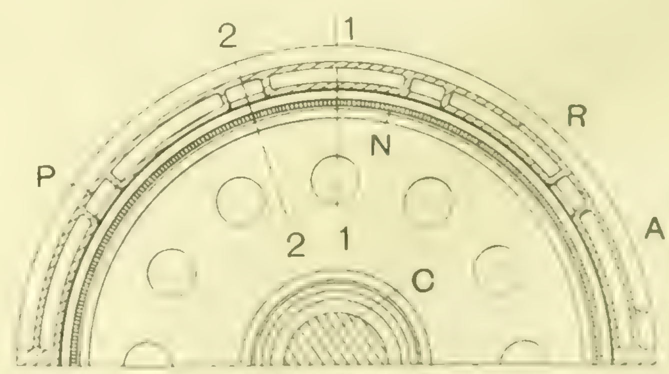


Fig. 5.—Curtis Marine Turbine.
Cross-section on line 5–5 of Fig. 1.

while an opening T (controlled by a valve) between the chamber Q and the admission side of the second drum stage serves to shunt steam around the second drum stage.

The shaft section of the high pressure element A is connected with the shaft section of the low pressure element B by a slip coupling. The casing of the low pressure element has fore and aft heads provided with stuffing boxes surrounding

reduced diameters of the shaft. One or more pipes U convey the steam from the chamber Q of the high-pressure element to the low-pressure element, and have a slip or expansion joint permitting the relative movement of the two elements. Within the casing of the low-pressure element is a drum-pressure stage having a number of annular rows of moving and stationary buckets operating on the impulse or reaction principle. The drum V of this drum stage is supported from the shaft in part by a steam tight pressure head W, formed and proportioned to withstand the difference in pressure to which it is subjected without change of shape. This pressure head is subjected on its forward side to the steam pressure existing at the admission end of the drum stage, while its rear side is open to the exhaust X, and hence receives the exhaust pressure. By properly proportioning the steam passage area through this drum stage and by giving it a proper thrust area, the thrust aft produced by it will balance practically, or reduce to a practicable amount, at all powers, the forward thrust of the propeller. Any unbalanced thrust, one way or the other, will be small. In Fig. 6, the high and low pressure elements are shown assembled. The reversing turbine is shown as enclosed in the rear end of the casing of the low-pressure element. It has a drum-pressure stage opposing the propeller thrust.

The turbine shown in Figs. 1 to 6 is useful in any arrangement of one or more propeller shafts, in which it is desired to employ a complete independent turbine on each shaft. A special construction of the turbine adapted for a 4-shaft arrangement is illustrated in Fig. 7. In this arrangement the turbine is divided into four elements, C, D, E, and F. The elements C and D are respectively high and intermediate pressure elements, the latter taking the entire flow of steam from the former, while the elements E and F are low-pressure elements which receive the steam from the intermediate-pressure element in multiple, each taking one-half the flow of steam. The elements C and D are of practically equal power, as likewise are the elements E and F, so that the power developed on each shaft will be the same. The two shaft sections G H of the high-pressure element are connected by a slip coupling. The high-pressure element, as shown, has one jet velocity stage J, and two drum-pressure stages K and L separated by a diaphragm, and connected so as to have a reversed steam flow by channels M. These drum stages have steam tight pressure heads N O, which exert thrusts upon the shaft section G in opposite directions so as to practically neutralise the thrust within the high-pressure element of the turbine at all substantial powers. The low-pressure element

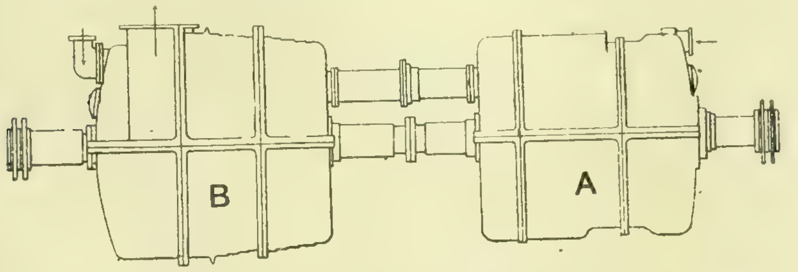


FIG. 6.—CURTIS MARINE TURBINE.
Elevation showing two elements of one shaft turbine connected together.

E, which is mounted on the shaft section H, has a single direct drum-pressure stage proportioned with respect to the area of its steam passage and to its thrust area so as to practically neutralise the propeller thrust at all substantial powers. The shaft sections G and H are provided with independent thrust blocks. The intermediate-pressure element D receives the full flow of steam from the high-pressure element through pipes P. This element is provided with two drum-pressure stages having steam tight pressure heads S and T, separated by a diaphragm. The drum-pressure stages Q R receive the steam flow in opposite directions, the discharge end of stage Q being connected with the head end of stage R by steam channels U. The reversed drum-pressure stages Q, R are proportioned so as to produce thrusts in opposite directions and to practically neutralise at all substantial powers the thrusts upon the shaft within this element of the turbine. The rotating parts of this element D are mounted upon the shaft section V, which is connected with the shaft section W by a slip coupling. The low-pressure element F, which is mounted on the shaft section W, is similar to the low-pressure element E, having a single direct drum-pressure stage with a steam tight pressure head adapted to practically neutralise the propeller thrust at all substantial loads. The shaft sections V W are provided with independent thrust blocks. The exhaust from the intermediate-pressure element is divided between two pipes X Y, which divide the steam flow between

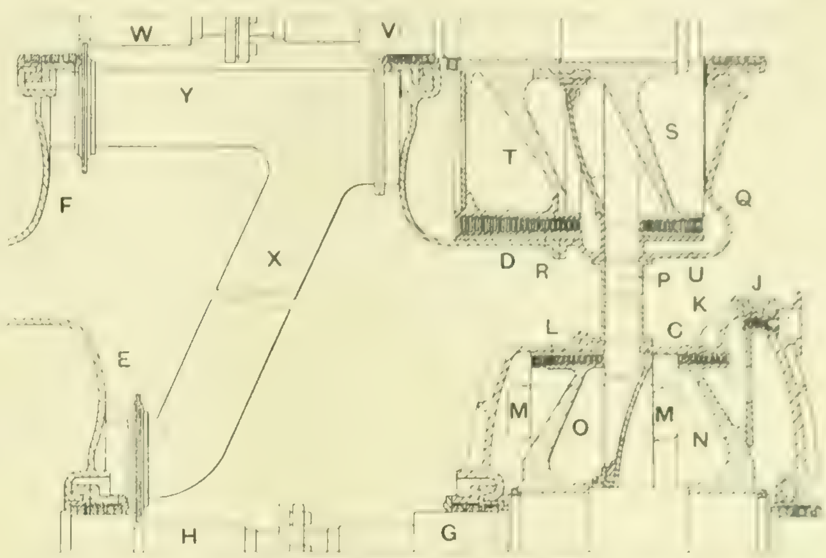


FIG. 7.—CURTIS MARINE TURBINE.
Four-shaft arrangement.

the two low-pressure elements E and F, giving the large bucket areas required to pass the steam at the low pressure and large volume existing near the exhaust end of the turbine It will be understood that the shafts shown in Fig. 7 are two shafts of a 4-shaft arrangement, and that the other two shafts will be provided with a similarly-divided turbine.

THE DANGER OF OPEN BLOW-OUT TAPS.

THE danger of entering a steam boiler with a blow out tap open, if it be one of a range, has been exemplified by many fatalities, for groups of boilers are almost invariably connected to a common waste pipe, and in the event of one of the blow-out taps of the other boilers being opened under pressure the water and steam in the waste pipe is liable to back up into the empty boiler and scald anyone who happens to be there. This danger applies also to keirs used at bleach and dye works, where it is customary for two or more of these vessels to be coupled to a common supply pipe by which caustic or other hot liquor is introduced. A sad fatality arising in this way occurred on Monday, the 1st inst., at the Whitehall Bleachworks, Chinley. Two men were laying cloth in one of a pair of keirs, and owing to some oversight the tap of the waste pipe at the bottom was left open after emptying the previous charge. While so engaged an attendant proceeded to blow off the companion keir, with the result that the scalding caustic liquor was showered on the two men, one of whom was so horribly injured that he died the following day.

A 2,000-frequency Alternator.—In the course of a paper read before the Physical Society of London. Mr. W Duddell described and exhibited a small 2,000-frequency alternator which he had designed and had constructed for testing purposes, mainly in connection with telephone measurements. The alternator was of the salient pole revolving field type, running at 8,000 revs. per minute. The stator was smooth and wound like a gramme ring, the object being to obtain as near as possible a sine wave. The author gave curves showing the open-circuit characteristic, the short-circuit current, and the regulation of the alternator at four different frequencies. The output of the alternator amounted to as much as ½ kw. at the higher frequencies. Oscillograph curves of the alternator on open-circuit and when loaded with non-inductive resistance, inductances, and condensers were shown. These appeared to be practically sine waves. This was not, however, strictly the case, as there was a slight third harmonic present. To demonstrate this a further set of oscillograph curves of the P.D. of the alternator were exhibited. In taking these curves the non-inductive resistance in series with the oscillograph strips was replaced by a small condenser so as to accentuate the upper harmonics.

OIL FUEL IN THE NAVY.

ONE important consequence of the strike which will not be without a certain effect on coal output and price is the unexpected impetus which the stoppage has given to the use of oil fuel for Admiralty purposes. There is little prospect, even if the cost is considerably enhanced, of coal being supplanted by oil in the great proportion of the industrial purposes for which it is used on land owing to the expense of liquid fuel; but in the Navy, where efficiency is the main factor, and expense takes a back seat, the superior heating power of oil has for a long time encouraged experiments in its use, and its adoption has already, in many types of vessel, made great headway. In some ships this fuel is used almost exclusively, while in others arrangements, which will probably now be extended, are made by which it can be used to supplement coal for boiler-firing purposes; while the development of the oil engine foreshadows a time when steam may become obsolete and be replaced by oil fed directly into the engine cylinder in all cases. The Navy Estimates for the coming year contain a large provision for storage accommodation for oil fuel, and include extra provision for the tanks in the Medway, the Humber, at Invergordon, Cromarty Firth, and at Portsmouth, Dundee, Dover, Portland, Pembroke, and Haulbowline, no less than £429,750 additional expenditure is being incurred on this particular service.

Nearly all the pre-Dreadnought battle-ships carry some 400 tons of oil as an emergency fuel, while in later ships this amount is greater, and in a large number of small craft oil is used exclusively. The first vessels so equipped were the 36 torpedo boats, which were originally called "coastal destroyers." These vessels of 225-300 tons are fitted with engines of 4,000 h.p. The designed speed is 26 knots, but their steaming radius, although they carry only from 20 to 25 tons of fuel, is 1,000 knots. The success of these vessels led to further advances, and oil-fired boilers were applied exclusively to the 12 destroyers of the "Tribe" class, the designed speed of which was 38 knots. These boats proved very successful on the score of speed, though it was officially admitted that the heat in the furnaces made the repairs a constant and costly business. In the next batch of destroyers (1908-9) the Admiralty dropped oil altogether, and relied solely upon coal. This policy was reflected in the speed records, for though the vessels were designed for only 27 knots, they hardly ever exceeded 25 knots in service, whereas in the "Tribe" class the designed speed has in one case been exceeded by over seven knots.

Since 1908 all the destroyers laid down for the British Navy have been entirely oil-driven. In last year's vessels the designed speed was 32 knots, and in the new programme it is understood even this speed will be exceeded. The storage capacity in the first coastal torpedo boats was only 25 tons; this was increased to 90 in the "Tribe" class, 174 in the vessels of the 1910 programme, and is now to be further increased to 200 tons or more.

The use of oil fuel, however, is by no means free from difficulties. Certain problems of storage, both on ship and on shore are serious, but its compactness and ease of handling is a great advantage. A ton of oil occupies about 38 cub. ft., and a similar weight of coal about 44 cub. ft.; but the steam value of oil is, weight for weight, some 33 per cent. superior to that of the best Welsh coal, so that 38 cub. ft. of the liquid fuel is equal to about 60 cub. ft. of coal. The reduction in the stokehold personnel is, of course, great. Taking wages and victuals into account, it is estimated by competent authorities that on a naval vessel the cost of burning a ton of oil is only about 4d., as compared with about 2s. 6d. for an equal weight of coal. Further, oil can be taken on board more quickly than coal, and whereas a torpedo boat or destroyer burning coal can only run at full speed for three or four hours, owing to the necessity of cleaning the furnaces, an oil burning furnace can run continuously.

The Geared Turbine Steamer "Hantonia."—The steamer "Hantonia," the second of the two vessels built by the Fairfield Company for the London and South-western Railway Company, attained a speed of 20½ knots in a recent run on the measured mile, which is considerably more than the Fairfield Company guaranteed. It is expected that the vessel will be running on the Southampton-Havre service during the Easter holidays. The first vessel, the "Normannia," was completed and handed over some time ago.

THE WORKING OF THE BOILER EXPLOSIONS ACTS.

THE Assistant Secretary to the Board of Trade, in his report on the above Acts, just published, remarks as follows:—

Under the provisions of the Boiler Explosions Acts, 88 preliminary enquiries and 12 formal investigations have been held respecting boiler explosions which occurred during the year ending June 30th, 1911. Of these 100 explosions, 47 resulted in loss of life or personal injury—13 persons being killed and 61 injured. The 13 deaths were caused by 11 explosions, of which nine occurred on land and two on ships. Although the number of explosions included in the report is considerably above the average, it is satisfactory to note that the number of persons killed is only half the average (26·2) since the Act came into force in 1882. The number of injured (61) is slightly above the average (58·1). It may be noted that in one explosion (Report No. 2,047) there were 11 persons injured, this number being a considerable proportion of the total for the year. A summary of the reports of enquiries and also the causes of the explosions and the types of boilers which exploded are given in the appendix, which also shows the cases in which the boilers were under the inspection of public bodies, and the cases in which no inspection had been made by any competent person for several years before the explosion.

A report by the Board's solicitor on the formal investigations is given in Appendix C. In seven out of the 12 cases in which these investigations were held, the courts found that persons who had been connected with the boilers were to blame for the explosions, and they made orders for the payment of costs in six of these cases, the total sum ordered to be paid amounting to £365. Dealing with these reports in detail, the Board's solicitor states that in two cases owners were found to blame; in one case the owners were found responsible for the explosion; in one case an engineer-in-chief and a superintending engineer were found responsible for the explosion; in one case a foreman mechanic was found to blame; in one case the user and an engine owner who advised him were found responsible for the explosion; in two cases the users of boilers let on hire-purchase agreements were found to blame; in one case the owner, who was killed, was found responsible; in five cases no one was found to blame.

BOOKS RECEIVED.

The Seven Follies of Science. A popular account of the most famous of scientific impossibilities. By John Phin. Third edition. 8½in. by 5½in., 231 pages. London: Constable and Co., Ltd. Price 5s.

Meteorological Instruments and Weather Forecasts. London: Percival, Marshall, & Co. Price 6d. net.

Centrifugal Pumps: Their Design and Construction. By Louis C. Loewenstein, Ph.D. and Clarence P. Crossley, M.E. New York: D. Van Nostrand & Co. London: Constable & Co., Ltd. 9½in. by 6½in., 435 pages. Price 18s. net.

Ship Wiring and Fitting. By T. M. Johnson. London: Constable & Co. 1s. net.

Sketches of Engines and Machine Tools. By Wallace Bentley, M.I.Mech.E. Halifax: The Bentley Publishing Company. Price 2s. 6d.

Emery and the Emery Industry. By A. Haenig, translated from the German by G. Salter. London: Scott, Greenwood, and Sons. 7½in. by 5in. 103 pp. Price 5s. net.

Irrigation: Its Principles and Practice as a Branch of Engineering. By Sir Hanbury Brown, M.Inst.C.E. 9in. by 6in. 300 pp. London: Constable & Co. Price 16s. net.

The Energy Diagram for Gas. By F. W. Burstall, M.I.Mech.E., Chance Professor of Engineering in the University of Birmingham. 10in. by 7in. 20 pp., with large diagram mounted on cloth. London: Constable & Co. Price 5s. net.

Elementary Internal-combustion Engine. By J. W. Kershaw, M.Sc., Lecturer in Engineering, University of Sheffield. London: Longmans, Green, & Co. 7½in. by 5¼in. 174 pp. Price 2s. 6d. net.

Inductance of Coils. By Messrs. Morgan Brooks and H. M. Turner. Bulletin No. 11, University of Illinois Engineering Experiment Station. Published by the University. Price 10 cents.

STEAM REGENERATIVE ACCUMULATORS.*

BY D. B. MORISON.

(*Concluded from page 426.*)

Accumulator Proportions.—The factors which determine the size of a heat accumulator, for any given proposition, depend on the quantity of contained water, its range of temperature, the time available for regeneration, the area of water surface and its efficiency.

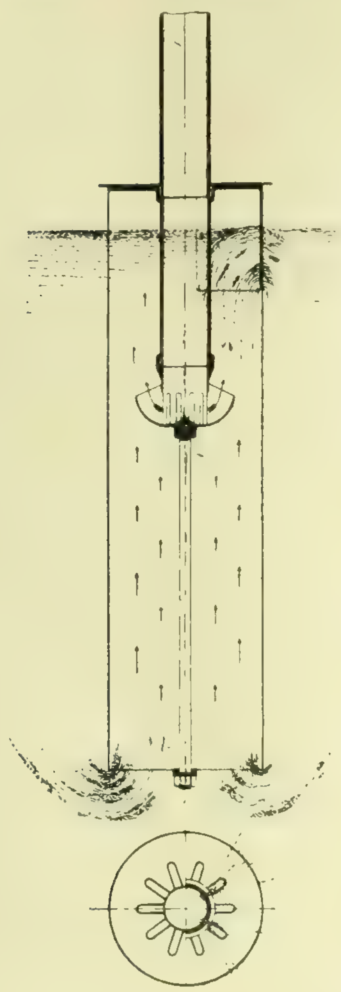


FIG. 8.—CIRCULATING UNIT. RATEAU-MORISON SYSTEM.

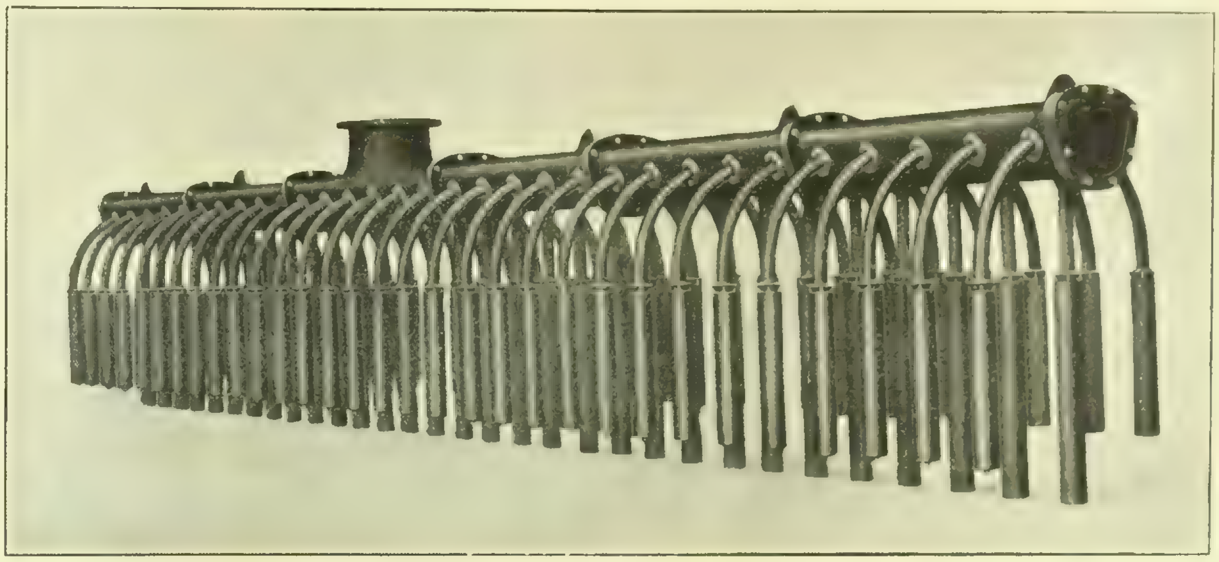


FIG. 9.—CIRCULATING TUBES. RATEAU-MORISON SYSTEM.

Let W = lbs. of steam to be regenerated per second.
w = lbs. of water contained in the accumulator.
T = period of regeneration in seconds.
L = latent heat per pound of steam regenerated.
t = temperature difference of the water in the accumulator at the beginning and end of regeneration.

The latent heat L is nearly constant, and assuming it to be so, then the total heat of steam regenerated above the temperature of the water is $W \times T \times L$ B.Th.U.'s, and the quantity of heat energy stored in the accumulator available for regeneration is $w \times t$ B.Th.U.'s.

Hence $W \times T \times L = w \times t$,

which determines the sizes of the accumulator. From this equation it is seen that the capacity is independent of the time of absorption; also that in order to obtain maximum efficiency it is necessary for the whole body of contained water to be at a uniform temperature when regeneration commences. Therefore, in order closely to approach this ideal result, a very effective method of circulating the whole mass of water must be adopted.

Circulation. — The capacity of an accumulator is a simple thermodynamic problem, but its efficiency depends on effective circulation. It is, therefore, obvious that the best solution of the necessary mechanical circulation will result in the most efficient heat accumulator of the water type. The problem consists in heating, in the shortest possible time, a given quantity of water by means of a given quantity of steam passing through submerged nozzles offering a minimum of resistance, the initial difference in temperature being about 10° Fah., the final temperatures being as nearly equal as is practically possible. After a very exhaustive series of tests involving a large number of designs the arrangement of nozzle placed within a vertical circulation tube, Fig. 8, was found to give by far the best results.

In plan the nozzle is in the shape of a star having radial arms, each of which is provided with a narrow slot on its upper surface through which the steam passes in films, thereby exposing a large surface area to the upwardly induced streams of water that flow between the arms. It is placed about 9in. below the water level, and the steam supply is by a tube connected to the main steam-supply pipe which is situated in the steam space of the accumulator. The nozzle is fixed centrally within a circulating tube which extends from the bottom of the accumulator up to the water level. There can be no short circuiting of the water with this arrangement, as the entire volume within the effective range of the tube is compelled to travel from the bottom to the top. Having decided what shall be the normal resistance of steam-flow through the nozzle, each unit is so proportioned that the kinetic energy of the steam jets is practically wholly absorbed in circulating through the guide tube the greatest volume of water. Any submerged

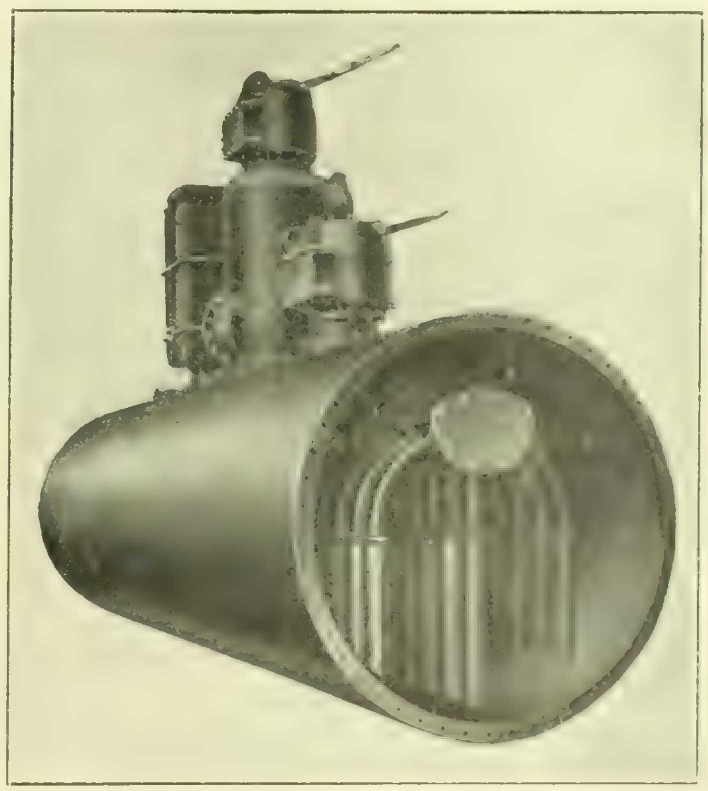


FIG. 10.—ACCUMULATOR WITH [illegible]

nozzle will, of course, cause a circulation, but the conditions in an accumulator are very difficult, as the resistance of the nozzle must of necessity be low, or undue back pressure will

* Abstract of paper read before the Institution of Engineers and Shipbuilders in Scotland, March 19th, 1912.

result, and the condensing efficiency must be very high as the mean difference in temperature between the steam and the water is only about 4° Fah. Therefore, the essence of the proposition is the uniform circulation of the entire mass by utilising to the full the kinetic energy of the jets of steam.

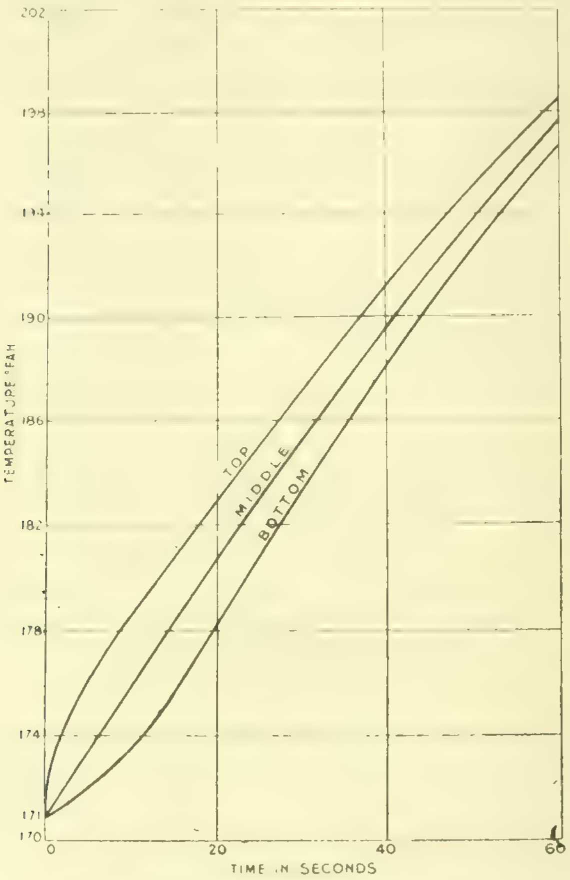


Fig. 11.—Temperature Diagram.

Having ascertained the circulating capacity of one nozzle, the number required for a given quantity of water is easily determined. Circulation by multiple units in the manner described has been proved to be extremely efficient in practice, and the merits of the arrangement are fully recognised by Prof. Rateau.

Fig. 11 shows the results of very carefully-made tests with a circulating unit, in a depth of water of 6ft. Thermometers were placed in the water at the top, middle, and bottom, and simultaneous records were taken by three observers at equal intervals of time. Velocity of the ascending column of water is so quickly established that the difference of temperature between the top and bottom is within 2° Fah. at the end of a normal period of absorption.

Limit of Back Pressure.—After a period of regeneration, and when the pressure in the steam space of the accumulator is at a minimum, any sudden rush of steam causes undue back pressure on the primary engine by reason of the very high speed of steam through the nozzles, and as the circulating efficiency is at a maximum at the normal pressure for which the nozzles are proportioned, it follows that any excess of pressure is very disadvantageous. But if a by-pass valve is fitted between the discharge pipe from the primary engine and the supply pipe to the turbine, and is loaded at a pressure slightly above that for which the nozzles are designed, then the predetermined back pressure on the primary engine will never be exceeded, and will always be associated with the best conditions for effective circulation. Such a combination of apparatus, by effectually overcoming a difficulty which has often been experienced in practice, greatly enhances the value of accumulators of this type.

Effect of Oil.—In the practical working of accumulators, the presence of oil has been found to have a very degrading effect on efficiency. In order to minimise this loss it has been customary to fit oil separators on the supply pipe, but these to be reasonably efficient must be large and, therefore, costly. Even then oil passes into the accumulator, and as the accumulator itself is such a highly efficient separator, the oil is retained and accumulates until the vital properties of heat absorption and heat regeneration are prejudiced to an extent not generally realised.

Fig. 12 is a diagram showing the degrading effect of oil. A is the line of temperature, and corresponding pressures. B is the curve of absorption with clean water, and it is of interest to note that the nearness of this curve to the theoretical line A demonstrates the high circulating effect of the system. C is the curve of regeneration, the noteworthy feature being that there is no time lag, the ebullition commencing the instant the pressure falls. After these tests had been made, oil was admitted until the entire water surface was covered by a thin film. The absorption was at once affected, and curve E shows the rapid fall in condensing efficiency. But by far the most serious effect is on the regeneration, as the time lag is so great that the pressure has to fall $1\frac{3}{4}$lbs., or

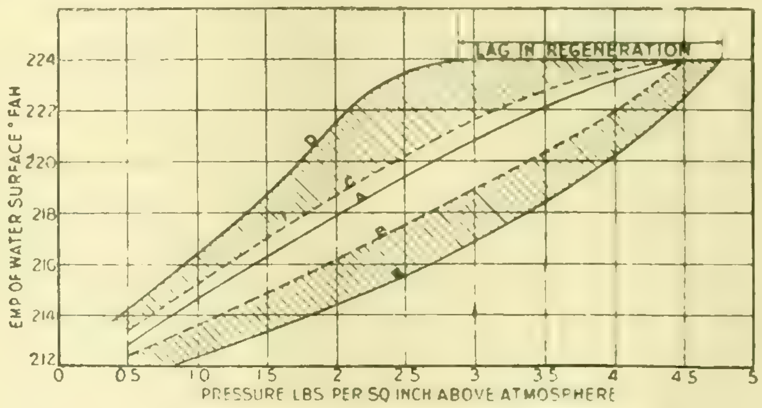


Fig. 12.—Effect of Oil on Absorption and Regeneration.

60 per cent. of a total range of 3lbs., before the normal regeneration is established. Therefore, oil in these experiments has so degraded the regenerative effect that an accumulator with clean water is 100 per cent. more efficient than one on which a film of oil covers the water surface.

Automatic Scumming.—A device which is completely successful in overcoming this very serious practical difficulty is illustrated in Fig. 13. The top of each circulating tube terminates in a cowl, and as all the cowls discharge longitudinally in the same direction, a surface wave or current is set up which continuously and effectively forces oil, scum, and all floating impurities towards one end into a quiescent collecting chamber, from which it is drained away periodically or continuously as may be desired.

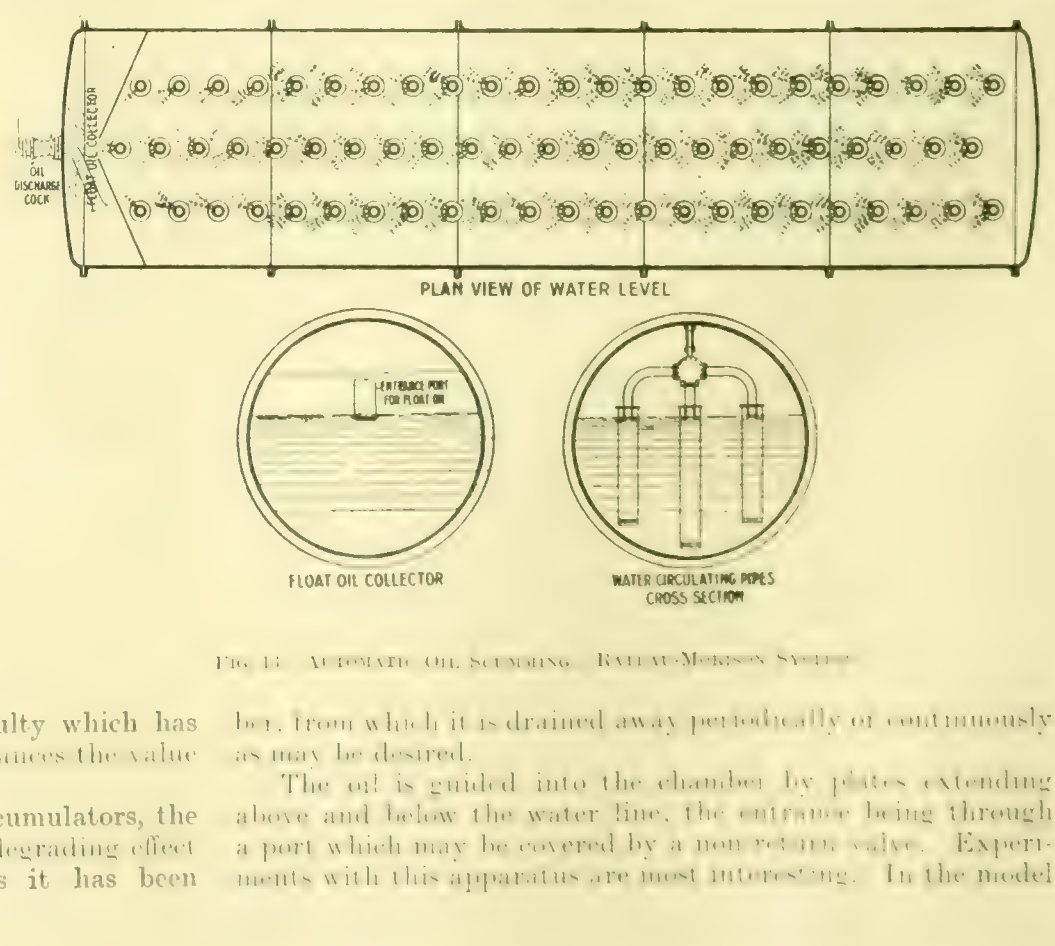


Fig. 13.—Automatic Oil Scumming. Rateau-Morison System.

The oil is guided into the chamber by plates extending above and below the water line, the entrance being through a port which may be covered by a non-return valve. Experiments with this apparatus are most interesting. In the model

shown, if very thin oil is allowed to spread itself over the surface, and the nozzles are operated by air of low pressure, the entire oil can be collected in a single globule at one end, or if a considerable amount of oil is poured into the water, it can be wholly collected and withdrawn. A valuable feature of the apparatus is that the cleansing action is continuous and the scumming automatic. If the steam supply pipe of the nozzle nearest to the oil port is perforated near the water line, the issuing jet will greatly assist the flow of oil into the collecting chamber, and at the same time overcome the resistance of the non-return valve, which is usually in the form either of a hinged flap or a slightly raised weir.

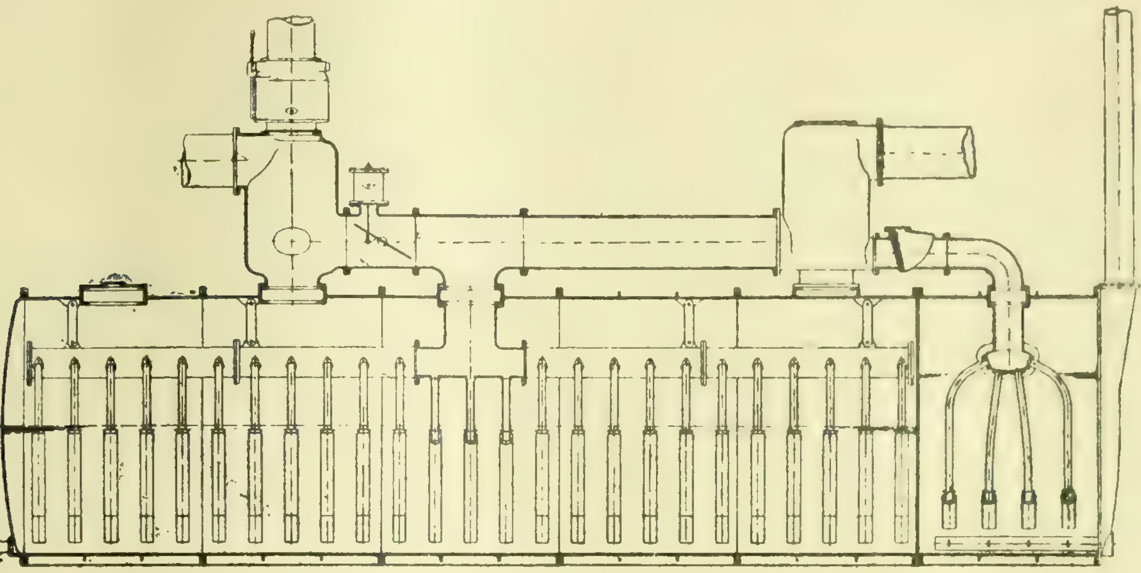


FIG. 14.

The multiple-unit circulator is also very valuable as an exhaust-steam feed-water heater when the heating steam is delivered intermittently, and the feed reservoir is of considerable capacity. A heater on this system fitted in a forge effected a saving of 10 per cent. in the cost of coals over a year's working.

Delayed Ebullition.—The great desideratum in a heat accumulator is rapidity of absorption, especially at periods of abnormal supply, so that as much steam as possible is condensed. If, during the period of absorption, the pressure in the steam space in the accumulator is maintained above the pressure corresponding to the temperature of the water, it follows that ebullition will be delayed, and condensation, and, therefore, rapidity of heating, will be promoted. This relative increase may be secured by arranging a by-pass connection between the steam-supply pipe to the nozzles and the steam-supply pipe to the turbine, the connection being provided with a throttle valve which may be automatic, but which can be so adjusted or set as to meet the condition of any particular installation satisfactorily. Generally, however, the arrangement shown in Fig. 14 is to be preferred.

Accumulator Constructions.—It is sometimes convenient to convert oil boiler-shells into accumulators, but the oil boiler proposition is advisable only if the boiler is in good condition, as if it is defective, the natural sequel will be costly repairs, continual annoyance, and ultimate replacement. An exhaust-steam plant is also such an exceptionally good investment when well installed, that temporary makeshifts which usually cause constant irritation are to be avoided. A construction of accumulator which has the merit of strength and simplicity consists of curvilinear cast-iron sections built together by flanged joints. Easy transport to site is often of the utmost convenience, and for this reason alone the sectional construction is very attractive. Cast iron is also less susceptible to corrosion than steel, whilst the requirements of manufacture prevent any undue liberties being taken with the thickness of shell.

A very recent design of accumulator is shown in Fig. 15, and consists of a ferro-concrete tank, the steam inlet and outlet being by concentric pipes. The arrangement of interior fittings is also very simple, and the entire construction offers considerable possibilities.

Influence of Vacuum.—The influence of vacuum on the steam consumption of exhaust-steam turbines being very great, the employment of condensing plant of high efficiency is commercially imperative. An increase in vacuum of from 26in. to 28in. will reduce the steam consumption of an exhaust-steam turbine by about 25 per cent. High vacuum being imperative, it follows that the hot well temperature is correspondingly low, but as the heat in exhaust steam can be utilised to maximum advantage in raising the temperature of feed water up to pumping limits, it is very desirable that all steam-power propositions should include a system of exhaust-steam feed-heating, always provided the heating cannot be accomplished by waste gases. Suppose, for example, a vacuum of $28\frac{1}{2}$in. is carried in a surface condenser, the temperature of condensate will be about 80° Fah.; if this water is raised to, say, 200° Fah., the thermal gain will amount to practically 12 per cent.

Combined Accumulator and Feed Heater.—In all exhaust-steam plants there are times when the steam supply from the primary engine is greater than can be taken by the turbine and absorbed by the accumulator; under such conditions the surplus escapes either (1) to the atmosphere, (2) is by-passed to the condenser, or (3) may be utilised for feed heating. The first two represent highly wasteful practice, the third alternative results in maximum efficiency.

In one arrangement the accumulator has a compartment at one end which constitutes a feed tank. Within it are a number of circulating tubes the nozzles being submerged at such a depth that the resistance to the flow of steam through

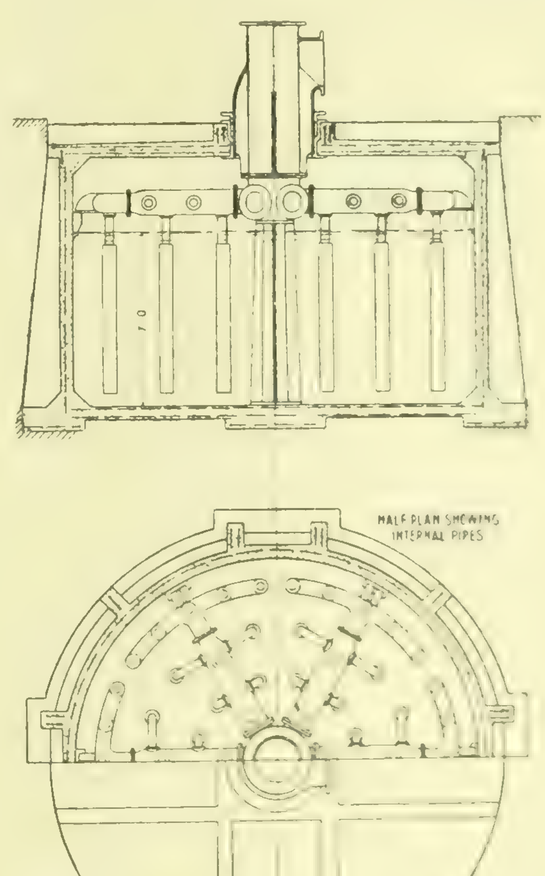


FIG. 15.—FERRO-CONCRETE CONSTRUCTION OF ACCUMULATOR.

them is slightly less than the load on the main safety valve, consequently the surplus steam passes preferentially through the nozzles and heats the feed water, which, being in considerable and constant bulk, is able to condense intermittent supplies without much variation in temperature. Instead of forming part of the accumulator, the feed tank may be

independent, an old boiler shell, if in good condition, being very convenient for the purpose.

Gasometer Type Accumulator.—A recent design of accumulator in use on the Continent is shown in Fig. 16. It is practically similar to a gasometer, and stores the steam when in surplus supply. For large propositions it would be impossible by reason of its size, whilst in all cases the upkeep would undoubtedly be considerable. After a period of, say, 10 years it is highly probable a water accumulator would be as good as ever and would have cost practically nothing for upkeep, but in view of the rapidity of movement, and the inevitable corrosion, it is an interesting speculation as to what would be the condition of a gasometer type in half that time. The advantage claimed is reduction of back pressure, but if a water accumulator is fitted with compensating valves, the difference in back pressure between the two systems is negligible. Other obvious disadvantages of the gasometer type are radiation losses and danger of collapse when under vacuum.

The use of receiver-type accumulators must of necessity be limited by considerations of size and cost, whereas the water type offers facilities for propositions which a few years ago were unheard of. For example, a regenerative accumulator is under consideration which will contain 500 tons of water, and which is intended to supply a 1,500 kw. turbine for a bridge period of 15 minutes.

The knowledge that cheap electrical power can be generated by means of exhaust steam has been current for a decade, yet progress has been somewhat slow, perhaps because the results promised appeared too good to be true. It was left to the progressives as usual to lead the way, but after it

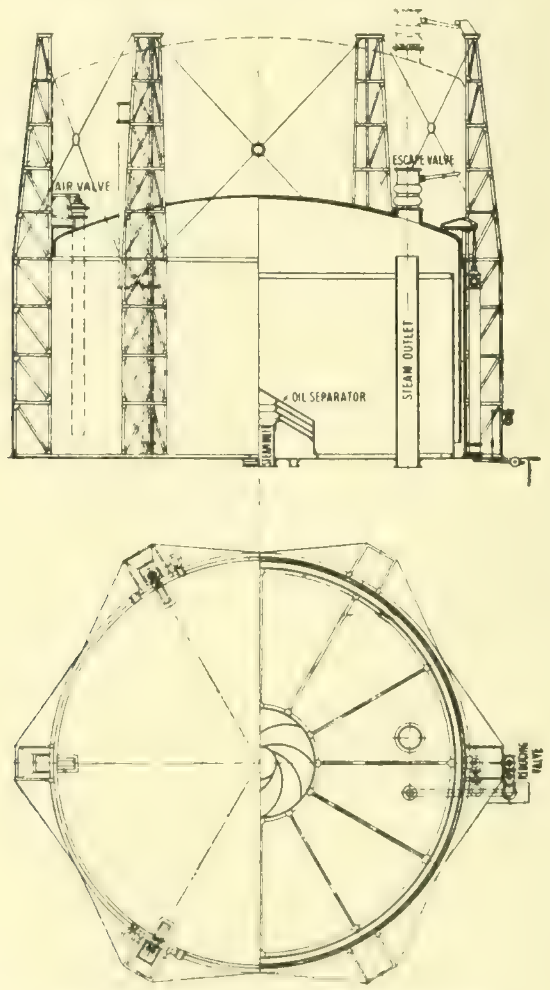


Fig. 16. Gasometer Type Accumulator.

became apparent that far-sighted colliery owners and others, with the experience of one plant, were adopting the method again and again, the barriers of conservatism fell, and to-day the number of plants under construction constitutes a record.

From the technical standpoint the position is very simple. The low-pressure turbine is unrivalled as the means of converting steam heat into work, and if such a turbine is used in combination with reciprocating engines of a higher pressure, the combination gives more power from a given weight of steam than any other known system of compounding.

The commercial objective is to obtain the maximum power output from a given weight of steam, and consequently to prevent the financial loss due to the enormous quantity of exhaust steam now going to waste. It, therefore, behoves those who own installations producing waste exhaust steam to take advice from specialists on the subject, and ascertain the cost of a plant for the utilisation of this exhaust steam and the return which may be expected from the capital outlay. Each case must be considered on its merits, but there are a very large number in which savings can be effected that would relieve the financial tension from which every factory is suffering.

The problem presented day by day with increasing insistence is how best to meet by savings the growing demands of labour. The heat accumulator first introduced by Prof. Rateau is one of the factors which helps forward a solution, as it facilitates the production of cheap power.

RELATIVE CAPACITY OF DRY BATTERY CELLS.

At a meeting of the Faraday Society, held on Tuesday, March 26th, Mr. S. W. Melsom, of the National Physical Laboratory, read a paper entitled "Dry Batteries: the Relation between the Incidence of the Discharge and the Relative Capacity of Cells of Different Manufacture." The paper describes the results of a series of tests made in order to ascertain to what extent the tests in general use afford an indication of the relative value of different types of dry cells. Four types of cell were used for the tests, these being chosen on account of their widely different characteristics. A number of each of these types were subjected to tests at various rates of discharge. Table I. gives the relative values obtained from the tests for each set of cells, taking for purposes of comparison the output of cells A as 100. Test No. 1 is a near approximation to actual working conditions. Table II. gives the capacity (watt-hours) of the cells at the various rates of discharge.

Table I.

Relative Capacity of Cells at Various Rates of Discharge.

(The values are in watt-hours, except where otherwise stated.)

No.		Cells.			
		A.	B.	C.	D.
1	5 minutes an hour on 50 ohms ...	100	93	83	28
2	5 minutes an hour on 1 ohm initial ...	100	59	43	7
	After 6 months' storage	100	58	50	—
	After 12 months' storage	100	53	42	—
3	6 hours per day on 5 ohms—				
	Mean of V.B. and V.E. curves ...	100	50	50	35
4	Continuous at 20 milliamperes—				
	Initial ampere-hours	100	43	36	30
	Initial watt-hours	100	45	40	29
	After 8 months' storage, watt-hours...	100	50	45	5
5	Continuous on 10 ohms—				
	Initial to 0·7 volt	100	75	53	60
	Initial to 0·5 volt	100	76	55	60
	After 6 months' storage—				
	To 0·7 volt	100	59	44	28
	After 12 months' storage	100	67	50	2
6	Continuous on 100 ohms	100	68	51	35
7	Continuous on 500 ohms—				
	To 1·3 volts	100	102	87	10
	To end, *i.e.*, 118 weeks	100	94	—	

Table II.

Relation between Incidence of Discharge and Capacity.

(The capacity in each case is given in watt-hours.)

Test No.	Cells.			
	A.	B.	C.	D.
1	43	40	36	12
2	44	26	10	3
3	126	63	63	16
4	105	47	42	31
5	64	49	35	38
6	107	73	55	38
7	70	66	—	—

charge. The results given in Tables I. and II. indicate that the tests in general use do not afford reliable data as to the relative value of different types of cells or of the actual capacity that may be obtained under working conditions, and it is therefore recommended that the conditions of test should approximate as nearly as possible to actual working conditions.

VALVE ARRANGEMENTS FOR INJECTORS.

Various injector arrangements have been designed by Mr. R. G. Brooke, Upton Grange, Macclesfield, embodying means for preventing premature closure of the overflow valve due to pressure values in the delivery chamber at starting. This is highly important, but it is also equally important that the first movement of the overflow valve at starting should not be opposed. This ordinarily will not happen with the injector arrangements referred to, but it is, nevertheless, in certain circumstances, possible for some fluid to remain imprisoned in the pressure chamber pertaining to the overflow valve sufficiently long to offer some slight resistance to opening of the overflow valve. To prevent such possibility of resistance to opening, Mr. Brooke has patented the arrangements illustrated herewith, which, when the injector is not at work, places the pressure chamber freely in communication with a space where pressure is not in excess of that of the atmosphere. The arrangements are such that the communication is interrupted during the time that the overflow valve is being maintained closed by the fluid in the pressure chamber whilst the injector is at work.

In the arrangement shown in Fig. 1 the pressure chamber A pertaining to the overflow valve B is connected to the delivery C of the injector by way of a passage D and the latter is interrupted at some point in its length by a spring-loaded piston valve E for the purpose of preventing premature closure of the overflow valve B. The valve E is adapted, when it is closed, to establish free communication between the pressure chamber A and the atmosphere and, when opened, to interrupt such communication. The piston E slides in the hollow part of a sleeve F screwed into a housing in the injector body in such a way as to leave an annular space G that communicates with the pressure chamber A through passages M. The interior of the sleeve F is open at its outer end to the atmosphere, as shown, and the control piston E is provided with a longitudinal passage H, lateral ports L, and an annular groove J, adapted, when the piston valve is closed to the delivery of the injector, as shown, to co-act with lateral ports K in the sleeve F, and thus vent the pressure chamber A. When the injector is at work, the fluid under pressure from the delivery C of the injector will move the piston along the sleeve in a direction away from the valve seat until the end of the piston uncovers the ports K, and so may pass into the annular space G around the sleeve F, and thence into the pressure chamber A. The venting passage H will thus be

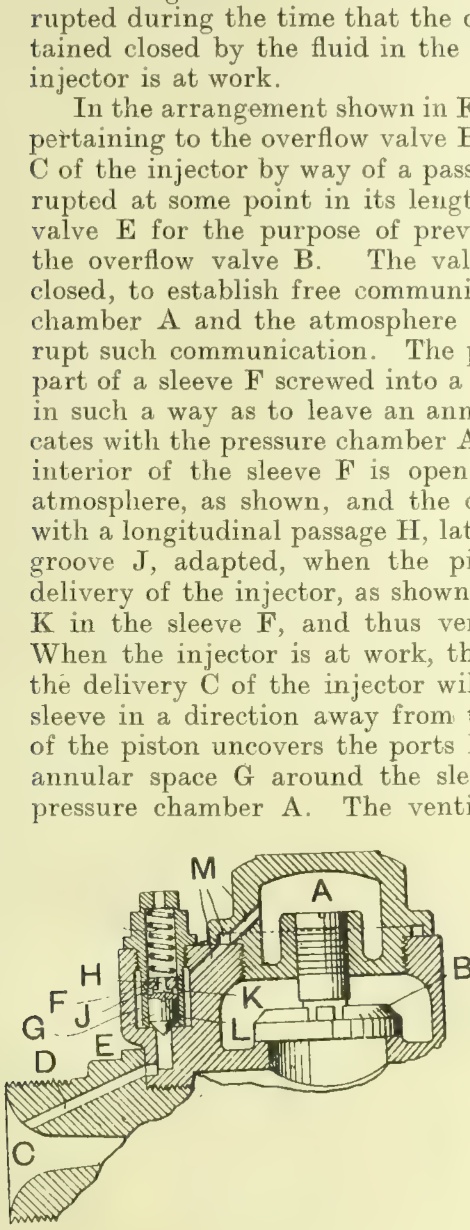


Fig. 1.

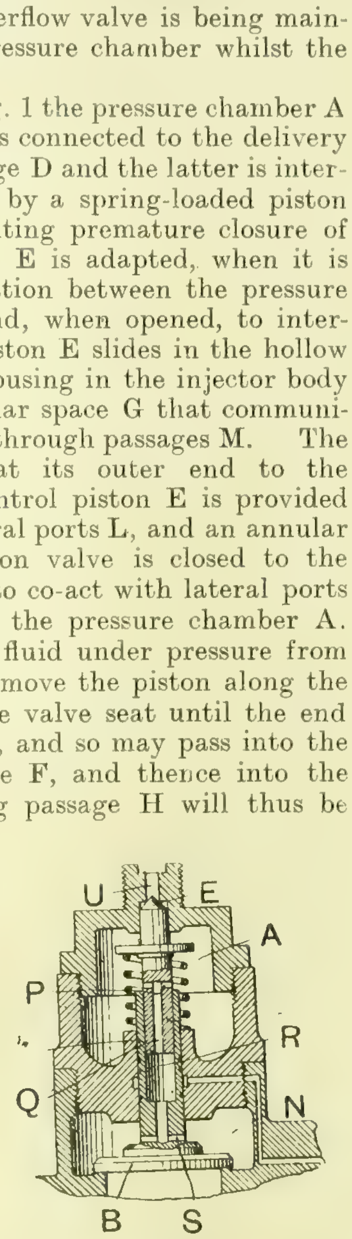


Fig. 2.

Valve Arrangements for Injectors.

closed when the piston valve moves to admit fluid under pressure into the pressure chamber.

Where, as shown in Fig. 2, a spring loaded valve E controlling the communication between the delivery of the injector and the pressure chamber A is located in the latter and telescopes within the stem of the overflow valve B, the telescoping parts may constitute a valve which, when the injector is not at work, places the pressure chamber A in free communication with the overflow outlet N of the injector. For this purpose the stem of the loaded valve E is formed with lateral ports P leading to a longitudinal passage Q that opens into the hollow part R of the overflow valve stem, this hollow part likewise having lateral ports S leading to the overflow outlet N. In order to ensure that the lateral ports P in the stem of the loaded valve E shall be closed when the injector is at work and the overflow valve B closed, the loaded valve is formed as a piston or plunger so that it has to retract some distance before the communication between the pressure chamber A and the delivery of the injector by way of the passage C is established.

Where the premature closure of the overflow valve after it is opened is prevented by providing leakage means adapted to be closed with closure of the overflow valve when the injector is at work, the pressure chamber may be placed in free com

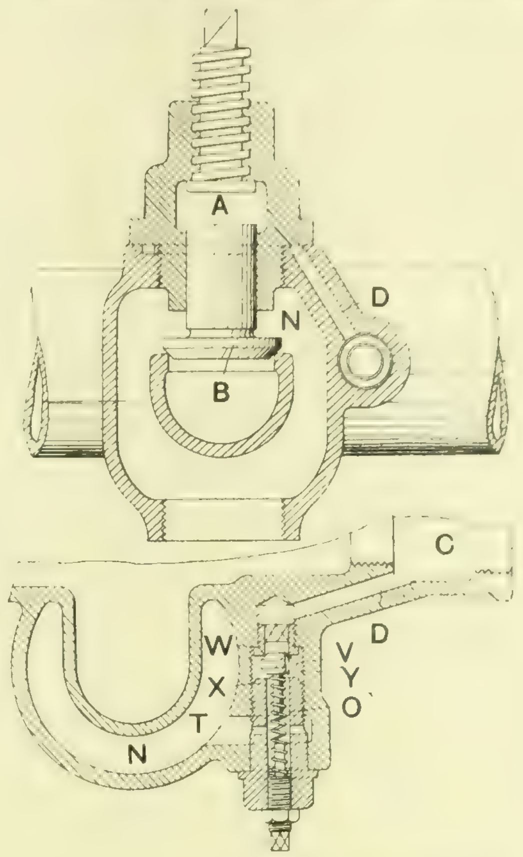


Fig. 3.—Valve Arrangements for Injectors.

munication with the atmosphere before the overflow valve opens, through a passage controlled by a loaded valve, such valve closing the passage when the injector is at work and being positively moved again into open position when the injector is not at work.

Fig. 3 illustrates a modified construction wherein the valve V controlling the passage D between the pressure chamber A and the delivery C is double acting and associated with two seats, W, X, the arrangement being such that when the injector is not at work and the valve is upon the seat W, as shown, the pressure chamber A is in communication with the overflow outlet N, by way of the passage D, space Y, passage O and lateral ports T. When, on the other hand, the valve V is upon the seat X the communication to the overflow outlet N is closed, and the pressure chamber A connected to the delivery C of the injector.

Improvements in Screw Propellers.—At the recent annual meeting of the German Institution of Naval Architects Dr. Wagner referred to an improved arrangement of screw propeller. In this arrangement a series of fixed blades are placed behind the rotating blades of the propeller, which blades are given such a shape as to cause the stream of water from the screw to be directed straight astern. It is true that the friction of the issuing stream of water against these fixed blades operates to retard the vessel and reduce the efficiency of the screw, but this is much more than offset by the gain due to the straightening of the issuing stream. Dr. Wagner claimed that careful tests on a vessel had shown that by means of these fixed blades the efficiency of the screw propeller could be raised some 10 to 15 per cent. and the net efficiency of the screw as a means of propulsion could thus be increased to 85 to 87 per cent. The device has been applied to 13 motor boats and other small vessels and to one steam-turbine driven torpedo boat. At very slow speed the device somewhat reduces the efficiency of the screw, but at cruising speed the efficiency is materially raised, and at the highest speed it is very much increased. It is also claimed that the vibrations of the vessels due to the action of the propeller were reduced and the vessels did not settle at the stern as much.

THE SIZE AND COST OF ELECTRIC GENERATORS IN RELATION TO THE TYPE OF PRIME MOVER.*

BY HUMPHRY MACCALLUM, B.SC., A.M.INST.C.E.

Introductory.—The cost per kilowatt of a fully-equipped electric generating station varies from about £12 in the largest sizes to some £50 or £60 in small sizes, but there will often be special or local conditions which may bring about wide departures from the normal figures, more especially in the case of small stations.

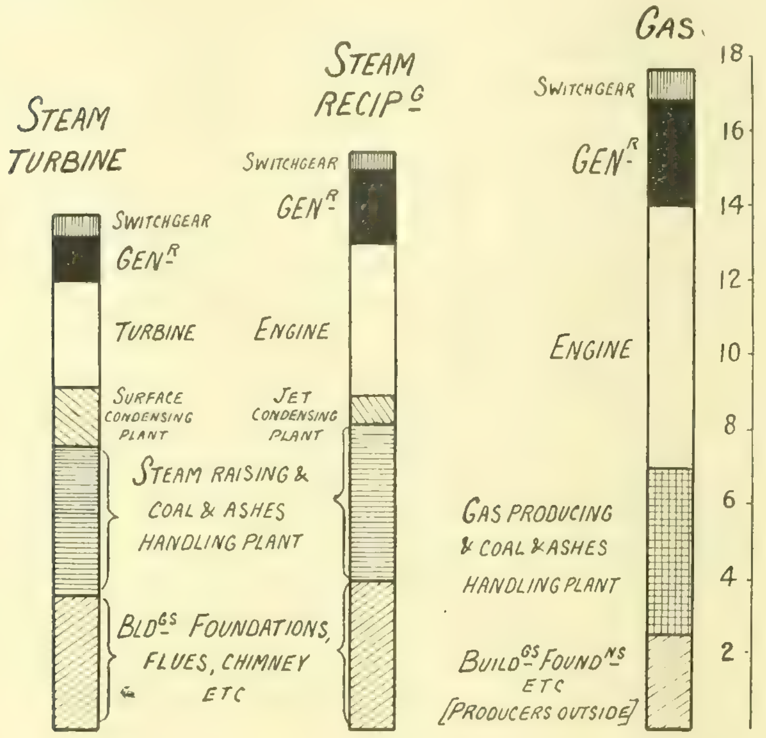


Fig. 1.

Fig. 1 indicates approximately how this expenditure is laid out in the case of a plant of large size under the alternative conditions of steam turbine, reciprocating engine, and gas engine drive, and it is at once seen that the sum invested in electrical plant, *i.e.*, in generators and switchgear, is relatively small. In neither case does the capital expenditure under this heading exceed some £4 per kilowatt, and in all three it works out at less than 25 per cent. of the total outlay. It would appear reasonable, therefore, in view of the smallness of this item, to regard the first cost of the electrical equipment as of secondary importance compared with its reliability and efficiency in working, and this is no doubt the case, but the same argument applies with equal force to the other links of the chain: the boilers, condensers, pumps, coal conveyers, &c., the cost of which when considered separately is relatively small.

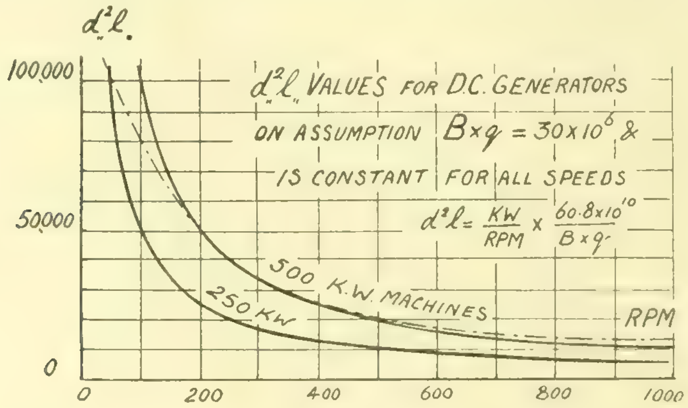


Fig. 2.
Dotted curve gives normal values of d^2l for 500 kw. machines at various speeds.

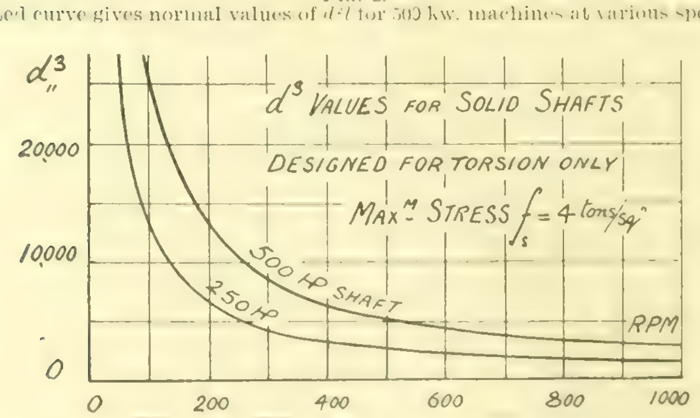


Fig. 3

* Abstract of paper read before the Ipswich Engineering Society

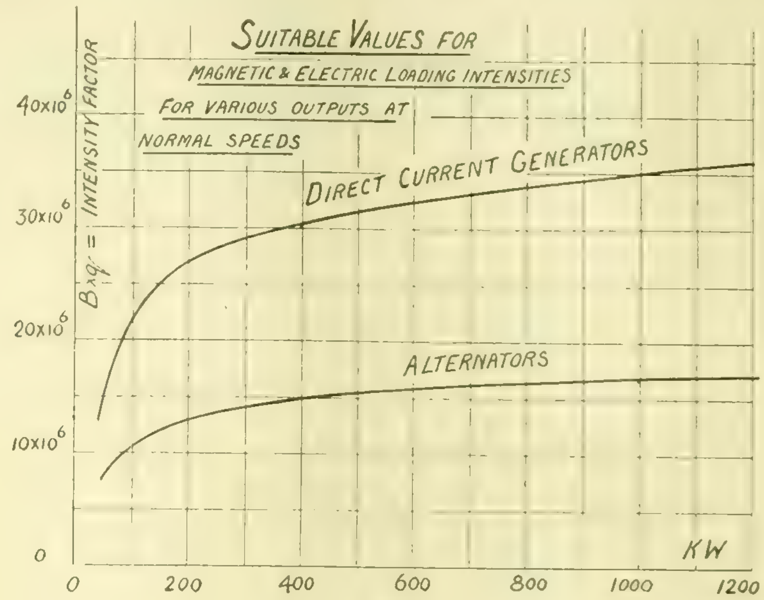


Fig. 4.

Now it is well known that the commercial success of any generating station is largely influenced by the amount of capital sunk therein, and it is evident therefore that the plant cannot be bought on a quality basis alone, but that each item must be scientifically dealt with and the suitable initial cost arrived at after a careful comparison of the practical alternatives.

Of the 25 or so per cent. of the total station cost which we find in practice is devoted to the electrical plant, by far the larger share, *i.e.*, some 15 to 20 per cent., is accounted for by the main generators—the cost of these, however, and likewise the cost of the prime movers is dependant, apart from other considerations, upon the output and speed of the individual units, and it is the object of these notes to deal briefly with this aspect of the subject and also to discuss the relation between the size and output of electric generators.

Size of Electric Generators—"d^2l Values."—For the purpose of comparison it is convenient, and usual, to measure the size of electric generators in terms of their d^2l, "d" being the diameter of the bore in inches and "l" the "iron length" of

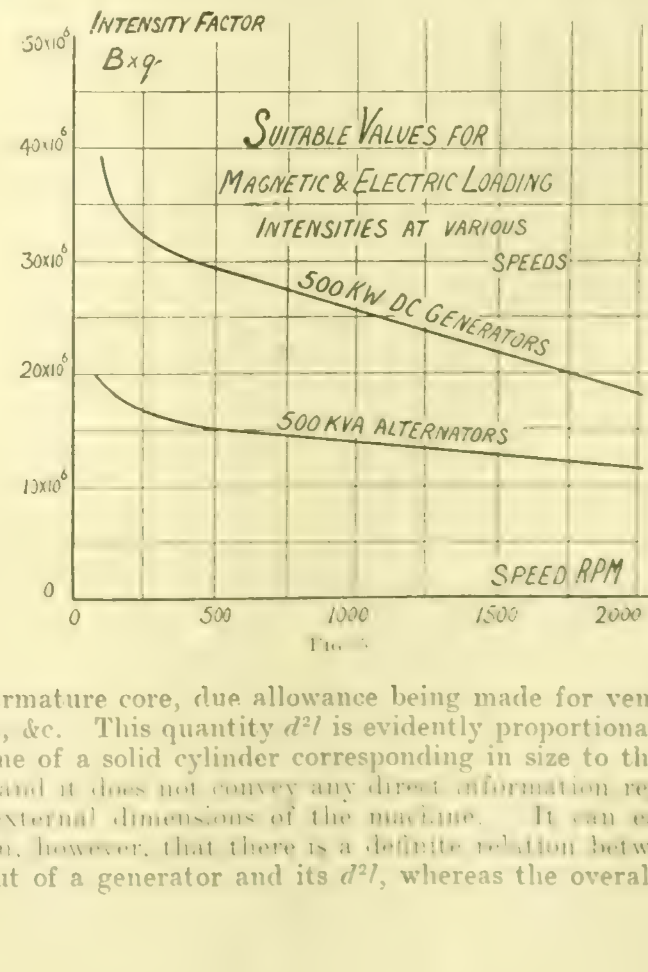


Fig. 5

the armature core, due allowance being made for ventilating ducts, &c. This quantity d^2l is evidently proportional to the volume of a solid cylinder corresponding in size to the armature and it does not convey any direct information regarding the external dimensions of the machine. It can easily be shown, however, that there is a definite relation between the output of a generator and its d^2l, whereas the overall size is

largely a matter of individual design and may be influenced to a great extent by mechanical considerations. It will hardly be possible therefore to deal generally with any other than the d^2l values, and this being the case, the following very approximate rule concerning the relation between the space occupied by a machine and its d^2l may be of use.

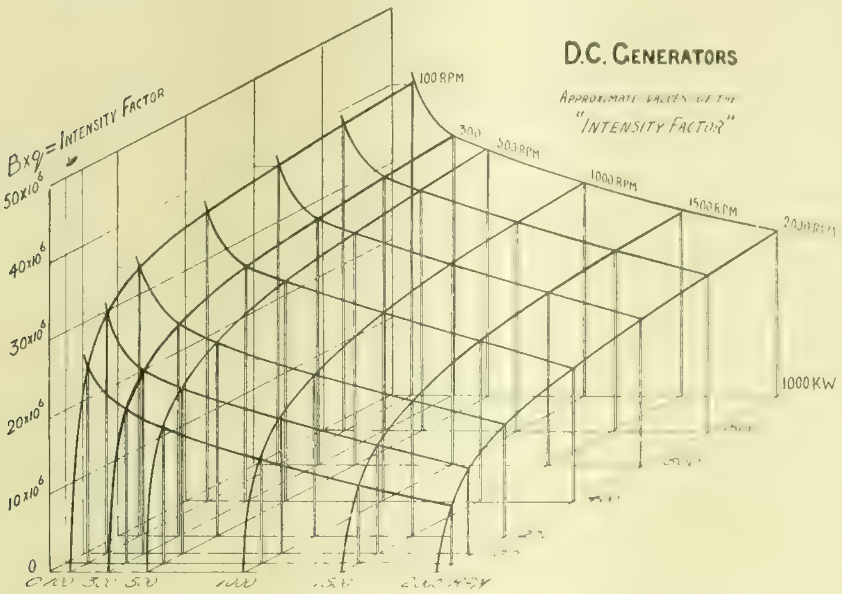


Fig. 6.

(i.) Cubage in cubic feet $= \dfrac{d^2l}{100} + 200$

where d and l are measured in inches.

Influence of Speed Rating.—For a given output the size of an electric generator, as of a steam engine or other machine, is very largely a matter of speed rating—the higher the speed the smaller the machine, and vice versâ. Taking as a simple illustration the case of a line shaft of circular section, which is subjected to pure torsional stresses, it is known that the value of the torque which it will transmit is proportional to the cube of its diameter and to the "skin stress," or:—

(ii.) Torque $= d^3 \times f_s \times$ a constant

and, since the power transmitted is proportional to the product of the torque and the speed, the following relation holds good:—

(iii.) H.P. $= d^3 \times f_s \times$ R.P.M. $\times$ a constant.

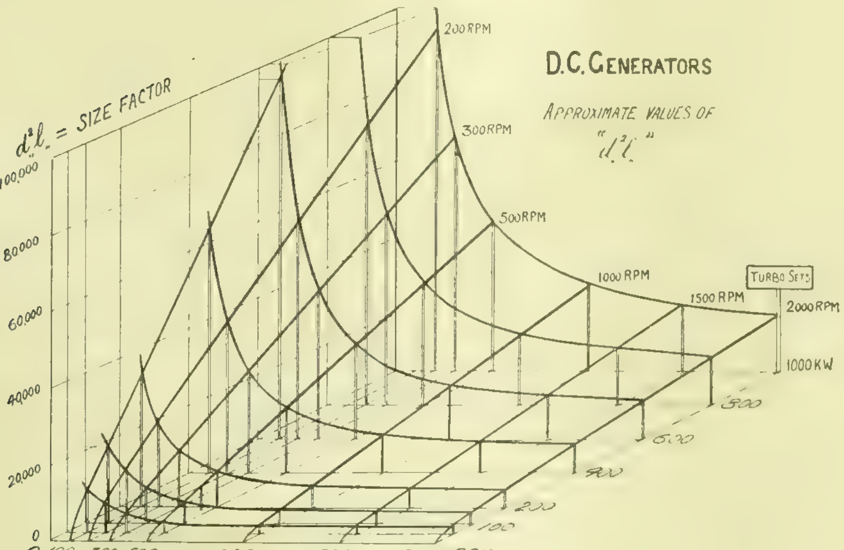


Fig. 7.

The torque equation ii. is built up of three factors, "d^3," "f_s" and "a constant." The first of these relates to *size*, the second to *stress* or *intensity of loading*, and the third is a number the value of which depends upon the units used. Now the torque of a steam turbine, of an engine, or of an electric motor or generator may also be expressed in terms of three such factors, as indicated in the accompanying table.

It will be noted that the size factors in the first column are of three dimensions and that in the case of the engine and the generator or motor we have the d^2l previously mentioned. In the second column the first four intensities are of a mechanical nature, but in the case of the magneto-electric machine there is, as might be expected, a magnetic and an electric loading

Table of Torque Factors.

(Torque in lbs. feet = size factor × stress factor × constant.)

	Size Factor.	Stress or Intensity Factor.	Constant.
Solid circular shaft ...	$d_{''}^3$	Skin stress f_s	$\dfrac{\pi}{16 \times 12}$
Hollow ditto	$\dfrac{D_{''}^4 - d_{''}^4}{d_{''}}$	Skin stress f_s	$\dfrac{\pi}{16 \times 12}$
Steam turbine (each set of blades).........	$D_{''}^3 - d_{''}^3$	Tangential force due to steam, regarded as a shear stress p	$\dfrac{\pi}{12 \times 12}$
Reciprocating engine (each cylinder)	$d_{''}^2 l_{''}$	Mean effective steam pressure in cylinder p_m	$\dfrac{1}{8 \times 12}$
Electric motor or generator	$d_{''}^2 l_{''}$	Magnetic B, Electric q	$1.16 \times 10^{[illegible]}$

intensity, the product of which, $B \times q$, is the true intensity factor.

Taking the expression for the torque of an electric generator or motor, as obtained from the table, and inserting it in the horse-power formula as follows, we obtain equation iv.:—

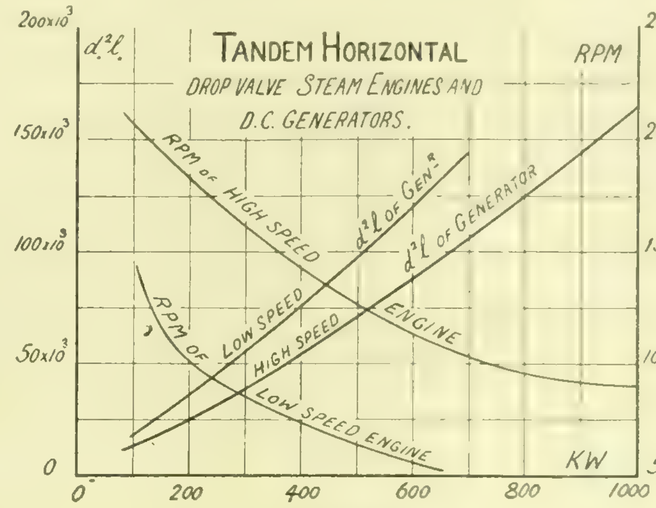


Fig. 8.

$$\text{H.P.} = \text{Torque} \times \frac{2\pi\ \text{R.P.M.}}{33{,}000}$$

$$= (d^2l \times B \times q \times 1{\cdot}16 \times 10^{[illegible]})\ \frac{2\pi\ \text{R.P.M.}}{33{,}000}$$

$$= d^2l \times \text{R.P.M.} \times B \times q \times 2{\cdot}2 \times 10^{[illegible]}$$

And Kw. $=$ H.P. $\times\ 0{\cdot}746$.

(iv.) $\therefore$ Kw. $= d^2l \times$ R.P.M. $\times\ B \times q \times 1{\cdot}64 \times 10^{[illegible]}$.

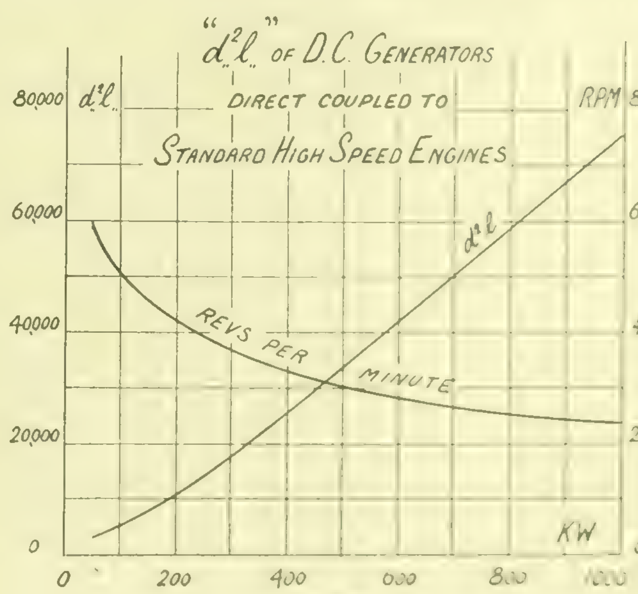


Fig. 9.

The curves, Fig. 2, showing the relation between size (d^2l) and speed (R.P.M.) for machines of 250 kw. and 500 kw. are rectangular hyperbolæ plotted from the above formula. The product $B \times q$ being assigned the value $30 \times 10^{[illegible]}$ for the

purpose. The corresponding curves for a shaft are shown in Fig. 3 and a comparison should prove instructive. It is unfortunate, however, that neither of these results is capable of general application. In the shaft curves it is necessary to vary the value of f_s in order to suit the material of the shaft and the class of load as well as to design for stiffness before strength in some cases, and, likewise with dynamo electric

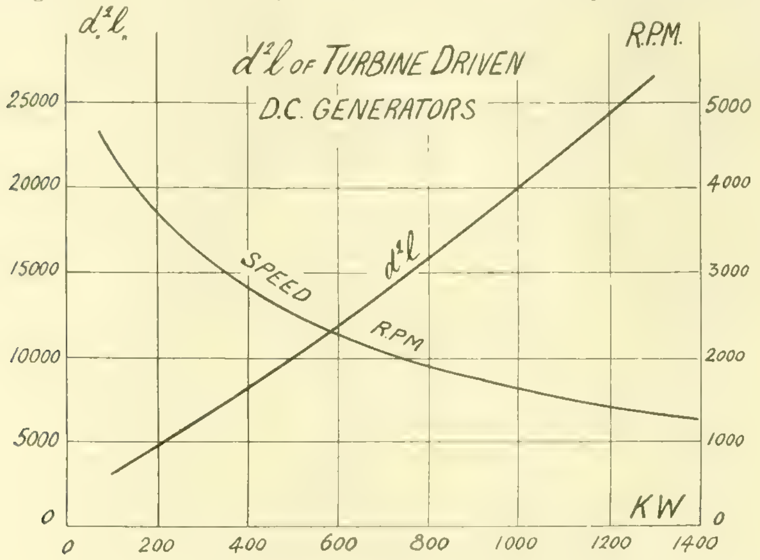


FIG. 10.

machines, it will be found that the suitable values of B and q (and their product to a lesser extent) vary according to the type of machine and depend largely upon the output and speed rating. For example, the value of $B \times q = 30 \times 10^6$, which was utilised above, applies to modern direct-current machines of some 500 kw. output at about 300 or 400 revs. per minute, so that the portions of the curves which extend beyond this region are misleading and it becomes evident that appropriate values for the intensity factor must be known if useful results are to be obtained.

The considerations which govern the relation between "B" and "q" are of a complicated nature, and a full discussion of this matter would be of interest to the electrical designer only. Let it suffice, therefore, to note that in general if the value of "B," the magnetic loading intensity, be pressed too high, abnormal iron losses and consequent overheating and loss of efficiency will result, whereas if the electric loading intensity "q" be carried beyond certain limits, sparking and instability may be looked for in D.C. machines or poorness of regulation in alternators. Leaving the adjustment of the ratio between these two quantities in the hands of the specialist, it will be found that the permissible value of their product ($B \times q$), upon which the size of the machine depends, is influenced by:—

(1) The class of machine (direct or alternating).
(2) The output of machine (kilowatts).
(3) The speed of machine (R.P.M.).

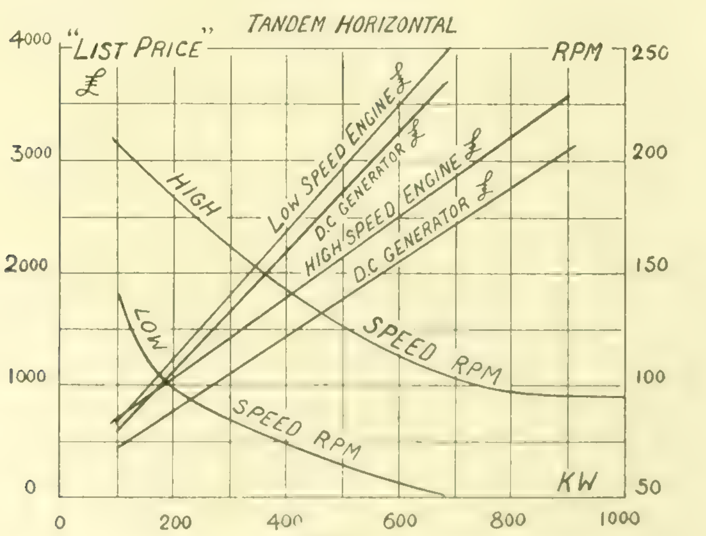


FIG. 11

In direct current machines the loading intensity is as a rule about twice that which is permissible in alternators, it is always higher in the large machines of a series (Fig. 4) and it decreases with an increasing speed in both D.C. machines and alternators (Fig. 5).

An attempt has been made in Fig. 6 to show, by means of a 3-dimension diagram, how this quantity varies with output and with speed, and the "size factor" diagram (Fig. 7) has been prepared to agree with Fig. 6.

From what has already been said it will be clear that there is no simple proportionality between the d^2l or "size" of a generator and its K.W./R.P.M., the relation being as follows:—

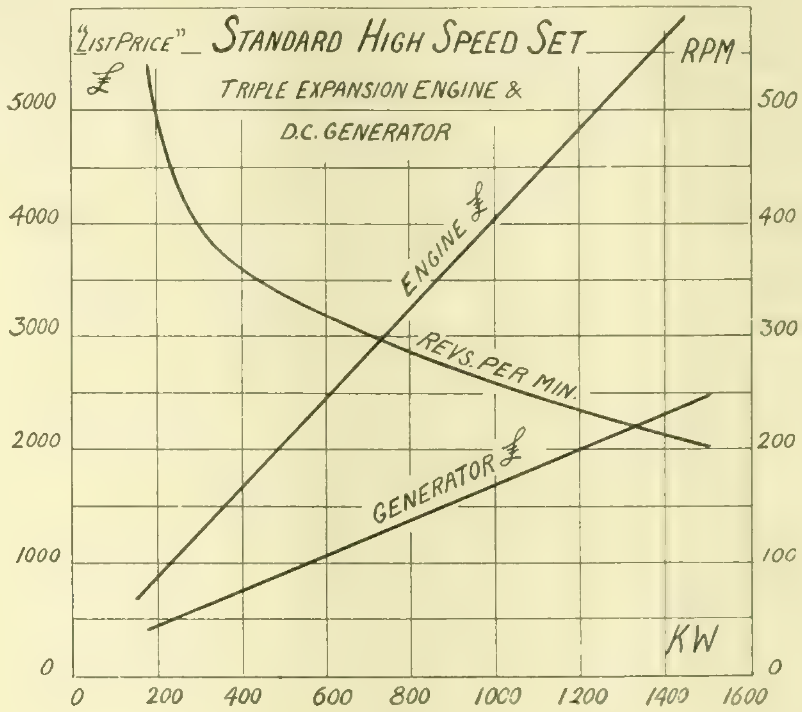


FIG. 12.

$$d^2 l = \frac{\text{K.W.}}{\text{R.P.M.}} \times S.$$

Where $S = \dfrac{60 \cdot 8 \times 10^{10}}{B \times q}$ and is therefore a number which varies with the speed and the output.

If, however, the quotient $\dfrac{S}{\text{R.P.M.}}$ were a constant quantity a simple proportionality would exist between the size factor "d^2l" and the output K.W. Now this is found to be approximately the case in practice where a line of generators is designed for normal engine speeds—a fact which is clearly demonstrated by the comparative straightness of the d^2l curves in Figs. 8, 9, and 10.

Cost of Generators, &c.—The costs of a line of generators are in a like manner found to be very nearly proportional to the K.W. output at normal engine speeds, and the same applies to the engine prices as indicated in Figs. 11, 12, and 13.

The author has found that the existence of such simple approximate relations as the above is not generally realised,

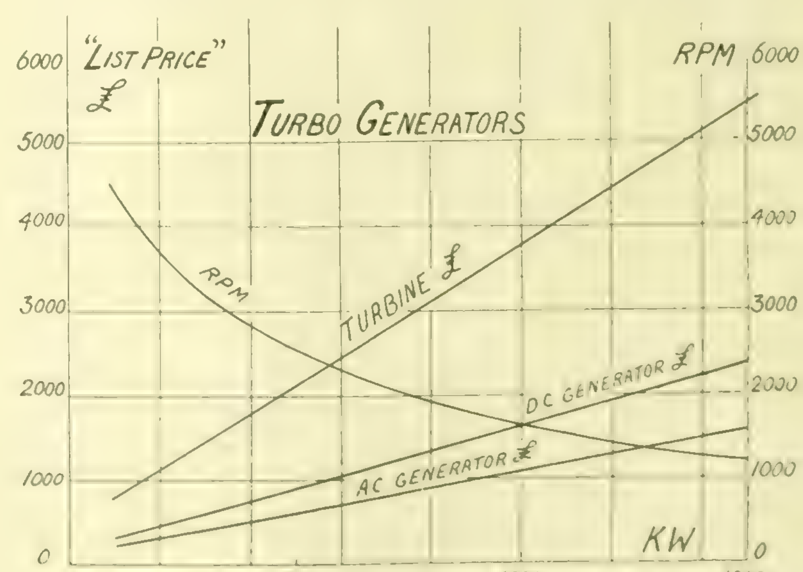


FIG. 13

it being more usual to express sizes and prices as a function of the B.H.P. per R.P.M. or the K.W. per R.P.M. in the case of the engine and generator respectively.

Now a curve connecting, say, price and K.W. per R.P.M. is undoubtedly a useful generalisation, which may be applicable over a fairly wide range, but it does not admit of

the simple algebraical treatment that may be applied to the straight lines in Figs. 11, 12, and 13. It is suggested, therefore, that it may be simpler in practice to remember and use the few linear formulæ corresponding to the principal types of prime mover than to rely upon a curve which may not always be at hand when required, or upon very much more complicated formulæ. By way of comparison, formulæ agreeing with Fig. 12 . are set out below, and it will be

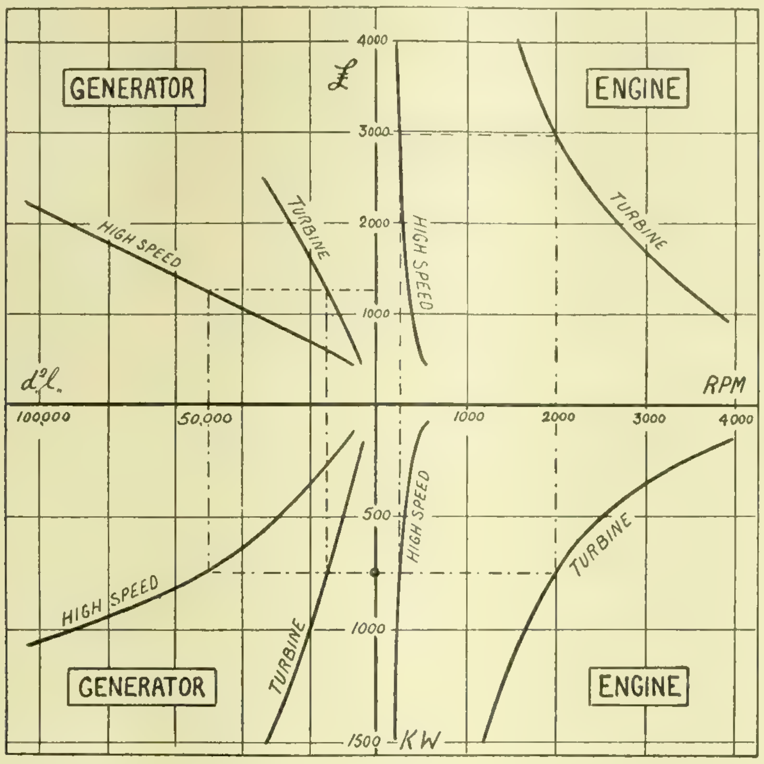


Fig. 14.

realised that whereas in the latter case a calculation involves the use of logarithms, in the former it is merely a matter of mental arithmetic.

List price, engine £ = 3·95 kw. + 75.

List price, generator £ = 1·55 kw. + 130.

Or alternatively :—

$$\text{List price, engine } \pounds = 1{,}200 \times \sqrt[1\cdot18]{\frac{\text{B.H.P.}}{\text{R.P.M.}}}$$

$$\text{List price, generator } \pounds = 725 \times \sqrt[1\cdot61]{\frac{\text{KW.}}{\text{R.M.P.}}}$$

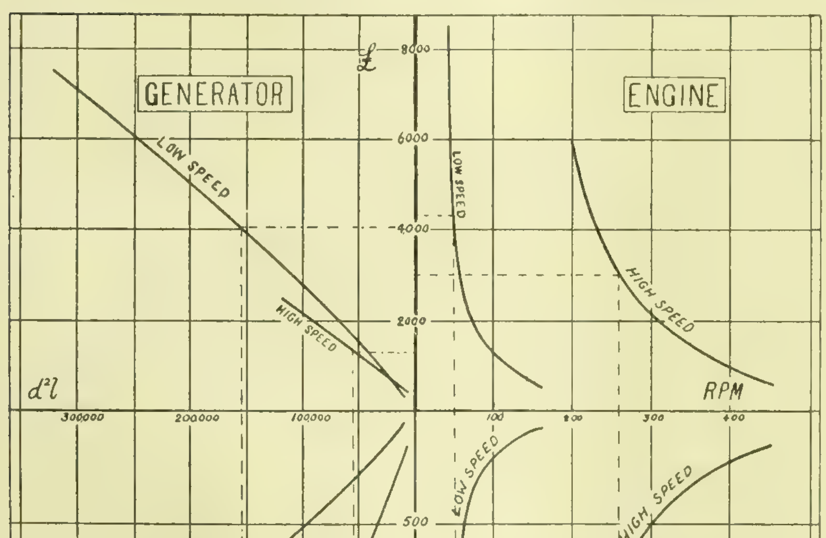


Fig. 15.

Figs. 11, 12, and 13, in addition to bringing out the above points, show at a glance what proportion of the total cost of a set is taken by the engine or turbine as compared with the electric generator. In the case of the low-speed horizontal sets the engine and generator are of approximately equal value, the engine price being only slightly in excess of that of the generator. The difference becomes greater as the speed increases, and in the case of the standard vertical enclosed high-speed engine its price is over twice that of the generator. This ratio is again increased in the case of the alternating-current turbo set, Fig. 13, but owing to the inherent unsuitability of the direct current generator to turbine speeds there is no corresponding increase with the direct current machines.

A perspective view of the subject is obtained in Figs. 14 and 15, where, by means of quadrant diagrams, a comparison may be made between the speeds, sizes, and prices of the various prime movers that are dealt with, and of the corresponding direct-current generators.

In conclusion, it should be stated that condensing plant has not been included in the figures given, which for this reason somewhat favour the turbine, and that the prices are what are known as "list prices," from which it is customary to depart very considerably in practice, and which in any case would be subject to considerable fluctuation owing to changes in the price of raw materials, &c.

THE FARADAY SOCIETY.

The next meeting of the Faraday Society will take the form of a general discussion on Magnetic Properties of Alloys. The discussion will take place on Tuesday, April 23rd, at 8 p.m., at the Institution of Electrical Engineers, Victoria Embankment, London, W.C. The meeting will be open to members of the Institution of Electrical Engineers, of the Physical Society of London, and of the Institute of Metals. Others interested in the subject desirous of being present should apply to the Secretary of the Faraday Society, 82, Victoria Street, London, S.W. Sir Robert Hadfield, F.R.S., will preside over the discussion. The following provisional programme has been arranged: Prof. E. Wedekind will read a paper on "The Dependence of Magnetisation on Valency in Chemical Compounds." Dr. Alexander D. Ross and Dr. J. G. Gray will read papers on "The Magnetic Properties of a Variety of Special Steels at Low Temperatures," and on "The Heusler Alloys." The following papers will be communicated: "The Equipment of the Magnetic Laboratory of the Physikalisch-Technische Reichsanstalt, Charlottenburg," by Geheimrat Dr. E. Gumlich; "The Nature of the Heusler Alloys": "The Physical Aspect," by Dr. E. Take, "The Chemical Aspect," by Dr. F. Heusler; "Variation of Ferromagnetic Properties of the Heusler Alloys with Composition and Heat Treatment," by Prof. A. A. Knowlton; "The Relations between the Mechanical Hardness and the Retentivity and Permeability of Ferro-Alloys," by Prof. C. F. Burgess and Mr. James Aston.

Requirements for Line Insulators.—In a paper on "High-tension Porcelain Line Insulators" read before the Manchester section of the Institution of Electrical Engineers, Mr. J. Lustgarten said an insulator had to satisfy two main conditions. First, it must withstand the mechanical stresses necessary to support the conductor, and, secondly, it must withstand the electrical stresses necessary to insulate it. Additional requirements were: (1) It should be able to resist atmospheric influences in service; (2) it should not be easily broken by stone-throwing, bullets, &c., nor in transport; and (3) its weight and cost should be as low as possible. The long spans which had come into use subjected the insulator to very great stresses owing to the following causes: (1) The weight of the wire coated with snow and ice; (2) wind pressure and extreme cold; and (3) the horizontal pull of the wire. The last stress was the most important, especially when the wire broke, while the stresses were exceptionally great at corners and deadends. The insulator withstood a compression test best; hence in the pin type the pin was threaded up into the head of the insulator, so that the porcelain was only in compression but not in shear. The insulator could be designed to withstand such heavy testing loads as three to four tons, and the pin bent before fracture of the porcelain started. The suspension cemented type could be designed to withstand a continued shear and tension up to five tons. In practice, conditions were arranged so that the wire would break or the pin would bend before the porcelain gave way.

THE DIESEL OIL ENGINE, GEARED TURBINE, AND SUCTION GAS ENGINE.*

RELATIVE POSSIBILITIES AS COMPARED WITH THE RECIPROCATING ENGINE FOR MARINE PROPULSION.

DIESEL OIL ENGINE.

BY E. L. ORDE.

ALTHOUGH much has been written on the subject of the Diesel engine as applied to the propulsion of sea-going vessels, it appears to the writer that the extent to which the earning power of a cargo vessel is affected by the adoption of this type of engine has not so far received the consideration at the hands of engineers and shipbuilders which it deserves. The importance of this question as a basis for discussion lies in the fact that a careful consideration of the best arrangements that can be made to utilise as far as possible the advantages of the Diesel engine, involves a number of points which in the present state of knowledge of the possibilities of this engine must be considered controversial, if not largely conjectural. As a simple way of opening these questions the writer submits two outline plans. Fig. 1 shows a shelter deck cargo steamer, one of a number at present at work, and Fig. 2 the same vessel rearranged and fitted with Diesel engines. The general particulars of the two vessels are given in Table I.

An estimate of the cost of working the two vessels is given in Table II. as a model of the calculations that have been made with a view of showing the limits of fuel cost within which either type of propelling machinery may work economically. Such estimates can, of course, only be regarded as approximate, as the local conditions of particular trades, such as the convenient distribution of fuel stations, and many other influences, which only shipowners can assess at their true value, must exercise considerable effect upon them: but as most of the items in the estimate are common to both ships the general comparison is probably sufficiently accurate to form a basis for discussion.

3,500 mile-tons is taken as the unit for the cost of working, as this represents a fair average voyage, and the bunkers in both vessels are arranged accordingly. The position of the engine-room in the Diesel ship is on the whole the most suitable in view of trim and ballast draught requirements, but the saving on the weight of the machinery and bunkers makes a deep tank necessary. The hull of the Diesel ship is more costly than that of the steamer, because of the fittings for twin screws, and the cost of oil-tight bunkers in addition to the deep tank.

The oil-tight bunkers are all in the double bottom, for though it is perhaps open to question whether this is the best arrangement, it is made imperative in this case if the cubic capacity per ton of freight-earning cargo is to be equal to that of the steamer. The machinery space is as short as is compatible with a convenient engine-room arrangement, and the register tonnage of the two vessels does not show any very great difference. The propelling machinery in the steamship is of the usual 3-crank triple-expansion type with cylinders 27in., 45in., and 75in. by 48in., and three boilers 14ft. 6in. by 11ft. 6in., fitted with Howden's forced draught. The actual results from a number of different voyages show an average of 2,400 i.h.p., and a consumption of 1·61lbs. per horse-power per hour for all purposes.

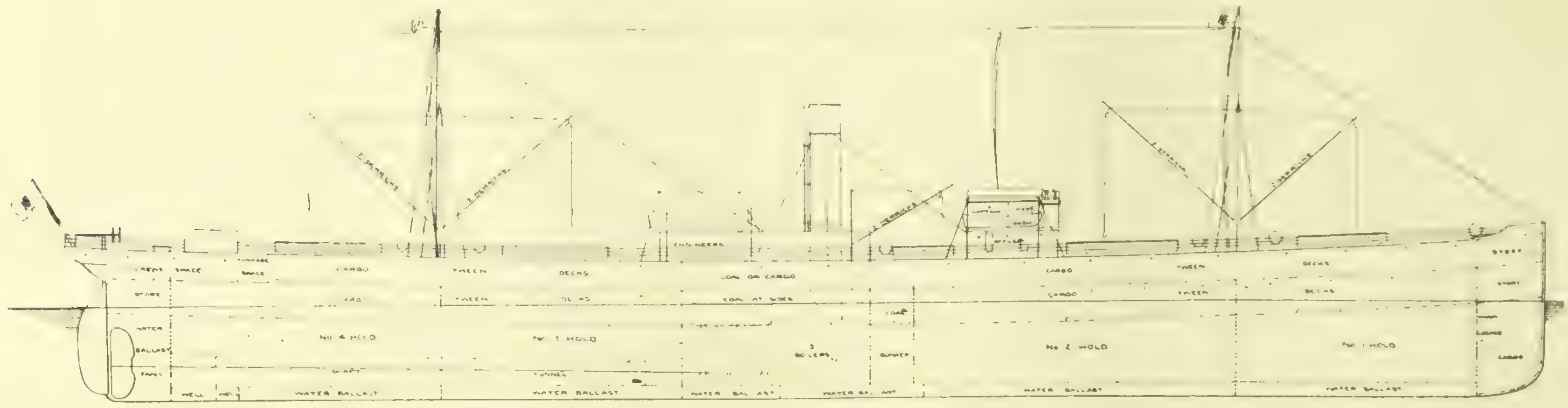


FIG. 1.—SHELTER DECK CARGO VESSEL PROPELLED BY STEAM ENGINES. Length overall, 412ft.; length between perpendiculars, 400ft.; Breadth, extreme, 52ft.; Depth, moulded, 29ft. 9in.; Draught of water, 26ft. 1in.

The propelling machinery of the Diesel ship is of the single-acting 2-stroke cycle type, designed to develop 2,150 b.h.p. in ordinary service at sea, at about 115 revs. The propeller performance at 115 revs. should be satisfactory, and it was considered unnecessary to make the form of the Diesel vessel any finer than that of the steamship, so that the comparison between the two is as close as it is possible to make it.

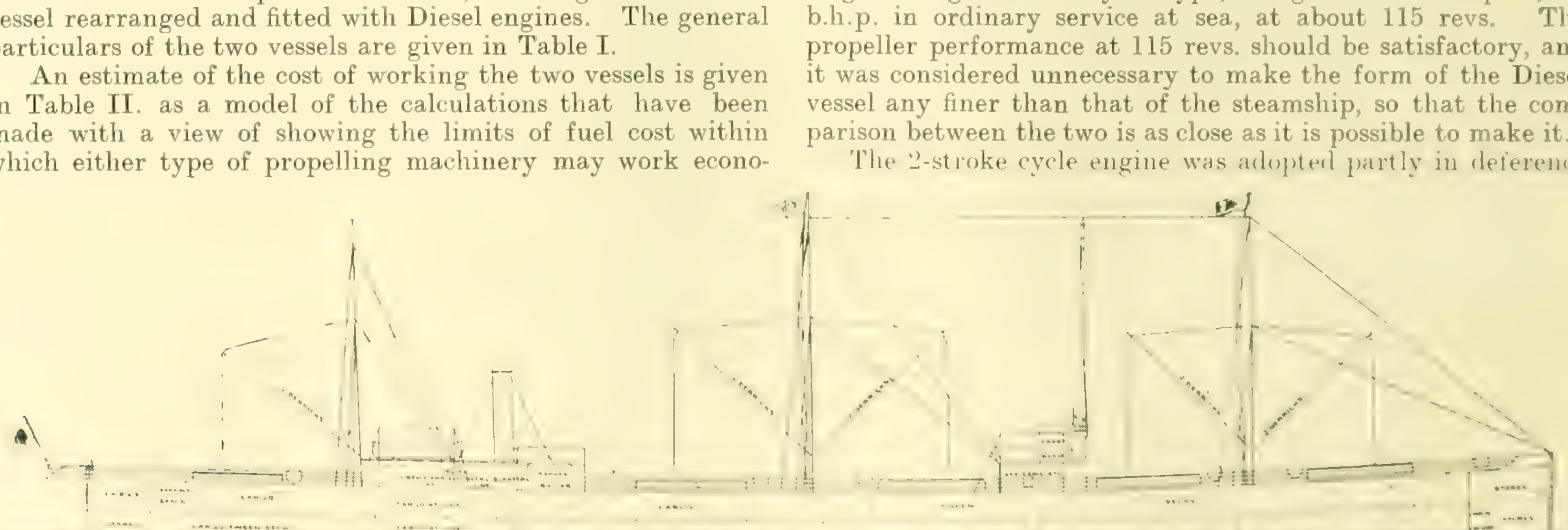


FIG. 2.—SHELTER DECK CARGO VESSEL PROPELLED BY DIESEL ENGINES. Length overall, 412ft.; Length between perpendiculars, 400ft.; Breadth, extreme, 52ft.; Depth, moulded, 29ft. 9in.; Draught of water, 26ft. 1in.

The 2-stroke cycle engine was adopted partly in deference to Dr. Diesel's opinion as expressed on several occasions, and partly because the balance of advantages seems to be with it rather than with the 4-stroke cycle engine. It is claimed on behalf of the 4-stroke cycle that the fuel consumption is considerably (according to some authorities, 10 per cent.) lower than that of the 2-stroke cycle engine. This appears to be due, first, to a thermal superiority in the 4-stroke cycle, perhaps due to the greater effective length in the cylinder, and the longer scavenging period; and, secondly, to the mechanical superiority which arises from the absence of the scavenging pump. It seems doubtful, however, whether these gains can amount to 10 per cent. if balanced against the loss due to the idle strokes in the 4-stroke cycle engine, and the general

* A discussion introduced April 1st, 1912, by E. L. Orde, the Hon. Sir Charles A. Parsons, K.C.B., F.R.S., R. J. Walker, and A. C. Holzapfel, before the North-east Coast Institution of Engineers and Shipbuilders.

consensus of opinion, so far as the writer is aware, seems to be that the 2-stroke cycle type is the better adapted for marine propulsion purposes. The weight is about 12 to 15 per cent., and the cost about 10 to 12 per cent. less than that of the 4-stroke cycle engine.

The estimate of working shows how important it is to keep the first cost of the vessels as low as possible. The costs of the vessels which have been taken for the purposes of this estimate are not to be regarded as definite quotations, but are calculated on precisely the same basis, and are therefore comparable. The influence of cost and weight of machinery on the earning power of cargo vessels is considerable, and in choosing between the 2-stroke and 4-stroke cycle it deserves special attention, as a point is soon reached when the saving due to the lower consumption of the 4-stroke cycle engine is counterbalanced by the capital charges on the higher cost and the loss on freight-earning cargo shut out by the extra weight of the engine.

Table I.—*Shelter Deck Cargo Vessel.*

Dimensions:	Feet.	Inches.
Length over all...	412	0
Length between perpendiculars	400	0
Breadth	52	0
Depth	29	9

	Steam Engines.	Diesel Engines.
Gross tonnage	4,655	4,800
Net tonnage...	2,930	3,030
Draught	26ft. 1in.	26ft. 1in.
Total deadweight in tons	8,640	8,775
Average sea power	2,400 i.h.p.	2,150 b.h.p.
Average sea speed in knots	10½	10½
Radius of action in knots...	3,500	3,500
Fuel consumption—tons per day	42 (=2,400 i h.p. at 1·6lb. per i.h.p. hr.)	12·7 (2,150 at ·55lbs. per b.h.p. per hour.)
Freight-earning cargo in tons	7,880	8,530
Freight-earning cargo per ton, total d.w.	·914	·972
Freight-earning cargo per ton, gross register	1·69	1·77
Freight-earning cargo per ton, net register	2·68	2·82
Capacity for cargo (grain) in cubic feet	488,000	523,800
Cargo capacity per ton of freight-earning cargo in cubic feet	62	61·5

Table II.—*Approximate Estimate of the Comparative Costs of Working Steam and Oil-propelled Cargo Vessels.*

Capital.	Oil Engine.		Steam Engine.	
	£78,000.		£63,000.	
	Per voyage.	Per month.	Per voyage.	Per month.
Insurance ...	—	490	—	370
Fuel (oil at 40s., coal at 15s.)...	360	—	455	—
Wages and provisions ...	—	350	—	410
Wear and tear ...	—	110	—	100
Deck and engine-room stores ...	—	110	—	100
Port charges at 5s. per ton ...	755		735	—
	1,115	1,060	1,180	980
16 voyages ...	17,840		18,880	
12 voyages ...	12,720		11,760	
	30,650		30,640	
5 per cent. depreciation ...	3,900		3,150	
Management ...	500		500	
	£34,960		34,290	
Tons freight-earning cargo carried ...	16 × 8,530 = 136,480		16 × 7,880 = 126,080	
	34,960 × 240 = 8,390,400d.		34,290 × 240 = 8,229,600	
	136,480 = 61·4d.		126,080 = 65·2d.	

This critical point depends on the length of the voyage, or the distance between fuel stations, and the cost of the fuel oil. In the vessels under consideration it appears to occur at about 3,500 miles, when the cost of the oil is 20s. per ton, and the limiting length of voyage decreases slightly as the cost of oil rises.

Fig. 3 is a diagram showing the comparative costs of working the two type vessels with fuel at prices ranging from 10s. to 50s. per ton. The ordinates are taken from a number of voyage estimates, of which the model is shown in detail in Table II. The lower curve shows the cost per 3,500 mile-tons of working the Diesel ship at a consumption of ·55lb per brake horse-power and per hour; the upper the corresponding cost for the steamship at a consumption of 1·6lbs. per indicated horse-power and per hour. The comparison shows that with coal at 15s. per ton the cost of oil in the Diesel ship must not exceed 50s. per ton, as the economical limit within which the Diesel ship shows to advantage.

Table III.—*List of Crew.*

	Coal Fuel.		Diesel Oil Engines.	
	Wages.	Provisions per day.	Wages.	Provisions per day.
	£	s. d.	£	s. d.
Captain...	24	2 6	24	2 6
1st Officer	18	2 6	18	2 6
2nd ,,	16	2 6	16	2 6
3rd ,,	14	2 6	14	2 6
Carpenter	7	1 6	7	1 6
Steward...	7	1 6	7	1 6
2nd Steward...	6	1 6	6	1 6
Cook	6	1 6	6	1 6
Boatswain	6	1 6	6	1 6
Storekeeper ...	6	1 6	6	1 6
10 A.B.'s at £5. 10s. ...	55	1 6	55	1 6
Chief Engineer	22	2 6	22	2 6
2nd ,,	16	2 6	16	2 6
3rd ,,	12	2 6	12	2 6
4th ,,	10	2 6	10	2 6
12 firemen at £6 ...	72	1 6	36	1 6 (six greasers)
1 donkeyman	7	1 6	7	1 6
(37 men) per month ...	£304	£100	£268	£75 (31 men)
Wages ...	£304		£268	
Provisions ...	100		84	
Per month ...	£404		£352	

The high cost of Diesel engines and the important influence of capital charges on the earning power of cargo vessels largely affect the question of driving the auxiliary machinery, and it seems very doubtful whether electric power or compressed air can ever be used for this purpose without a considerable sacrifice both in first cost and future earnings. In the type ship steam has been adopted supplied by two oil-fired boilers, one for use at sea, the other in port.

This question deserves very careful consideration, and it is to be hoped that some light may be thrown upon it during this

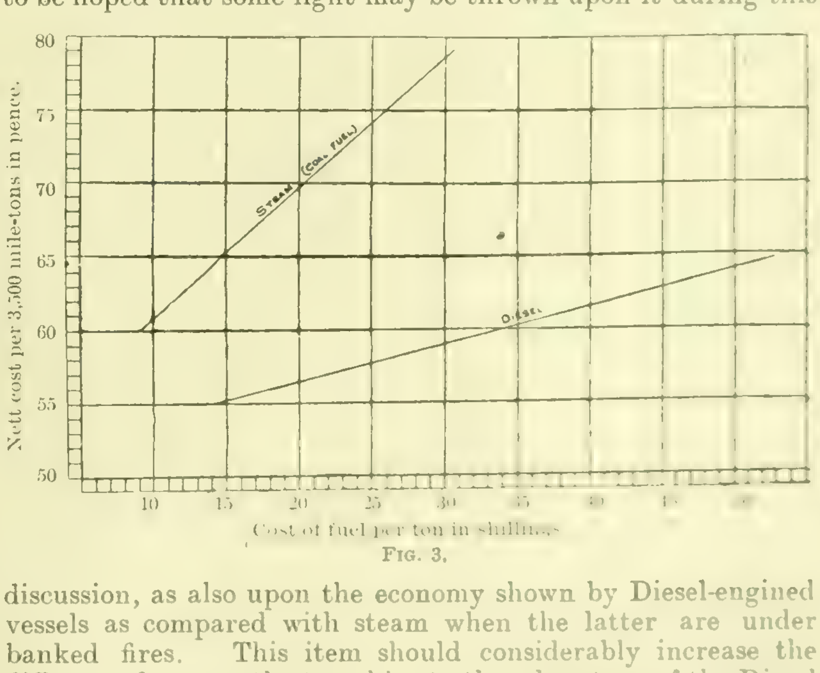


Fig. 3.

discussion, as also upon the economy shown by Diesel-engined vessels as compared with steam when the latter are under banked fires. This item should considerably increase the difference between the two ships to the advantage of the Diesel vessel, but as the writer looks on the point as one which is largely conjectural, he has not attempted to deal with it in the estimate of working cost.

Geared Turbines.

BY THE HON. SIR CHARLES A. PARSONS, K.C.B., F.R.S., AND R. J. WALKER.

The application of the steam turbine and mechanical gearing to ship propulsion was first put to a practical test for commercial purposes in the cargo steamer "Vespasian." The actual results of the trials of this vessel as compared with the performances of reciprocating engines, and the experience gained on actual service were fully dealt with in papers read before the Institution of Naval Architects in 1910 and 1911. The object of the present contribution to this discussion is to furnish a few brief notes as to the possibilities of geared turbines when applied to vessels of moderate and slow speeds.

When considering such propositions, the relative earning power, first cost, and reliability of the propelling machinery must necessarily be taken into account as being of first importance to the shipowner. The principal advantages of geared turbines as compared with triple-expansion engines may be summarised as follows: Increased economy in coal and oil consumption; absence of racing in rough weather; reduced wear and tear of engines; reduced stress on screw shafting, due to even turning moment of engines and absence of racing; reliability of running in all weathers; reduced weight of machinery; increased deadweight cargo, due to increased economy in coal consumption and reduced weight of engines.

Referring to the question of efficiency and economy in steam consumption, so far as the turbine is concerned the principles upon which economy and efficiency depend are identical with those which hold good in steam turbines for land purposes, but for ship propulsion not only has account to be taken of the efficient use of steam in the turbines, but also of the propulsive efficiency obtainable by the combination of the most efficient turbines with the most efficient propeller.

In the higher-speed vessels to which the turbine has hitherto been applied, a judicious compromise between turbine and propeller efficiency has been arrived at, by accepting a slightly higher speed of propeller than would obtain for maximum efficiency and lower rates of revolutions for the turbines than is obtainable with advantage in turbines for land purposes. It has not, however, been found practicable (compatible with weight and first cost) to apply the turbine direct to the propeller shaft in vessels of moderate speed, *i.e.*, of designed speed of, say, 15 knots and under, on account of the comparatively low rate of revolutions necessary for reasonable propeller efficiency at such speeds.

The problem of applying the steam turbine to vessels of moderate and slow speeds, however, may be said to have been satisfactorily solved in the association of mechanical gearing with high speed turbines. By the interposition of gearing between the propeller and the turbines such limitations in propulsive efficiency are not met with, inasmuch as the maximum efficiency of turbine and propeller can be obtained independently of each other.

The comparative trials that were carried out in the "Vespasian" with geared turbines and the reciprocating engines which were originally fitted in that vessel showed a gain of economy in steam consumption of over 15 per cent. in favour of the geared turbine engines. It has been stated by some engineers that the reciprocating engine with which the geared turbines was compared did not represent the best that could be obtained with a modern triple-expansion engine, whilst on the other hand others confirm the result of steam consumption obtained as representing a very fair average for that particular class of reciprocating engine. It is not professed, however, that the results obtained with the geared turbines in the "Vespasian" (the machinery in that vessel being somewhat experimental) are the best that can be obtained with geared turbines. As a matter of fact, a consumption of saturated steam of about 12lbs. to 13lbs. per shaft horse-power for the main engines could be confidently expected, which would be equivalent to about 11lbs. to 12lbs. per indicated horse-power of reciprocating engine, assuming a ratio of shaft horse-power to indicated horse-power of 90 to 92 per cent.

The results of the trials of the geared turbine ship "Normannia," the first of the two new vessels for the London and South-western Railway Company, were dealt with in a paper read by Prof. Biles at the recent meeting of the Institution of Naval Architects. The horse-power of the "Normannia" is 5,000, divided over two shafts. Her propelling machinery consists of a high and low-pressure turbine geared to each propeller shaft. The steam consumption of the turbines was shown on the official trials to work out at 12lbs. per shaft horse-power, as compared with the estimate of 12½lbs.

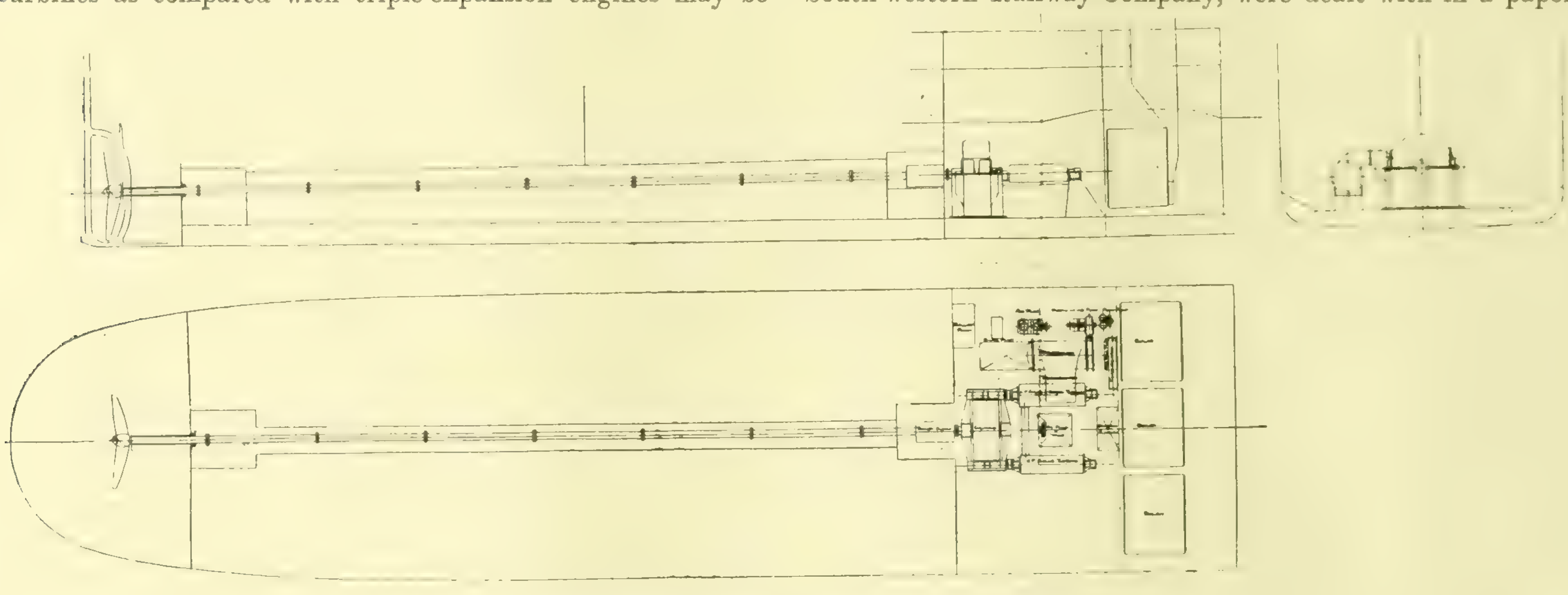


Fig. 4.—Single Screw Cargo Steamer. Arrangement of Turbines and Gearing.

As illustrating the possibilities of still further increasing the economy in steam consumption, it may be said that if experience in actual service for any lengthy period has shown that superheaters can be successfully applied on board ship, and the shipowner is prepared to adopt same, then a further saving in steam consumption can thereby be effected in geared turbines. Superheated steam has been in use on turbine installations for land purposes for a considerable period, and of late years superheats of 50° to 250° in land turbines have become almost universal. The saving in steam consumption as ascertained with land turbines is about 1 per cent. for every 10° of superheat, so that with, say, 100° of superheat a saving of about 10 per cent. can be effected in the steam consumption, but when referred to fuel consumption it should be stated that the percentage of saving in coal is not so great, as a certain amount of coal is expended in producing the superheat.

As regards the question of economy in fuel consumption, there is the possibility in certain trades of adopting oil fuel with advantage. It has, we think, been clearly demonstrated that for certain classes of vessels considerable advantage accrues from the use of liquid fuel. The evaporative efficiency per ton of fuel is about 40 to 50 per cent. greater than with coal; less space is required in the stokeholds; and the handling of the fuel is reduced to an absolute minimum, as the feeding to the boilers is carried out mechanically by means of pumps.

Mr. Harold Yarrow, in his very interesting paper read before the Institute of Naval Architects recently on "The Results of Some Experiments with a Water-tube Boiler, having Special Reference to Superheating," incidentally gives some useful figures as to evaporative efficiency with oil fuel.

For a moderate degree of air pressure it is possible to obtain an evaporative efficiency of 15½lbs. to 16lbs. of water per pound of oil from and at 212° Fah. This would be equivalent to an actual evaporation of about 14¼lbs. of water per pound of oil, with a feed-water temperature of about 190° and a boiler pressure of 180lbs., as compared with an evaporative efficiency of about 10lbs. with coal.

The possible racing of the turbines and gearing in a heavy seaway, the wear of the teeth of the gear, and the reliability of the machinery generally have been advanced as objections to the geared turbine system. We think, however, that the working of the "Vespasian" has shown that any such fears are quite groundless.

Since the "Vespasian" was first put on service with her new propelling machinery, she has completed some 62 voyages between the Tyne and the Continent, covering a distance of over 37,000 miles. During this period some exceptionally rough weather has been experienced, especially when steaming in light condition, and one of the most noticeable features in her running has been the remarkable freedom from racing of the engines in the roughest weather. The gearing has not given the least trouble nor has any appreciable wear been detected in the teeth of the pinions or gear wheels since she was first put on service nearly two years ago. She is, at the present time, on a return voyage from Malta.

We are indebted to Mr. Orde for the principal dimensions and particulars of a typical cargo vessel fitted with triple-expansion engines, with which we have been able to formulate a statement as to the possibilities of geared turbines when compared with triple-expansion engines. In Tables I. and II., column A, particulars are given for the vessel with triple-expansion engines. The particulars in column B refer to a proposal of geared turbines on a single shaft, and in column C for geared turbines with twin screws.

Fig. 4 shows an arrangement of geared turbines driving a single screw, consisting of two turbines in "series," viz., one high-pressure and one low-pressure turbine. At the after end of each of the turbines a driving pinion is connected with a flexible coupling between the pinion shaft and the turbine, the pinion on each side of the vessel being geared into a wheel which is coupled to the propeller shaft. The reversing turbine is incorporated in the exhaust casing of the low-pressure turbine. The diameter of the gear wheel is about 12ft. and of the pinions 6·3in. The total width of the face of the wheel is 32in. The inclination of teeth is 45° to the axis—double helical. The revolutions of the propeller would be 66 and of the turbine about 1,500.

Fig. 5 shows an alternative arrangement of machinery arranged on two shafts, consisting of one high-pressure, one intermediate-pressure, and two low-pressure turbines, steam being admitted to the high-pressure turbine on one side of the vessel, exhausting into the intermediate-pressure turbine on the opposite side of the vessel, and thence from the intermediate-pressure turbine to each low-pressure turbine and to the condenser. A reversing turbine is fitted in the exhaust casing of each low-pressure turbine. For manœuvring, by a suitable arrangement of valves and pipes, the turbines on one shaft of the vessel can be arranged to work independently of the turbines on the other side. The diameter of each gear wheel would be about 10ft. 6in., and the pinions 5in. Width of wheel face 15in. Revolutions of propeller 110 and of the turbines about 2,600. The machinery for both proposals has been arranged in the same space as that for the reciprocating engined vessel under column A of Table I.

In conclusion, it may be mentioned that, apart from the question of superheat or oil fuel, a saving of 15 per cent. in coal consumption on a vessel of the dimensions and power stated in the paper should represent a considerable financial gain per annum to the shipowner. Assuming an average of 260 steaming days per year, such a vessel with reciprocating engines of 2,400 i.h.p. would consume 10,000 tons of coal per annum. A saving of coal of 1,500 tons at an average value of 15s. per ton would give £1,000, and for every ton of coal saved an additional ton of cargo could be carried. The value of this cargo would, of course, depend on the trade the vessel was engaged in, but assuming a value of 10s. per ton, the additional freight would be equivalent to about £750. Then, again, there is the additional cargo which could be carried corresponding to the reduction in weight of machinery, so that taking these points into consideration the gain to the shipowner in round figures would be in the neighbourhood of £2,000 per annum.

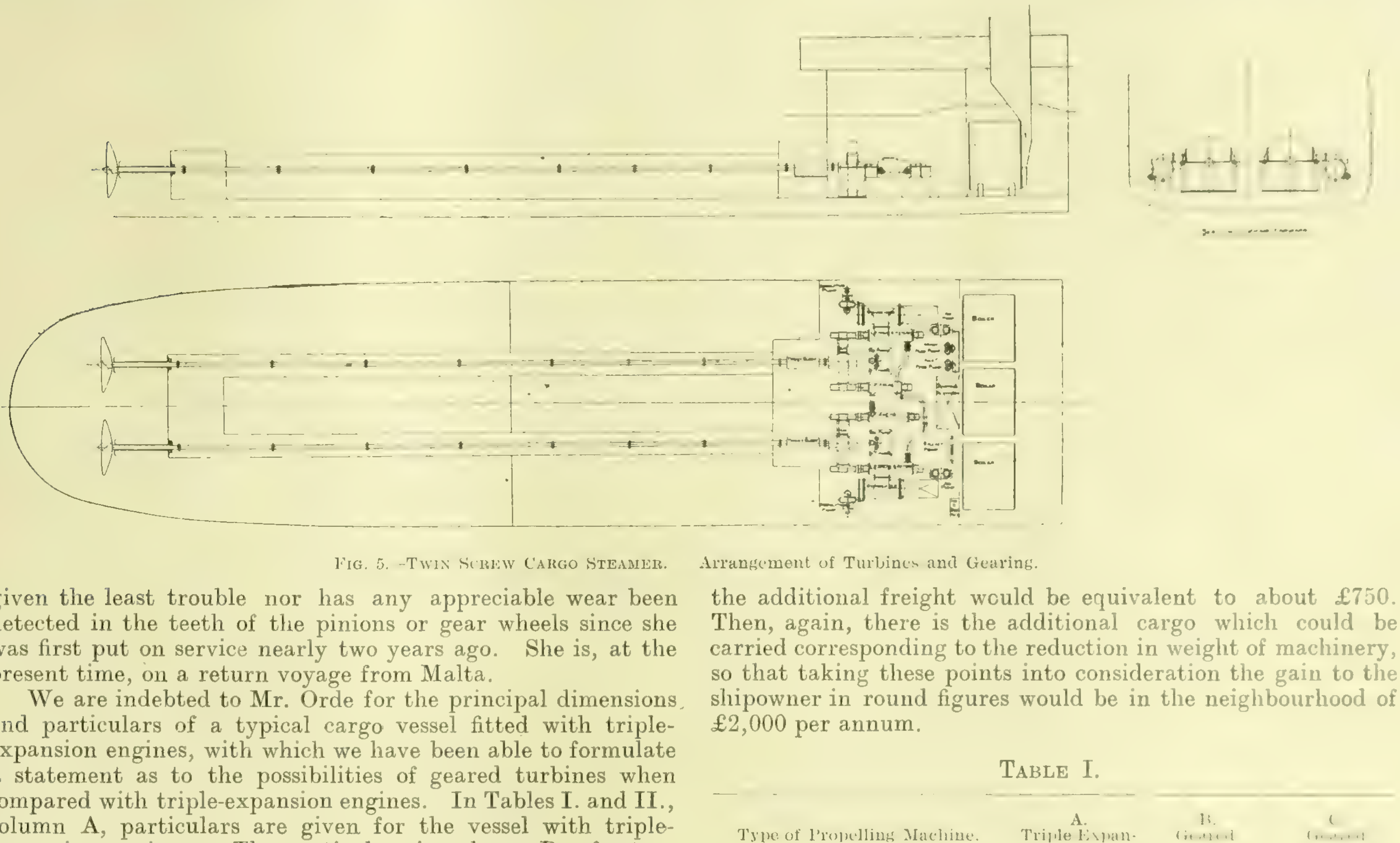


FIG. 5.—TWIN SCREW CARGO STEAMER. Arrangement of Turbines and Gearing.

TABLE I.

Type of Propelling Machine.	A. Triple Expansion Engines.	B. Geared Turbine	C. Geared Turbine.
Number of propellers	1	1	2
Revolutions	66	66	110
Diameter of propeller	18ft.	18ft.	12ft.
Pitch of propeller...	18ft.	18ft.	12ft.
Length of vessel B.P.	400ft.	400ft.	400ft.
Breadth extreme...	52ft.	52ft.	52ft.
Depth moulded	29ft. 9in.	29ft. 9in.	29ft. 9in.
Deadweight	8,465 tons	8,535 tons	8,540 tons
Draught of water...	26ft. 1in.	26ft. 1in.	26ft. 1in.
Displacement	11,760 tons	11,760 tons	11,760 tons
Speed on service	10½ knots	10½ knots equivalent	10½ knots equivalent
I.H.P.	2,400	2,400	2,400
S.H.P. assuming ratio S.H.P. to I.H.P. of 90 per cent. ...	—	2,160	2,160
Weight of propelling machinery			
Propeller shafting, thrust block, and fittings aft of engine-room after bulkhead ...	64 tons	64 tons	92 tons
Engines, condensing plant, auxiliary machinery, and all fittings within engine-room	180 tons	146 tons	14[illegible] tons
Boilers, fans, funnels, and all fittings within boiler-rooms	281 tons	245 tons	245 tons
Total steaming weight	525 tons	45[illegible] tons	[illegible] tons

TABLE II.

	A.	B.	C.
Estimated consumption saturated steam main engines per I.H.P. ...	—	—	—
Estimated steam consumption auxiliaries per I.H.P. of main engines.	—	—	—
Estimated consumption saturated steam main engines per S.H.P. ...	—	11·8	11·25lbs.
Estimated steam consumption auxiliaries per S.H.P. of main engines.	—	1·2	1·2
Estimated total consumption of saturated steam per S.H.P., all purposes	—	13·0	12·45
Estimated total consumption of saturated steam per I.H.P., all purposes	15·5	equivalent 11·7	equivalent 11·2
Estimated coal consumption per I.H.P., all purposes	1·55	equivalent 1·17	equivalent 1·12
Estimated coal consumption per S.H.P., all purposes	—	1·3	1·25
Estimated consumption of steam (100° superheat) per S.H.P. main engines	—	10·6lbs.	10·2lbs.
Estimated consumption auxiliaries per S.H.P. of main engines	—	1·2	1·2
Estimated consumption of steam (100° superheat) for all purposes, per S.H.P. of main engines...	—	11·8lbs.	11·4lbs.
Estimated steam consumption per I.H.P. of main engines (with 100° superheat), all purposes...	—	equivalent 10·6	equivalent 10·2
Estimated consumption of oil per I.H.P. (saturated steam), all purposes...	—	equivalent ·81	equivalent ·78
Estimated consumption of oil per S.H.P. (saturated steam), all purposes...	—	·90	·86
With oil fuel and 100° superheat—estimated oil consumption, all purposes, per I.H.P. of main engines.	—	equivalent ·76	equivalent ·73
With oil fuel and 100 superheat estimated oil consumption, all purposes, per S.H.P. of main engines.	—	·85lbs.	·81lbs.

EXPLANATORY NOTES IN CONNECTION WITH TABLES I. AND II.

The ratio of shaft horse-power for the turbine proposal to indicated horse-power of the reciprocating engine proposal has been taken as 90 per cent., which agrees with that obtained on the trials of the "Vespasian."

The weight of boilers for the reciprocating engined vessel has been reduced by 15 per cent. for the turbine proposals in view of the saving in steam consumption.

The deadweight of proposals under columns B and C has been increased to correspond to the saving in weight of propelling machinery and boilers.

The consumption of the reciprocating engined vessel, column A, has been assumed at 15½lbs. per i.h.p. all purposes.

The figures of steam consumption for the geared turbines are based on the results of actual measurement of water consumption of previous vessels.

The evaporative efficiency (lb. of water per lb. of fuel) has been taken as 10lbs. for coal and 14½lbs. for oil, with a feed temperature of 190° and a boiler pressure of 180lbs., the auxiliary exhaust being utilised in heating the feed water, and in the case of the reciprocating engine vessel being supplemented with steam taken from I.P. receiver of main engines.

The auxiliaries in the turbine proposals are all independently driven. The air, circulating, and bilge pumps are driven by the main engines in the reciprocating engined vessel, the feed pump, fans and other auxiliaries being independent.

At the time of writing, the authors have not been able to obtain any reliable information regarding the economy in steam consumption in reciprocating engines with steam superheated to 100°. Therefore, all references to estimated consumptions with superheat have been omitted from column A, Table II.

The saving in steam consumption in the geared turbine proposals for 100° of superheat has been taken as 10 per cent. and the saving in oil fuel at 6 per cent.

(*To be continued.*)

Death of Rear-Admiral Melville.—We regret to record the death of Rear-Admiral George Wallace Melville, U.S.N., retired, which took place at Philadelphia, Pa., on March 17th. For the past 16 years he was chief of the bureau of steam engineering in the United States Navy Department. Among the colleges which conferred honorary degrees on Rear-Admiral Melville in recognition of his scientific work were the University of Pennsylvania, Harvard, Columbia, Georgetown, and Stevens Institute. He was a past president of both the American Society of Mechanical Engineers and the American Society of Naval Engineers. He was a noted authority on Arctic exploration, as well as engineering and naval affairs. At the time of his death he was 72 years of age.

THE WORKS FOR THE WATER SUPPLY OF BIRMINGHAM FROM MID-WALES.*

BY E. L. MANSERGH AND W. L. MANSERGH, MM.INST.C.E.

THE Elan supply scheme was originated in 1890, by the late Mr. James Mansergh, F.R.S., M.Inst.C.E., in consequence of the inadequacy of the then existing sources. These, consisting of five local streams and six wells in the new red sandstone, had proved insufficient to meet the needs of the city and district, which then had a population of about 648,000. Investigation having shown that no extension of the local sources would be satisfactory, the Welsh scheme was laid before Parliament in the Session of 1892, and the necessary powers were obtained. The watershed of the Elan and Claerwen, which is situated in Radnorshire and Breconshire, has a gross area of about 71 square miles, and a mean rainfall of 65in. The collectable rainfall is estimated by the authors at 37in., giving an average yield of 102 million gallons per diem. The first instalment only, that is, works for the supply of 25 million gallons per day at Birmingham, and the prescribed quantity of compensation water to the river, namely, 27 million gallons per day, has at present been constructed; but the powers granted cover the full utilisation of the yield of the watershed and works necessary for a total supply of 75 million gallons per day to the city and district.

Three reservoirs have been constructed: the Caban Côch, which is a combined supply and compensation reservoir, containing 7,815 million gallons, with a dam 122ft. high; Pen-y-gareg, for supply only, containing 1,330 million gallons, with a dam 123ft. high; and Craig Gôch, also for supply only, of 2,000 million gallons, with a dam 120ft. high. These reservoirs are all on the River Elan, and three more on the Claerwen are contemplated when the demand for water justifies their construction. For one of the latter—the Dol-y-mynach reservoir—the foundations and lower part of the dam have been already built in order to get the work above flood-level of the Caban Côch reservoir. A submerged dam has also been constructed in Caban Côch reservoir to maintain such a water level as will charge the aqueduct to Birmingham. From the Claerwen Valley a tunnel has been driven connecting it with the latter reservoir above this submerged dam, in order to bring into supply the dry-weather flow of that river.

The compensation water which has to be discharged into the river day by day in a regular flow has been utilised to produce water under pressure to work a large number of valves in connection with the Caban Côch dam and the valve tower at the head of the aqueduct, and also electricity for lighting and power purposes. The latter is required at the head of the aqueduct in connection with an installation of roughing filters, which had to be made in order to free the water from germs which elsewhere had been found to cause deposit in cast-iron pipes. A short permanent line of railway was constructed from the Mid-Wales Railway near Rhayader to the lowest dam, and while the works were in progress some 36 miles of main line and sidings were constantly in use. In addition, a number of ancillary works, such as roads, bridges, culverts, &c., were constructed on the watershed.

The aqueduct, which is nearly 74 miles in length, consists of two main classes of work: conduit in tunnel or cut and cover, and steel or cast-iron pipes under pressure crossing valleys. There are 15 tunnels with an aggregate length of 12¾ miles, and the cut-and-cover conduit is about 23¾ miles in length. The inverted siphons, of which there are 11 in all, have an aggregate length of nearly 36¾ miles, and the pressures to which they are subject range between about 25lbs. and 250lbs. per square inch. The pipes in the siphons vary from 14in. to 42in. in internal diameter, according to the gradient obtainable, and are for the most part of cast iron, but for pressures over 400ft. of head, welded steel pipes were used. Out of an ultimate total of six lines in each siphon two only have been laid for the first instalment. The ruling gradient for the conduits, which are haystack shaped, approximately 8ft. by 8ft., is 1 in 4,000, and that for the pipe siphons is 1 in 1,760.

At the heads of all the siphons rather elaborate automatic arrangements are made to cut off the water in case of a pipe

* Abstract of paper read before the Institution of Civil Engineers, April 2nd, 1912.

bursting, and also at the outlet ends to prevent water flowing back under similar circumstances. Sluice valves, air valves, and washouts of the usual description are provided on the lines of pipes. With a few exceptions the pipes are carried over all streams and rivers crossed, and this has involved the construction of several large bridges, the chief of which is at the crossing of the River Severn between Bewdley and Arley, where the river itself is spanned by a handsome steel arch of 150ft. span.

The aqueduct terminates at the Frankley service reservoir, about 6 miles to the south-west of the centre of the city. This reservoir, which holds a little over 200 million gallons, is semi-circular in plan, divided into two segments; it is about 30ft. deep, and is constructed of concrete lined with asphalte and blue brickwork. Eighteen ordinary slow sand filters, having an aggregate area of about 14 acres, have also been installed, as all the water is filtered before use. Although the top-water level of the reservoir, 603ft. above Ordnance datum, is high enough to supply water to the greater part of the city and district by gravitation, for certain parts pumping had to be resorted to. A pumping station is therefore provided to raise water to two high-level service reservoirs, the one about $\frac{3}{4}$ mile to the south, and the other about $3\frac{1}{2}$ miles to the north of Frankley reservoir, each of about $1\frac{1}{4}$ million gallons capacity. Approximately $18\frac{1}{2}$ miles of 43in. and 42in. cast-iron mains have been laid to carry the water into the trunk mains in the city.

The works in the valleys were carried out by direct administration, and the remainder by contract, and the total cost of the whole of the works, including land, was, in round figures, £5,750,000.

LIGNO-CONCRETE.

In a paper on this subject by Mr. Gerald O. Case, read before the Society of Engineers on Monday, the 1st inst., the author referred to the use in America and Australia of concrete in combination with timber, and pointed out that while the concrete effectively preserved the timber, it was not used to the greatest advantage. The object of the author's investigations was to ascertain if it were possible to reinforce concrete with timber rods. Roughly speaking, steel was about eight or nine time stronger than timber, but 10 to 15 times as expensive. The efficiency of timber, as a reinforcing material, depended on whether there was sufficient adhesion between the timber and the concrete, and whether the difficulties of the absorption of moisture by the timber from the wet concrete, and the splitting of the latter, could be overcome. The paper described the experiments made by the author to ascertain (*a*) the amount of water absorbed by 18 kinds of timber immersed in fresh water, along the grain and through the end grain respectively; (*b*) the relative absorption by the timber of fresh and sea water in the same period; (*c*) the relative amount of water absorbed by timber embedded in 6 to 1 concrete and neat cement blocks; (*d*) the effect of applying wood preservative, creosote, varnish, &c., to the timber before insertion in the concrete or cement blocks; (*e*) the effect on the adhesion between the timber and the concrete of soaking the rods before insertion. Examples were given to show that concrete effectively preserved timber embedded in it.

Particulars were given of the construction of 25 concrete beams reinforced by timber rods. Three ligno-concrete beams, 8in. deep by 4in. wide, were tested with a central load on a 4ft. span, the average ultimate load producing fracture about 3 tons. The results of these tests were compared with the tests on ferro-concrete beams recorded by Mr. E. Marburg in the proceedings of the American Society for Testing Materials (1904, Vol. IV.). It appeared that for the same ultimate strength of beam it was necessary to use 9 per cent. of sectional area of pitchpine tensile reinforcements, as against 1 per cent. steel reinforcements. A comparison of the prices of steel and pitchpine showed a saving in favour of ligno-concrete.

As the author pointed out, in cases where more than about 1·2 per cent. of steel reinforcement was required, ligno-concrete could not compete with ferro-concrete, because the required size of the timber bars would be too large for convenient use. There appeared, however, to be a big field for it for use in constructing bungalows, buildings for small holdings, floors, piles, posts, fencing, coast and river works, &c. It had already been used for making fence posts and for building a short length of sea wall. The ligno-concrete fence posts cost about 2s. per cube foot. They were about 20 per cent. cheaper than creosoted deal, and about 40 per cent. cheaper than English oak. In Canada, four bungalows had been built with ligno-concrete slabs, and the Pacific Coast Construction Company, of Victoria, British Columbia, now had contracts in hand for 20 buildings in which the material was to be used.

RANKINE'S FEED-WATER FILTER.

The accompanying illustrations show a design of feed-water filter of the multiple-tube type, the invention of Mr. D. A. Rankine, 11, Water Street, Liverpool, in which the tubes are so arranged in the casing that any single tube or small group of tubes may be withdrawn for inspection or replacement of the filtering material without disturbing the casing cover.

Referring to Figs. 1 and 2, which represent a vertical filter arranged for triple filtration, A is the cover through which

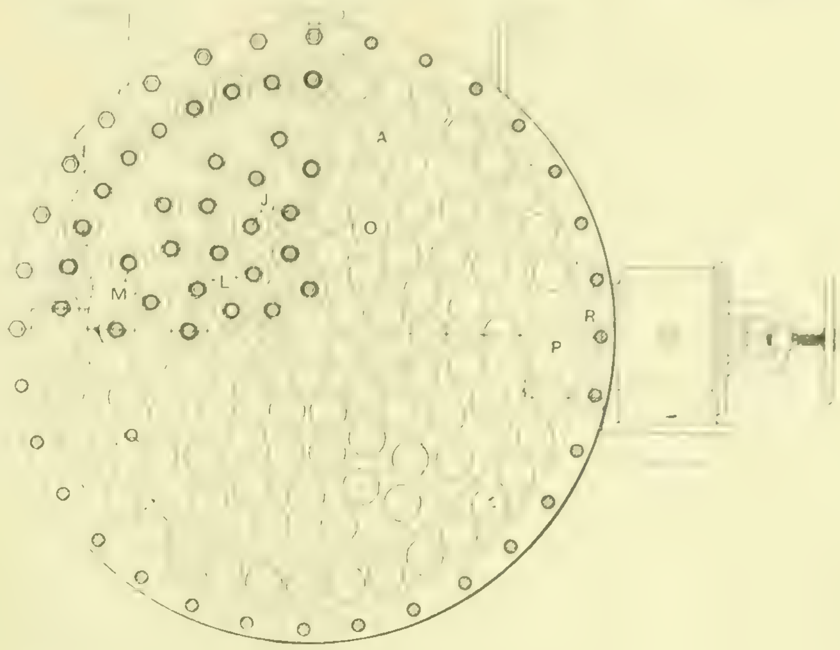


FIG. 1.

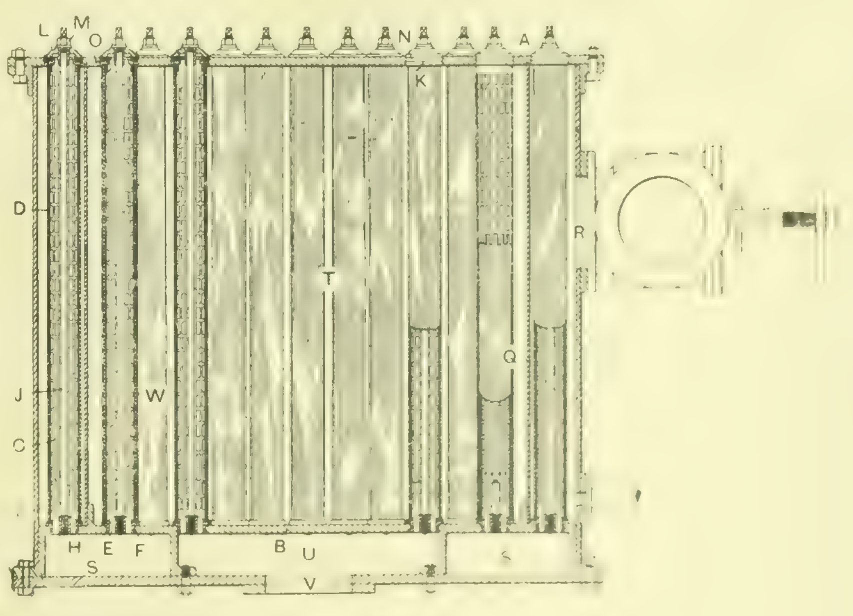


FIG. 2.
RANKINE'S FEED-WATER FILTER.

the filter tubes are withdrawable, and B is a transverse diaphragm or tube plate separating the filtered from the unfiltered water. The filter tubes C are perforated and covered with a filtering fabric D, the ends of which are folded in over the tube ends. The bottom of the tube with the fabric in position, fits over the spigot E of the seating F, which is screwed in the tube plate B. This seating has a central boss G united to the rim by arms H, leaving waterways round the boss, and a stay bolt J, extending higher than the cover A, is fixed in the boss G. The upper end of the filtering tube is closed by a cap K, slightly larger in diameter than the tube

with its filtering fabric in position, and the stay bolt J passes centrally through this cap and also through an upper washer L, being provided with a nut M bearing against the washer L. Between the cap K and the washer L, space is left for a washer N of india-rubber, which is adapted to be expanded radially when compressed between the cap K and the washer L, and for this reason, the washer is prevented from expanding inwardly, and its recess is bevelled outwardly as shown. A hole O opposite the corresponding seating F is provided in the cover A for each tube, being an easy fit round the cap K, so that the tube can be easily passed through it. The fabric-covered tube being in position, with its cap K, india-rubber washer N, and washer L in place, it will be seen that pressure applied by turning the nut M draws the tube firmly down into its seating F, and at the same time draws the cap K firmly on to the top of the tube and also expands the india-rubber washer so as to effectually close the hole in the cover. As the ends of the filter fabric are folded in round the tube ends, the joints are all made staunch; and no fluid can pass out of the casing except by passing through the filtering fabric. By unscrewing the nut M of any particular tube, that tube with its cap and washer can at once be removed, the stay bolt J and seating F remaining fixed in position. The tubes with their filtering cartridges are of the single type, that is to say, each cartridge is adapted to effect single filtration, and where multiple filtration is desired, such cartridges must be arranged so that the water passes through several in series. In the design illustrated, the outer circle or first set of cartridges is located in the annular compartment P of the filter case, formed by the inner wall Q, and the unfiltered water enters this compartment by the inlet R. The lower ends of this outer set of cartridges open into the annular lower chamber S below the diaphragm. The next two circles or second set of cartridges are located in the inner compartment T of the filter case and their lower ends also open into the annular chamber S. The remaining or third set of cartridges are also located in the inner compartment T, but their lower ends open into the central lower chamber U, which has the filtered water outlet V.

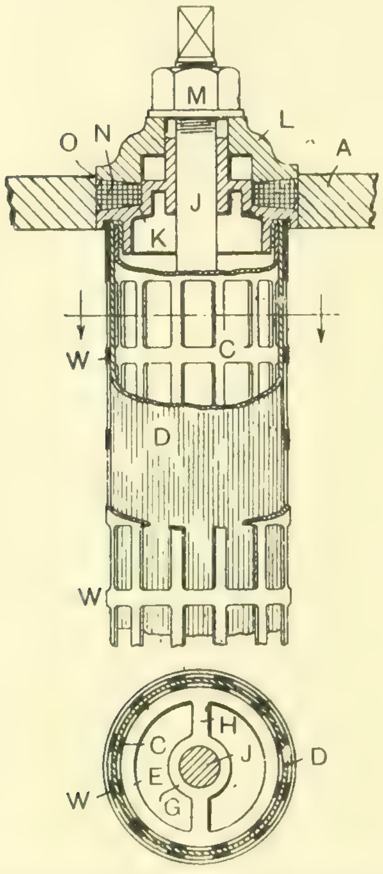


FIG. 3 RANKINE'S FEED-WATER FILTER. ENLARGED VIEW OF FILTER TUBE.

The water entering the outer compartment P passes through the filtering material of the first set of cartridges to the interiors of the tubes and descends into the chamber S; thence it rises into the interiors of the second set of cartridges and passes through the filtering material from inside to outside to the compartment T. Finally the water flows from outside to inside of the third set of cartridges into the chamber U and leaves by the outlet V. There are thus but the two compartments P and T and two chambers S and U to give the triple filtration, which result is obtained by reversing the direction of flow in the second set of cartridges. To permit of this without displacing or damaging the filtering material, an outer perforated tube W, as shown in Fig. 3, is fitted externally to the filtering material, in the case of the second set of cartridges.

Torpedo Boat Destroyers.—Of the 20 destroyers in the programme for 1912-13, orders have been placed provisionally for 16 with the following firms. Four boats with the Fairfield Shipbuilding and Engineering Company, Govan; and two with each of the following firms: Swan, Hunter, & Wigham Richardson, Wallsend-on-Tyne; Parsons Marine Steam Turbine Company, Wallsend on Tyne; Yarrow & Co., Glasgow; J. S. White & Co., East Cowes; Denny Brothers, Dumbarton; and Thornycroft & Co., Southampton.

FOUNDRY MELTING AND MIXING.*

BY DAVID M'LAIN.

WHILE employed as a moulder in a crucible steel foundry in which coke furnaces or so-called "coke holes" were used for melting I could not help but notice the difference in the metal when different melters were in charge of the furnace. For weeks at a time there was scarcely a complaint made about blow holes in castings. Again it seemed as if we were unable to make castings free from blow holes. The same grades of material were purchased, but for some reason it became a fixed habit for the metal to go wrong at intervals. As the steel-casting business was in its infancy in this country at that time, it was considered as one of the mysteries connected with the making of steel castings.

We had one 30-pot furnace, but as the business was increasing right along a Siemens-Martin regenerative 24-pot furnace was built. For a time after this was in operation the coke holes were operated only when necessary and by one melter. This melter when in his cups used to blame the blowy castings on the other melter because he claimed the latter was only a "handy man," not a full-fledged melter. All were aware that the new furnaces were a decided improvement over the old ones; but, using the same percentages of the same material that was put into the pots in the new furnaces, a larger percentage of good castings was obtained from the metal made in the coke holes.

In the general bustle of the day's work the real cause of the defective castings was not located by the powers that be. The writer probably would not have become aware of it if the old melter had not drawn my attention to the fact that some of my castings poured of the metal from the new furnaces were bad; and you may believe that I tried at every opportunity to get metal from the coke holes to pour my work. I was not in position to apprise my foreman of this fact, because the old melter had sworn me to secrecy. I had a notion that he used better material than that used in the new furnaces, but later learned that this was not the case.

The Siemens-Martin furnaces were much superior to the coke holes, but the mode of operation was entirely different. Operating the coke holes, the melter was able to try the metal often, and if he found a cold pot could give it more attention than could be given in the other furnace; but, considering the average melting, better results were obtained from the Siemens-Martin furnaces, and eventually the coke holes were abandoned entirely.

As the company was desirous of making larger castings, it was decided to install a Bessemer converter. An addition was built to the plant, a large jib crane, cupola, and converter were purchased, and Bessemer steel castings were made. The Bessemer process did not appear to be a great success for castings at the start. As it was a 7-ton converter, it was not convenient to pour small work, as the jib crane swung in a circle and did not allow sufficient floor space. Bessemer steel is suitable for pouring in ingots, as the metal in ingot form was run through the rolls later, which worked out many of the imperfections; but it is not as suitable for castings which are merely machined. There were many "cold blows," and this was not conducive to good steel. In the beginning very little attention was given to the melting of the metal in the cupola. Sometimes the metal from the cupola would be cold; at other times it would be held in the cupola ladle much longer than usual before going into the converter, and then it was noted we invariably had a cold blow.

Eventually, more attention was given to the cupola in order to get hotter metal. This they were soon able to do, learning that with a less percentage of silicon in the mixtures an extra amount of steel scrap could be used in the cupola. Aware of this fact, I was more impressed than ever with the fact that good melting made quite a difference in the castings.

For economical and other reasons, our company decided to install an open hearth furnace of 20 tons capacity, which necessitated the rebuilding of the entire plant and the dismantling of the Bessemer outfit. A few heats demonstrated

* Abstract of paper read before the Pittsburg Foundrymen's Association March 8th, 1912.

to all that it was the ideal metal for steel castings. In a short time there was a change of melters and our losses on defective castings ran up rapidly. The trouble was blow holes and the cause poor melting. Finally a good melter was secured and at once the casting losses were reduced.

I was offered charge of a small crucible steel plant which had been a failure under the management of a very capable iron founder, and the owners were amazed to learn that I did not require different grades of material from what had been used. Later they said: "Your ability at the start was questioned because you did not give us a big list of material to purchase." Imagine their surprise to learn that good castings, free from blow holes, could be made of the materials formerly used, and simply because good melting was being done.

A few years later, when arranging a plant to make grey iron and steel castings, the owner neglected to state that he wanted to make non-ferrous castings until it was too late to install a brass foundry department. Hearing of his desire, I told him we would melt brass in the crucible steel furnace. He claimed brass foundrymen would not use oil for melting purposes. (This was 14 years ago.) I wondered why, but determined to seek advice from men who knew all about it, and was told not to use oil as it would spoil the metal. This must sound strange to those who are melting brass with oil to-day, although many still use coke.

We made tons of high-grade, non-ferrous castings, but were treated to a surprise while doing so. Our steel crucibles were often in fairly good shape after being abandoned for melting steel, and I believed were capable of a few heats at least for melting brass. To cut a long story short, these old steel pots gave us an average of 11 heats in brass, many running 16 heats. This led me to try a new steel pot for brass exclusively, and this pot stood up for 52 heats. The brass mixtures were melted in the steel furnace after the last pot of steel was pulled and oil shut off, for quite often the temperature of the furnace was so high no extra oil was used to melt the metal; but the general practice was to use oil. How was it possible to use these crude furnaces for this purpose? Good melting.

How was it possible for one man to use 30 to 50 per cent. steel scrap while others can only use 10 per cent.? To answer the latter question, a more definite explanation is required than simply to say "good melting." It really requires scientific melting.

To get the best results from the cupola the details must be well arranged. The proper amount of air must be delivered through pipes proportioned to offer the least resistance; tuyeres should be made to allow the air to enter the cupola by volume; the material should be charged intelligently—the size of the charge to be determined by the size of the cupola. The coke should be high in carbon, which means low ash, and it must be low in sulphur. Much good, high carbon coke is being made to-day; but when purchasing you should specify the carbon and sulphur content. Then when the coke is still on track samples should be sent to a commercial chemist for report, in order to learn whether you have been shipped coke up to specification. There is no excuse whatever for the use of poor coke, because if you know good coke and specify what you want, the coke companies will supply it. Mistakes in shipments will happen, of course, but an analysis of each car of coke will prevent mistakes eventually. Even though you have to pay more money to get the best coke, pay it, because less coke is required to melt the iron. And when you learn that some men are melting 15lbs. of iron with 1lb. of coke between charges, when you learn that not less than 12lbs. of iron should be melted with 1lb. of coke between charges, you will then believe that scientific melting means more to the foundry than you have ever given it credit for.

Some claims that have been made lead the uninitiated to believe that all you have to do is to install the cupola and converter and that "your grey iron foreman will be competent to do the rest." Can you imagine a steel foundryman, who never worked a day in an iron foundry, probably, going into a general jobbing grey iron shop and directing the men so that they will know he is their superior at every stage of the game? I say "No" most emphatically, and the same holds good in the converter steel shop, only more so. The superintendent of an open-hearth or crucible foundry encounters an entirely different proposition when he assumes charge of a converter plant. He may be a very capable man in either of the above, but melting conditions demand that he become master of good cupola practice.

Some converter shops are using coke of the following analysis: Carbon, 76 to 82 per cent.; volatile matter, [illegible] to [illegible] per cent.; ash, 12 to 18 per cent.; sulphur, 0·90 to 1·10 per cent. Now this is lamentable. One plant had the tuyeres set high enough so that two tons of iron remained in the cupola before tapping. What can they expect using this poor coke and allowing the iron to remain in cupola for some time to absorb more sulphur from the fuel? High tuyeres and poor coke were not all that was wrong with this melting outfit; they were using high blast and oxidising the silicon, carbon, and manganese. One would think they were trying to blow steel in the cupola instead of the converter.

The best castings are made when some man in your shop is able to mix irons by analysis. This means more than being able to figure a charge or heat when the percentage of elements in the material is known. The man who is responsible for the mixtures must know just what proportion of those elements should be in each charge, and if he is going to pour light or heavy cylinders. He will then be competent to change the mixtures for the next charge for some other class of castings.

The successful mixer of irons should have a chemist report on each car of pig and coke, and he knows that he must order pig iron containing elements most suitable for his castings; he will not order by number. He knows what melting losses to figure against, as well as those that will be increased, and estimates in advance just the percentage of pig and scrap to use to give him the desired result in the castings. He knows that good melting enables him to carry a lower silicon in the mixture, which invariably means stronger castings. He will have no use for "silvery" or high silicon pig. He is aware that his cupola is not a blast furnace, therefore will have no use for limestone for short heats. He uses steel in the mixtures to make stronger castings. It is not necessary to have a chemist in your employ unless you melt a large tonnage.

Since from 80 to 90 per cent. of the money expended in a foundry is spent before melting begins, you can either make a profit or a loss by mixing and melting the material scientifically or by guess. I repeat that some man in your shop should do the mixing. A company making agricultural castings formerly had its mixtures made by specialists, and although straight mixtures were used throughout the heat the analyses of the castings would show from 2·75 to 1·90 silicon. But when the foreman began to do the mixing better and stronger castings were made and the analysis of castings seldom runs less than 2·15 or more than 2·25 per cent. silicon, 0·07 to 0·08 sulphur, 0·55 to 0·65 phosphorus, and 0·50 to 0·65 manganese.

A company of which I was foundry superintendent had just built a foundry to make iron, steel, and brass castings, having previously purchased all castings from jobbing shops, which practice proved very unsatisfactory as the castings consisted of parts for air brake equipment used on street cars. The records of the machine shop proved that the loss on small cylinder head castings ran as high as 60 per cent., and this loss was not discovered, unfortunately, until the castings were machined and put to the test, which was 200lbs. air pressure.

Investigation proved there were also large losses on this particular cylinder head pattern in every foundry in which the pattern was placed. At that time the pattern was in a foundry having a good reputation on this class of work, and as their losses were only about 50 per cent., our machine shop superintendent advised that we allow the pattern to remain there. To cut a long story short, the pattern [illegible] and my troubles began. In a short time the loss was reduced to 35 per cent., and as a plan had been devised to test castings before machining (not a final test), the company [illegible] immensely pleased with the showing.

But to think of a loss of 35 per cent. on iron castings, when I had been able to make steel castings with a loss of 2 per cent. and under, was very discouraging, I assure you,

and I put every effort and spare moment on this particular pattern. Experts were called in—chemists had their say—but without bettering our product. Foundry friends all advised that the pattern be changed; but our manager would not listen to it, as he claimed when the metal was right castings were right, and later developments proved that he was correct.

The writer gave much study to the use of steel, also to the thought that manganese must be used; but on referring to text books, found the following information:

"Manganese increases the saturation point of iron for carbon."

"Manganese will remove sulphur if used in the ladle."

"Manganese is a hardening element above 0·85."

"Manganese is not good for use in the cupola because the temperature is not high enough to melt it."

"Manganese converts graphitic carbon to combined carbon."

"Would steel increase the temperature of the metal? No."

Now with all this expert opinion against me, I felt at times as if it were better to let steel alone; but several incongruities in the above statements left a loophole to work on. The statement that manganese converts graphitic carbon to combined carbon appeared all right if there was no silicon in the mixture, but as silicon converts combined carbon to graphitic carbon, what would happen if both manganese and silicon were fairly high? Good thought. All text-books inform you that steel is used to reduce carbon; but how are you going to make soft castings of light section if total carbon is low? It was apparent that if manganese increased the "saturation point of iron for carbon," it was necessary to use it; because if carbon is low, light sections will be hard. But as silicon must be low for close-grained metal, probably a low silicon, high carbon metal would solve the problem, and it did.

When figuring the estimated analysis of the material in charge entering the cupola, the total carbon was only 2 per cent. Now, it did not matter how high the silicon was in the castings, they would be hard if the total carbon was only 2 per cent.; but when metal was poured and analysed, it was found that the carbon had increased to 3·58 per cent., and these light castings were soft, although silicon was low. The steel and manganese did exactly what they were calculated to do, namely, increased the total carbon, reducing sulphur, and allowing the lower silicon mixture to be used, thereby giving a very close-grained metal, free from segregation and blow holes.

After solving this problem, what effect was noticeable in the machine shop? When it is known that pattern sections were as light as $\frac{5}{16}$in. to $\frac{3}{8}$in. and using 30 to 40 per cent. steel, the castings were run through milling machines to the tests with a loss of 2 to 3 per cent. — in some instances with less loss—you will agree that the results were wonderful. It truly was semi-steel, containing 30 to 50 per cent. steel. The transverse strength increased from 2,200lbs. to 2,400lbs. up to as high as 4,400lbs. Quite often we had men sledge these light cylinder heads with a 36lb. hammer, but the metal would not begin to crack until it had sunk in considerably.

In 1903 a full description of my method of using steel and manganese in the cupola was sent to one of our leading metallurgists, and the following extract from his letter is quoted to give you further confidence in semi-steel:—

"You have hit on a point which bears out all my years of contention on the oxidation of iron in the melting process. Where you use such high percentage of steel, you necessarily have a higher temperature in the melt, and with this higher temperature any addition of manganese means a reaction with the oxygen present, from the unavoidable burning of the steel in the charges. In ordinary cast iron this cannot take place, as the temperature is not high enough, hence manganese is not a good thing there. I presume that you must lose quite a lot of manganese by this process, which shows that it is effective and does the work it is put in for. I can only congratulate you on this work, and hope that you may reap some good returns from it. Nevertheless, it seems a pity that others should be made to lose money all the time for the want of knowing this."

Some foundrymen who are unable to make a close grained metal requiring high strength or that must stand hydraulic or other tests, use expensive alloys, but when it is known that cheap steel scrap used in cupola mixtures will make light castings with a transverse strength of 2,600lbs. to 3,200lbs. and from 3,200lbs. to 4,500lbs. for medium and heavy castings, do you not agree that steel scrap solves your problem? If a still stronger metal is required, then try alloys.

In making metal for "high" grade castings, steel and other scrap with pig are placed on the bed, making as many charges for semi-steel as desired, following with usual mixtures. If metal for dies, anvil blocks, or castings of like character is desired, semi-steel may be made on the latter part of the heat. When good practice is followed there will be no "bunging" up of your cupola and no harmful effects to later charges of regular mixtures.

No more coke is necessary to melt steel mixtures than grey iron, but it is best to use a heavier split of coke between the last charge of semi-steel and the following charge to prevent the latter from melting through. Contrary to all previous advice offered by "experts" the steel melts more quickly than the pig iron.

Steel scrap should never be melted in the ladle, but charged in the cupola, as a high temperature is necessary to melt steel properly, in order to liberate all gases; hence the necessity of good melting must be apparent. Steel borings and turnings may be used to advantage in the same manner as for grey iron. No boxes or cans are necessary. All kinds of steel scrap, such as steel foundry scrap, gates, risers, boiler clippings, punchings, shearings, structural material, angles, I beams, ties, channels, rails and railroad scrap may be used; also a percentage of wrought iron. You may use from 10 to 30 per cent. steel in castings of light sections, and 30 to 50 per cent. steel scrap may be used in castings of heavy sections. Many foundries use 45 per cent. steel in heavy gas-engine cylinders. Men who have tried to use 30 to 40 or even 50 per cent. steel and were not successful have not much faith in semi-steel, but in every single instance which came under my observation their melting conditions were not right.

I have been successful in arranging cupolas which had been poor melters so that the maximum amount of metal was brought down per hour, and have proved that any cupola may be arranged to melt 10lbs. per hour per square inch of cupola area, when just the proper amount of coke is used. The following table may prove of interest:—

A 30in. cupola should melt	$3\frac{1}{2}$ tons per hour.
A 36in. cupola should melt	5 tons per hour.
A 42in. cupola should melt	$6\frac{1}{2}$ tons per hour.
A 48in. cupola should melt	9 tons per hour.
A 54in. cupola should melt	11 tons per hour.
A 60in. cupola should melt	14 tons per hour.
A 66in. cupola should melt	17 tons per hour.
A 72in. cupola should melt 18 to 20	tons per hour.

You will find cupolas melting faster than this, but in every such instance we have demonstrated that it is a mistake to melt faster than quoted, unless on very long heats.

Generally, melting conditions are favourable when melting steel, but not so with iron melted in the cupola. The high carbon, silicon, sulphur, and phosphorous in iron mixtures melted with coke produce more gases and impurities, and a higher percentage of manganese should be used to free the iron of those impurities; but I will admit if the cupola is not melting up to capacity, the necessary temperature to cause perfect combustion is lacking. The claims made by eminent authorities that there must be a vast difference in the same brands of pig iron may easily be exploded—not by some mysterious laboratory experiment, but by scientific melting and mixing of iron which is possible when some man in your shop is capable of doing so.

Copper Statistics. — According to statistics published by Aron Hirsch & Sohn, of Halberstadt, the total production and consumption of copper in the world in 1911 amounted to about 1,000,000 tons, whilst the total supply of copper in stock at the end of the year was about 190,000 tons. Germany was again the principal consumer, accounting for about 240,000 tons, as against 216,000 tons in 1910, and a similar development took place in most other important industrial countries.

WEIGHT EFFICIENCY OF ELECTRIC MOTORS AND OF PRIME MOVERS.*

BY W. B. HIRD.

INDIVIDUAL manufacturers have, I suppose, at all times been in the habit of comparing the cost, design, and weight of their manufactures with that of similar articles turned out by their competitors. The suggestion here made is that such comparisons, and others of a like nature, might be extended to include different types of machinery. An important branch of the biological group of natural sciences is

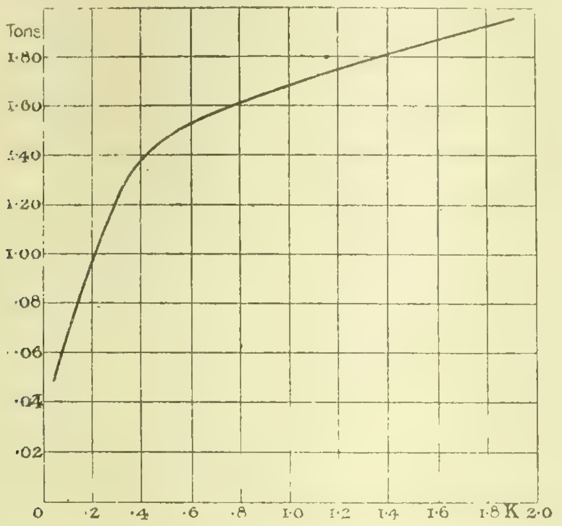


FIG. 1.

comparative anatomy, in which the structures and organs of different animals and plants are compared, their similarities and differences investigated, the evolution traced from lower to higher types, and some explanation of the differences observed is sought for. A systematic investigation on these lines of the methods employed and the results obtained in different branches of engineering would certainly be interesting, and might prove to be of great practical value. The directions in which an investigation might be made are numerous. As an instance, one might consider the factors of safety which it is considered good practice to employ in determining the strength of various structures used for dissimilar purposes. Does the constructional engineer, having calculated the strength of his materials and the stresses on his structure, consider it safe to use the same factor of safety for his girders as the mechanical engineer will employ to determine the dimensions of various parts of his machinery? Or, again, in the different classes of machinery used to obtain mechanical energy, what is the relation between weight and the power obtained or between weight and efficiency? Other lines of investigation will readily suggest themselves.

Of the differences in practice which would certainly be observed in any such comparison very many are without doubt justified by the circumstances of the cases. The different purposes for which a machine is to be used will frequently require that some one quality or another be obtained at the cost of serious sacrifices in other directions; but I venture to think that a good many of the differences which would become apparent in a systematic comparison of present-day practice in different branches of engineering would turn out to have no real justification, but to be due to the conservative attitude of the designer.

It is intended in what follows to consider on as general lines as possible one only of the suggested lines of investigation, namely, the relation of weight to output in electric motors and in various types of prime movers. If any such comparison is to be of any value it must rest on a broad basis and include figures from the greatest possible variety of cases. On many points of design reliable information would be difficult to obtain; this initial difficulty does not arise in the case of the proposed investigation, where the desired particulars are to be got quite readily.

The inclusion of the electric motor is, of course, of special interest to members of this Institution, and if the electric motor is not strictly a prime mover it exactly replaces one for the consumer taking his supply from public mains; and if the time ever comes when a method is devised of converting the stored energy of coal into electrical energy, the electric motor will become a prime mover in the strictest sense of the term. The information usually given in manufacturers' catalogues, and therefore easily available, is sufficient to allow of very interesting comparisons in the matter of weight. The particulars made use of are the weight of any given machine, its rated output in brake horse-power, and the revolutions per minute at which this output is obtained.

To arrive at the results which follow, a large mass of figures as to the weights of the electric motors, steam engines and turbines, gas engines, oil engines, petrol engines, and water turbines was examined and analysed, and I have to acknowledge the kindness of many manufacturing firms, too numerous to mention individually, who have given me information as to their machines.

The size and, therefore, weight of an engine or motor naturally increases with the power at which it is rated, but it decreases with the speed at which this power, this rate of giving out energy, is obtained. Roughly speaking, if the speed of any individual engine or motor be varied, the power to be obtained from it will vary directly as the speed. The variation of speed will be obtained by different methods, according to the type of motor under consideration: in an electric motor it may mean so considerable an alteration as is involved in totally new windings, in a steam engine it may involve only a change in the governor. Also the variation obtainable will be restricted within strictly defined limits, but within the permissible range the speed variation will be obtained without material alteration in the main dimensions of the motor, and therefore without material alterations in its weight.

In manufacturers' catalogues an engine or motor is frequently rated at several different outputs, each with a corresponding speed, and the powers in such cases are invariably found to be, within a close approximation, proportional to the speed. It is only to be expected that this should be so; if the power per revolution is constant the torque will remain the same, the strength of the parts must therefore be approximately constant, and since about the same quantity of working substance will be required at each revolution, the capacity of the cylinders, the conductors, &c., according to the type of motor considered, must remain about the same; it is therefore quite natural to find that the dimensions of any type of motor do not greatly vary, however the horse-power be varied, provided the speed varies proportionately.

It is proposed, therefore, to take as a basis of comparison the horse-power divided by the speed, this fraction being the same, or approximately the same, for any individual machine; then, taking any line of motors, a graph can be plotted of weights against the fraction—

$$\frac{\text{Horse-power.}}{\text{Revolutions per minute.}}$$

This fraction is represented throughout this paper by the symbol K, and may be called the output constant. A graph,

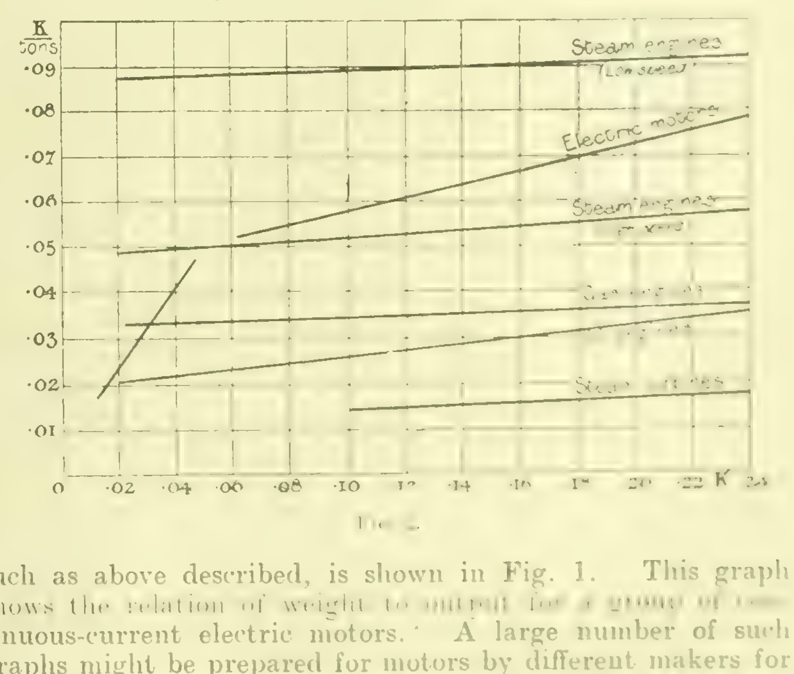


FIG. 2.

such as above described, is shown in Fig. 1. This graph shows the relation of weight to output for a group of continuous-current electric motors. A large number of such graphs might be prepared for motors by different makers for gas engines, steam engines, &c., but in order to obtain any

* Paper read before the Institution of Electrical Engineers.

clear understanding of the results so obtained a step further is required, and an endeavour has been made to find some general rule or formula connecting the weight with the output constant K.

If the constant K is divided by the weight in tons, and a graph of the results plotted to base K, the graph will show what output in brake horse-power per revolution is being obtained from each ton of material used, and it is found that in a large number of cases the points thus obtained for one line of machines lie very nearly in a straight line. It is true that another set of machines, perhaps even by the same maker, will give a graph different from the first one both in inclination and in its intercept on the axis; but in so many cases is it found that a straight line can be drawn through the points that it is fair to assume that if all the parts of a machine were made strictly of the best size and of a uniform line of design, the points would fall on a straight line. In order, however, to meet the requirements of manufacture, identical parts are in some cases used for two or three different sizes of machine; the same bearings, bed plates, and other similar parts are used for perhaps several sizes out of a line of machines, in order to save the multiplication of patterns and to facilitate standardisation of manufacturing processes; the natural result is that some machines are heavier than absolutely necessary, whilst others fall somewhat below the standard set for the whole line in the strength of some of the parts, and are therefore somewhat on the light side. From these and other accidental differences in design it is to be expected that in plotting curves of weight considerable variation from a smooth curve will be at times apparent, but such departures may be considered as accidental, and do not detract from the value of any working hypothesis which may be deduced from the general trend of the curve.

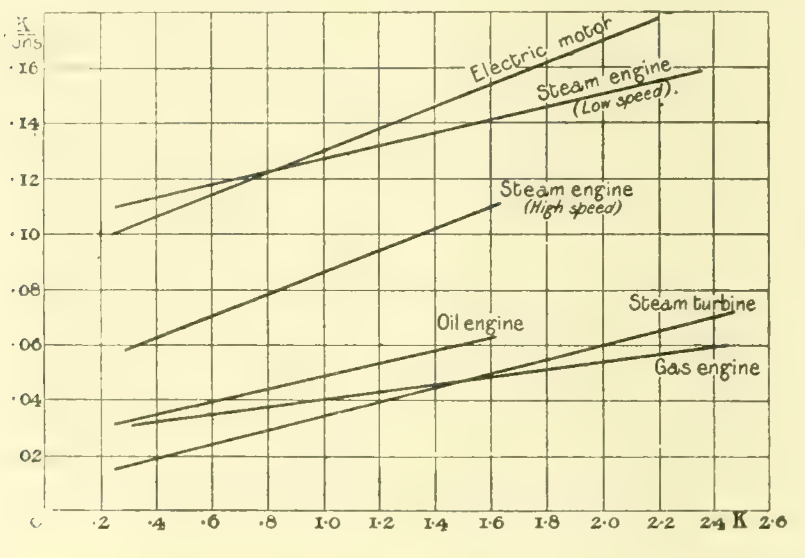


Fig. 3.

In the majority of cases where the figures for a manufacturer's line of engines or motors were available the general direction of the points obtained by plotting the horse-power divided by K against K were distinctly in a straight line, and the departures which occurred from this were irregular, and showed no indication that any smooth curve would have been drawn through the points and have represented their general position with greater accuracy than did the straight lines; and although cases did occur where the results of a line of machines might have been better indicated by a curved line, this was found to be as often curved to the axis as concave, so that, on the whole, for none of the types investigated did it appear that a straight line did not fairly represent the general trend of the results obtained.

General results such as are here aimed at require to be represented in a form easily grasped, and as a result of the above considerations it was decided that they would in this case be best represented by a series of straight line graphs showing the average result for each type of motor investigated. The process of obtaining these was carried out thus: Taking any one type of motor, say, the electric motor for the sake of example, lists of output, revolutions per minute, and weight in tons were prepared from the figures of as many manufacturers as possible. The brake horse-power divided by the revolutions per minute gave the constant K. This was used as the abscissa, and K/tons was plotted as ordinate; through the mean position of the points thus obtained for any one line of machines a straight line was drawn. Several lines of motors investigated, therefore, gave a number of such straight lines. The position of each of these lines is fully determined by noting its inclination to the horizontal axis and its intercept on the vertical axis; the mean value of the intercepts was calculated, also the mean value of the inclination, and with these constants a straight line was drawn indicating the mean value of the horse-power divided by the revolutions per minute which is being obtained in practice to-day for the employment of 1 ton of material. Such lines for the different types dealt with are gathered together in Figs. 2, 3, and 4, and some of the results are also shown in tabular form.

Fig. 3 embodies the principal results obtained, but as very many of the cases dealt with gave a value of K below 0·2, and therefore not easily plotted on the same diagram.

Fig. 2 is drawn to an enlarged scale, giving the results for motors having a value K less than 0·2.

In the case of the water turbine the slope of the weight efficiency curve was so much steeper than for the other engines investigated that a different scale was required, and the water turbine graphs are therefore given in Fig. 4.

All these lines have the same general characteristics—they slope upwards from left to right; that is to say, as we pass upwards from the smaller to the larger members of any lines of machines, the weight efficiency goes up and a larger value of horse-power per revolution is obtained for each ton of material used. No greater accuracy can, of course, be obtained in such a comparison, and very many instances of individual motors occur, the weight of which differs very materially from that indicated by the average line for their type. Especially is this the case with engines made singly and not manufactured as one of a line of similar motors. Some general engineers, for instance, manufacture (as one part only of their business) steam engines for various purposes, and their weights are extremely erratic, often varying by 100 per cent. or more from those indicated by the mean line of steam-engine weights. The figures are only intended to show the average results obtained on one type of motor as compared with what has hitherto been obtained on other types.

Table showing the Horse-power per Revolution obtained in Different Types of Motors for 1 Ton of Material.

K.	Steam Low Speed.	Engine High Speed.	Gas Engine.	Oil Engine.	Steam Turbine.	Electric Motor.	Water 30ft. Head.	Turbines 80ft. Head.	200ft Head.
0·02	0·097	0·048	0·033	0·021	—	0·023	—	—	—
0·10	0·099	0·052	0·034	0·027	0·014	0·057	—	—	—
0·20	0·110	0·056	0·036	0·032	0·017	0·082	0·055	0·075	0·081
1·00	0·130	0·086	0·040	0·048	0·034	0·130	0·120	0·140	0·160
2·00	0·150	—	0·054	—	0·060	0·170	0·195	0·230	0·260

Considering the results in detail, it appears from Fig. 3 and Fig. 4 that the water turbine gets the largest horse-power per revolution per unit weight of all the motors considered, the figures varying from about 0·07 h.p. per revolution per ton weight when K = 0·2 up to 0·23 h.p. per revolution per ton when K = 2·0. Next to the water turbine the electric motor, when of a fairly large output, has the highest weight efficiency of any of the types considered. The horse-power per revolution to be obtained from 1 ton of material varies between 0·082 of a horse-power when K = 0·2 up to 0·17 of a horse-power when K = 2·0. Or if it be preferred to avoid fractional figures, the electric motor of sizes varying between the limits indicated would give at 1,000 revs. (were such speed possible) 82 b.h.p. up to 170 b.h.p. for each ton of material used in the machine.

At a value of K of about 0·2 the slope of the curve for the electric motor appears to decrease somewhat suddenly, the values of output per ton below this value of K falling away rapidly as the machine becomes smaller; at K = 0·05 there appears to be another rather sudden change, indicated in Fig. 2. The examination of several different makers' recorded weights and output gives the same result of a sudden change in the slope of the curve, and agrees in giving that change in the neighbourhood of K = 0·05.

Of the other types investigated, the slow-speed steam

engine is the one from which the highest horse-power per revolution is obtained from 1 ton of material. The horse-power per revolution for 1 ton weight varies between 0·1 of a horse-power in engines having a value of K 0·25 up to 0·16 of a horse-power in engines having a value of K = 2·5. These figures relate to engines commonly described as slow-speed engines. For the high-speed totally-enclosed engines of the type commonly used for direct coupling to generator the figures are distinctly lower: the horse-power per revolution obtained from these for 1 ton of material used varies from 0·06 of a horse-power per ton when K = 0·25 up to 0·105 when K = 1·5. These figures are for engines working with about 180lbs. to 200lbs. steam pressure. Oil engines and gas engines appear to be very similar as regards output for a given weight, and give about 0·035 h.p. per revolution for 1 ton weight when K = 0·25, increasing to 0·05 h.p. per revolution for 1 ton when K = 1·5. Steam turbines working at about 180lbs. to 200lbs. steam pressure are lower in their output for the smaller sizes than either gas or oil engines, but in the larger sizes the curve of output rises above that of the gas or oil motor; the figures for the steam turbine being 0·02 b.h.p. per revolution for 1 ton weight when K = 0·25 and 0·075 b.h.p. per revolution for 1 ton when K = 2·5.

The consideration of the water turbine differs somewhat from that of other motors, in that the power of the same turbine varies with the head at which it works; it is, of course, true that in the same way the power of the steam engine varies with the steam pressure, but the steam pressure can usually be chosen for any installation and is under the control of the designer; the head at which a turbine shall work is, on the contrary, rigidly fixed. As, however, the speed of the turbine, as well as its power, depends on the head, the results of comparing the weights of turbines working at different heads are not so variable as might at first

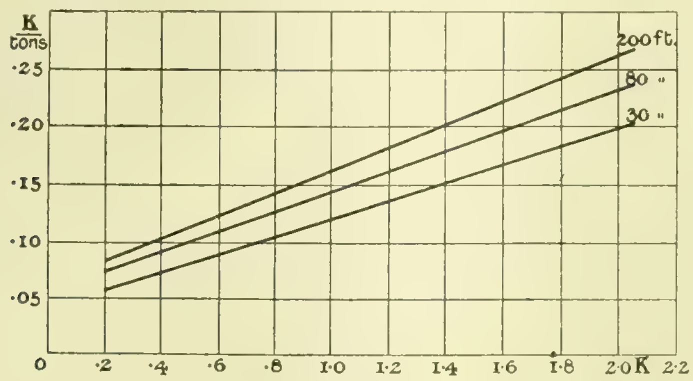


FIG. 4.

sight have been imagined. Curves of horse-power per revolution given out for each ton weight have been plotted for water turbines working at 30ft., 80ft., and 200ft. head (Fig. 4).

The comparison of results in Figs. 2, 3, and 4 raises the questions as to why the manufacturer of electric motors, of water turbines, and of steam engines is able to get so much more output out of a ton of material than is obtainable in a gas or oil engine, and whether these different results are entirely and essentially of the nature of the case, and therefore unavoidable. It is not proposed to discuss these questions here, but merely to put before you the results as they appear to emerge from an investigation of those particular figures to which I have had access.

In addition to considering merely the broad lines of comparison between different types of motors, many points of interest arise in individual cases. To mention one only, the very highest output per revolution per unit weight of material was found in two instances of a very widely varying nature, one case being that of a petrol engine manufactured for aeroplane work, in which as much as 0·4 h.p. per revolution is obtained from 1 ton of material. It was, of course, to be expected that in an engine built for such a purpose, where lightness is the one essential quality to be sought for, a very high weight of efficiency would be found. This high efficiency is in this case obtained by sacrificing durability. I understand that the standard aimed at in such an engine is that it should run at full load for 100 hours before requiring a thorough overhaul; if it fails to reach this standard it is deemed too flimsy for its work—the light weight has been obtained at too high a sacrifice.

The other case of very high output for weight is found in a very different class of machine. A slow-speed colliery winding engine is rated by the makers at brake horse-power which works out to 0·5 h.p. per revolution for each ton of material used. In this case, of course, weight is of comparatively little importance, and it is not by any systematic effort to reduce weight that the above result is obtained, but by a very high rating of the power, which is only required intermittently, and by sacrificing the fuel economy, the steam being admitted at full pressure throughout the stroke. It is interesting, however, to find two engines practically at opposite ends of the scale, and made for such totally distinct purposes, both coming out so high in the matter of weight efficiency, and to note by what very different processes this result is attained.

The lowest weight efficiencies naturally occur in cases where K is very low; there are on the market electric motors and water motors, to take only two instances, so small as to be toys rather than engineering apparatus, and in all these very small machines the weight efficiency is necessarily low. The lowest figure actually met with was 0·006[illegible] h.p. per revolution for 1 ton of material; that is, this particular motor, if it could have been increased proportionately to weigh 1 ton, would at 1,000 revolutions have given only 7·8 h.p., or only about $\frac{1}{75}$ part of the highest output met with, namely, 0·5 h.p. per revolution per ton.

A NEW ALLOY OF HIGH TENSILE STRENGTH.

BY C. VICKERS.

A NEW high-tensile copper alloy, recently developed in France, is made by melting chromium and aluminium together at a high temperature for one hour, the proportions of each metal being 11lbs. When the aluminium and chromium have been thoroughly incorporated, 242lbs. of copper are added, and the entire charge is held in a molten condition in the furnace for a period of one-half hour, after which 55lbs. of nickel are added and another hour-period of soaking follows. The metal is held in the furnace a total of 2½ hours, which is contrary to the practice of melting alloys of copper. After the nickel has been added and at the end of the period of rest, 44lbs. of zinc are alloyed with the mixture, which is then poured into ingots. The proportions of copper and chromium can be varied in accordance with the use for which the alloy is intended, but no change is permissible in the quantity of aluminium, or the order in which the metals are to be added.

To the experienced metallurgist it would seem that any change that could be made in the order in which the metals are added would be in the nature of an improvement. For instance, nickel being a highly refractory metal could be charged with the chromium and aluminium, and in fact this method actually has been followed in producing a chrome-nickel bronze of similar proportions. The resulting alloy fulfilled all requirements as to quality, rivaling high-grade steel in strength and resistance to impact. It may be asked why the aluminium, not being a refractory metal, should be added together with the chromium and nickel, and a direct answer cannot be given because, to the writer's knowledge, the experiment of adding the aluminium at a later stage has never been tried. It is assumed that the aluminium aids in the fusion of the chromium by dissolving it in the same manner in which copper will dissolve nickel, or zinc will dissolve iron or copper, and at a temperature much lower than the melting point of the more refractory metal. It is fair to presume, however, that the aluminium is injured by much prolonged melting at a very high temperature, and that it would be better to form the alloy in some way that would avoid the necessity of holding the more fusible parts of the mixture in the furnace at a high temperature. Several methods might be suggested.

The composition of chromax bronze is similar to the French metal, and to all intents and purposes it is the same. The proportions of the metals in the mixture are said to be as follows: Copper, 66·66 per cent.; zinc, 12·13 per cent.; nickel, 15·15 per cent.; chromium, 3·03 per cent.; and aluminium, 3·03 per cent. The tensile strength of the alloy is 79,000lbs. per square inch and there is reason to believe that this figure is not too high. The elongation is 3·3 per cent. Continuing the criticism of the French method of making chrome nickel bronze, it would be interesting to know in just what form the chromium is used. It might be

added as ferro-chromium containing from 60 to 70 per cent. of chromium; fused chromium metal containing from 98 to 99 per cent. chromium; chromium chloride, or as chrome copper containing 10 per cent. of chromium. If the latter metal is used the aluminium could be added at any stage, and it would not be necessary to keep the metal soaking in the furnace any longer than necessary to incorporate the nickel. Chromium is almost an infusible metal and is very difficult to alloy with copper by direct melting, as the copper will not dissolve the chromium in the same manner as nickel.

Ferro-chromium melts at a temperature lower than chromium metal and is employed as an addition to steel, but attempts to form an alloy of ferro-chromium and copper, by melting the latter under charcoal and after superheating it to a high temperature, adding the ferro-chromium in the powdered form, were unsuccessful. Chrome-nickel bronze, therefore, cannot be made by direct fusion of the chrome and copper in ordinary furnaces, but the alloy can be made by melting the chrome, nickel and aluminium together, afterwards adding the copper in small pieces, until a fusible alloy is formed that will not chill in the furnace. The remaining copper part of the charge can be added in the usual manner and the zinc is added last. This is a good method of making this alloy, as the more refractory metals are melted first, with the exception of the aluminium, which is considered necessary to aid in the fusion of the chromium.

If it is believed advisable to melt the chromium and aluminium together and if this can be accomplished successfully, the best manner in which to complete the alloy would be to add a portion only of the copper charge. About 50lbs. could be added, and when dissolved, the nickel should follow. The copper-aluminium-chromium mixture, being heated to a high temperature, would dissolve the nickel if the latter were added gradually, after which the addition, at suitable intervals, of the balance of the copper, would keep the temperature of the molten mass sufficiently low to permit the zinc to be finally added without undue oxidation. In the French method, all of the copper is charged before the nickel, and to dissolve the latter, the bath must be raised to a temperature too high for the economical addition of the zinc.

Another method by which this alloy could be formed consists of using the aluminium as a fuel to melt the chromium in the same way in which it will melt any other metal, in the form of thermit. This consists of granulated aluminium mixed with the oxide of the metal it is desired to reduce. This would prove an excellent method of making the alloy, as the chromium-thermit could be placed in the furnace and after the reaction the aluminium could be added if thought desirable, or the copper could be added in sufficient quantity to bring the fusibility of the mixture well within the capacity of the furnace. The nickel could be added next, followed by the balance of the copper in the manner previously suggested.

If the use of the 10 per cent. chrome-copper is preferred for making the alloy, it will be necessary to melt 110lbs. of chrome-copper, to which is added in the following order 55lbs. of nickel, 143lbs. of copper, 44lbs. of zinc, and 11lbs. of aluminium. After the chromium has been melted and alloyed with a portion of the mixture, there is no need of allowing the metal to soak in the furnace any longer than may be necessary to keep the temperature sufficiently high to dissolve the rest of the metals in the alloy. Otherwise, it will be difficult to obtain castings free from oxides which greatly reduce the strength of the alloy.

For this reason it is advisable to melt the metal twice, the first heat of new metal being poured into ingots, which are afterwards remelted to make the castings. The metal should be hot and liquid when poured and the castings will then be practically free from oxidation. The colour of the alloy is white and it takes a fine, silvery polish. The fracture is fine and dense, especially after being remelted. One test bar made from the first melt of new metal had a tensile strength of 66,670lbs. per square inch, although after being broken it was found that the bar was unsound to the extent of one-third of its area. Chrome-nickel bronze, owing to its high melting point, has a denser structure and greater compressive strength than manganese bronze. It can be rolled into sheets and wire, and while somewhat more difficult to cast than manganese bronze, there is reason to believe that chrome nickel bronze will replace the latter for many purposes, particularly where a high tensile, non ferrous alloy is required.—"The Foundry."

INDUSTRIAL AND TRADE NOTES.

Tin Mining in the Federated Malay States. In 1911 the export of tin from the Federated Malay States was 11,118 tons, valued at £8,125,301. The average local price was £181. 0s. 10d. per ton. In 1910 the average local value was £151. 18s. 4d. per ton. The total labour force employed in the mines at the end of 1911 was 186,127, as compared with 170,361 at the same time in 1910.

Roumanian Petroleum Production. A total of 1,404,100 metric tons of petroleum were delivered to Roumanian refineries in 1911, as against 1,215,300 metric tons in 1910, an increase of about 15½ per cent. The yield from petroleum in the refineries last year was as follows: Benzine, 260,653 metric tons; burning oil, 312,711 metric tons; mineral oil, 24,703 metric tons; and residue, 783,136 metric tons. Nearly half the production was used in Roumania.

Large Floating Dock for Russia. — The Russian Admiralty have ordered a 30,000 ton floating dock to accommodate their new Dreadnought battle-ships, the first of which is to be built by Messrs. Vickers, Ltd. The dock, designed by Messrs. Clark and Standfield, of Westminster, will be 656ft. long and 137ft. wide, and will be capable of lifting in two hours a battle-ship displacing 30,000 tons. Arrangements are made whereby the lifting of the dock can be increased later to 40,000 tons. At the outset the dock will be used at the Russian shipbuilding yard of Nikolaieff, but later it will be towed to Sebastopol.

The Mirrlees Watson Company, Ltd. The annual meeting of the shareholders of this company was held in the company's offices, Glasgow, on March 15th. The profit and loss account showed that the profit available for distribution after bringing forward from the previous year the sum of £1,995, and providing amply for depreciation and business contingencies, was £50,135. The directors recommended and the meeting approved of a dividend of 10 per cent. and a bonus of 5 per cent., both less income tax, that £30,000 be added to the general reserve account, and £2,478 be carried forward. Last year the company paid a similar dividend and bonus.

Germany's Foreign Trade.—According to a consular report, the total German foreign trade last year increased, as against the total in 1910, in imported quantities by 6 per cent., in exported quantities by as much as 9·1 per cent. The value of the total German exports increased by 7·5 per cent. The production of the German iron industry is benefiting to the full extent from all those technical improvements which it has for years endeavoured to perfect. The export of rails increased in its total by 5,000 tons, but to the United Kingdom it receded by 14,000 tons. The export of motor vehicles to the United Kingdom last year nearly doubled, whereas the British exports to Germany were reduced to half.

Another Clyde Oil-engined Ship. The second oil-engined vessel which the East Asiatic Company, of Copenhagen, have ordered from Messrs. Barclay, Curle, & Co., Whiteinch, is to be 480ft. in length, of 8,000 tons gross register, and 16 knots speed. She will be propelled by twin screws, driven by two sets of Diesel oil engines arranged on the same principle as the "Selandia," the "Jutlandia," and the "Fiona." There will be eight cylinders aggregating 3,000 h.p., on each shaft, so that the total horse power will be 6,000. The vessel, which is intended for the North Atlantic service, will have accommodation for 400 first and second class passengers and 1,600 third class. It is likely that the machinery will be constructed in the new works at Eidersho of the Burmeister & Wain (Diesel System) Oil Engine Company, Ltd.

British Trade with Switzerland. The Consular reports by the representatives of the British Consuls and Vice-Consuls in this country for the year 1910 have just been published. Mr. Milligan, the Consul at Zurich, values at £12,520,000 the commerce between Switzerland and England, out of a total value of £116,389,000 during 1910. In comparison with 1909 the exports from England to Switzerland and imports to England from Switzerland were in the ratio of 1 to 2. The Vice-Consul at Montreux, M. Cuenod, states that the lack of greater trade is owing to the small number of English commercial travellers, who only number 70 out of 700 travellers, and because English firms persistently insist on sending out circulars in English and English money terms. Great Britain stands second on the list of purchasers of Swiss goods but only fifth on that of vendors. More English enterprise and more English travellers are required to develop the trade between the two countries.

Petrol Electric Railway Car. The Great Central Railway Company have purchased from the British Westinghouse Company one of their standard 90 h.p. petrol electric cars. It is 31ft. 6in. long over headstocks and 8ft. [illegible] wide over pillars, with a clear inside height of 7ft. 6in. A compartment at one end contains

a six-cylinder petrol engine driving a specially wound electrical generator which supplies current to the axle motors. A small petrol-driven set works the pump for the vacuum brake and provides current for lighting. The car is driven either from this compartment or from one at the other end by a single handle which is fitted with the "dead man" control, so that should the driver release his hold upon it the power is automatically cut off. This arrangement, it is claimed, makes it safe to have only one man for driving and attending to the engine. The car, which is designed for a maximum speed of 40 miles an hour on the level, has seating accommodation for 50 passengers.

British and Foreign Shipping.—Some interesting details are given in Lloyd's Register of British and Foreign Shipping for the quarter ending December 31st, 1911. According to this, the number of steam vessels owned in the United Kingdom is 8,487, with a net tonnage of 10,519,676. British colonies own 1,414 steam vessels, having a net tonnage of 788,580. The number of British-owned sailing vessels is 847, with a tonnage of 579,982, and the Colonies own 694, with a tonnage of 195,193. This gives a total of 11,442 British and colonial vessels, with a tonnage of 12,083,831. The total number of registered steam and sailing vessels of all nationalities other than British and colonial at the same time was 15,574, with a total tonnage of 12,982,219. These latter figures, however, do not include vessels trading on the Great Lakes of North America. The returns do not include either vessels under 100 tons net. During the three months comprised in the returns 58 British and colonial vessels of all classes were lost, with a tonnage of 49,298. The vessels of all other nationalities lost during the same time numbered 113, with a tonnage of 118,936.

Harnessing the St. Lawrence.—A proposal is on foot to divert the course of the St. Lawrence River from the lower end of Grande Island, about half a mile from its present channel to the Ottawa River, and by the construction of an immense dam to keep the level of the St. Lawrence as far as its confluence with the Ottawa at the height of Lake St. Francis—some 85ft. above the level of the Ottawa River. An hydraulic lock would be constructed to enable steamers to pass up and down the river. The promoters of the enterprise claim that in some ten or twelve years' time, when the power would become available, there would be a sufficient demand in the district to take the 1,000,000 h.p. of electric energy that could be developed by means of the dam. Doubts are expressed, however, as to the effect of the dam upon the depth of the St. Lawrence River, which shows a tendency to decrease. It is stated that the execution of the scheme would involve the construction of from 25 to 30 miles of earth embankment, as well as of concrete dams across the St. Lawrence and Ottawa Rivers. The basin 11 miles in length, thus formed would then have to be dredged.

Marine Oil Engine Construction.—Important developments are impending on the Clyde with regard to the construction of marine oil engines, and an agreement is announced between the firms of Burmeister & Wain, shipbuilders and engineers, Copenhagen, and Barclay, Curle, & Co., shipbuilders and engineers, Whiteinch, whereby the Elderslie works recently acquired by the latter firm will be rapidly developed as works for the building of Diesel oil engines. Messrs. Barclay, Curle, & Co. have granted to the Burmeister & Wain (Diesel System) Oil Engine Company, Ltd., an option on 10 acres of Elderslie shipyard for the erection of a large oil-engine factory. Messrs. Swan, Hunter, & Wigham Richardson, of Wallsend-on-Tyne, are also interested in the Elderslie enterprise. Messrs. Burmeister & Wain are well known as the makers of the machinery for the two oil-engined vessels, the "Selandia" and "Fiona," built for the East Asiatic Company, Copenhagen, a sister ship, the "Jutlandia," having been built and engined by Barclay, Curle, & Co. It may be added that an entirely new company is being promoted under the title of the "Burmeister & Wain (Diesel System) Oil Engine Company, Ltd.," for the purpose of working the new factory. The capital of the new company will be £550,000.

New Dredger for Burma.—The dredger "Oswald" was launched a few days ago from the yard of Messrs. William Simons and Co., Renfrew. The dredger, which has been constructed to the order of the Indian Government, is of the well-known "Simons" suction reclamation type. It has been specially designed and constructed under the direction of Prof. J. H. Biles, naval architect and consulting engineer to the India Office, for the improvement of the waterways in Burma. The "Oswald" is a twin-screw, light-draught, cutter dredger, and she will work in conjunction with a floating pipe line and terminal pontoon, arranged for delivering dredged material over river or canal banks for land reclamation. The dredging pump is driven by an independent set of triple expansion engines, and the suction pipe is carried on a frame fitted at the forward part of the vessel. The lower end of the suction frame is fitted with a steel spiral rotary cutter, driven by gearing from a set of horizontal compound engines placed on the deck. Independent steam hoist gear is provided for controlling the suction frame, and very powerful manoeuvring winches are placed at each end of the vessel. The dredger is propelled by twin screws, each driven by a set of triple expansion engines. Steam is supplied by two cylindrical multitubular boilers, constructed to Lloyd's requirements for a working pressure of 160lbs. The boilers are fitted with Howden's forced draught for burning Indian fuel. A repair shop, with electrically driven machine tools capable of undertaking minor repairs, is fitted on board.

British Patents in 1911.—According to the annual report of the Comptroller-General of Patents, Designs, and Trade-marks, the number of applications for patents in 1911 was 29,353, as against 30,388 in 1910 and 30,603 in 1909. There were 19,524 provisional and 18,662 complete specifications, the numbers in the two previous years being 20,768, 19,105, and 21,553 and 18,705 respectively. The patents sealed were 17,164, the numbers in 1910 and 1909 being 16,269 and 15,065 respectively. The applications accompanied by provisional specifications fell from 20,768 in 1910 to 19,524 in 1911, a decrease of 6 per cent., while those accompanied by complete specifications rose from 9,620 to 9,829, an increase of 2·2 per cent., and the highest number on record for any one year. Thus the total number of applications fell from 30,388 to 29,353, a decrease of 3·4 per cent. The complete specifications filed on previous provisionals fell from 9,485 to 8,833, a decrease of 6·9 per cent. The total number of complete specifications received was thus 18,662, as compared with 19,105 in 1910, a decrease of 2·3 per cent. The total number of specifications (provisional and complete) received was 38,186, as compared with 39,873, a decrease of 4·2 per cent. There were 1,518 applications made by way of communications from abroad, of which 755 came from the United States of America, 467 from Germany, 43 from France, 28 from Canada, and 27 from India. Of the complete specifications filed upon applications made in the year 1910, 1,181 were reported as wholly anticipated, 10,252 as partly anticipated, and 5,506 as not anticipated. Of those anticipated, 10,363 were amended without a hearing taking place, and 740 after a hearing and decision. In 321 cases a reference to a previous specification was inserted. The number of applications made for the revocation of patents worked exclusively or mainly outside the United Kingdom was five. In two of these cases the patent was revoked, in one the application was dismissed, in one the patent expired after the proceedings had begun, and the remaining case is still pending.

Semi-steel Castings.—At a recent meeting of the Scottish branch of the British Foundrymen's Association, held in Glasgow, a paper was read by Mr. M. Riddell, of Falkirk, on "Semi-steel," which he described as the latest attempt in foundry practice to make sounder and stronger castings of foundry iron into which a variable proportion of mild steel had been melted. The earliest attempt was made many years ago by Mr. Stirling, who introduced malleable iron into his castings, but without any great success, and later investigations with the aid of chemical control had demonstrated the feasibility of using as much as 15 per cent. of steel scrap in the cupola charge. Considerable care was needed to get this thoroughly incorporated with the cast iron, and owing to the carbon absorbed the resulting metal was still iron without the special properties of steel. The various difficulties which arise in the practical working were discussed, the chief of these being shrink holes and hard spots, which are often more troublesome than when properly regulated mixtures of good foundry iron are used alone.

Admiralty Survey Ship.—H.M.S. "Endeavour," which was launched on Saturday, the 30th ult., by the Fairfield Shipbuilding and Engineering Company, Govan, has been specially designed and built for the work of surveying the navigable waters of the world, and she is the first vessel specially constructed for this purpose by the Admiralty. Up till now survey work has been carried on by ships which have been converted from other uses and rearranged for hydrographic purposes. The "Endeavour" is a vessel of 1,300 tons displacement and 13 knots speed. She is 200ft. long by 34ft. wide, and has accommodation for 136 officers and men. She is propelled by twin screws, each driven by a set of triple-expansion engines having cylinders 13in., 20½in., and 33in. diam. by 21in. stroke. She mounts one three-pounder and two Maxim guns, and carries a powerful searchlight forward. Her special equipment for survey purposes consists of a special sounding winch, sounding machines, derricks, platforms and jackstays, laboratory with drawing table, work table, sink, and chronometer room, and a well-equipped photographic dark room.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1910.

Production of gaseous fuel for metallurgical purposes. Reynolds. 29367.

1911.

Muffled roasting furnaces. Ridge. 3981.
Gyroscopic transmission apparatus. Fieux. 6128.
Differential worm gear for converting rotary into reciprocating or reversible linear motion. Spence. 6581.
Apparatus for railway signalling. Fletcher. 6592.
Clutches. Bowley. 6781.
Punching and perforating machines. Cameron, and John Cameron, Ltd. 6800.
Manufacture of steel. Paul. 6808.
Production of heat for forging and welding. Armstrong and Mordan. 6830.
Torsion meters for rotating shafting. Burga. 6913.
Turbine engine. Fisher & Peck. 7058.
Internal-combustion engines. Evans. 7101.
Clutches for transmitting and interrupting the transmission of motion. Lawton. 7345.
Magneto trip mechanism for internal combustion engines. Guinness. 7376.
Steam turbines. Waugh & Bedford. 7762.
Rotary engines, pumps, and compressors. Pollard. 8036.
Burners for gas fired furnaces. Keith & Keith. 8480.
Crucible furnaces. Bayley. 8671.
Steam engines. John Musgrave & Sons, Ltd., and Musgrave. 9357.
Valves and valve gear for internal combustion engines. Gerhardt. 9741.
Substitute for moulding sand. McPherson. 9771.
Transmission gearing of motor vehicles. Craig. 9801.
Process for treating pulverulent ores of iron. Soc. Anon. des Ciments Portland Artificiels de Buda. 9901.
Packing ring for hydraulic presses, fluid pressure engines, and pumps. Wagner. 10302.
Steam boilers. Barsby. 11248.
Production of blooms from steel ingots. Taylor and Taylor Bros. and Co. 11314.
Apparatus for indicating and recording the speed of ships. Cooper. 11632.
Vacuum gauges. Regina Elektrizitäts Ges. 12128.
Riveting tools. Collingwood & Richards. 13543.
Two-cycle motors. D'Harveng. 13565.
Apparatus for automatic analysis of gases. Binz. 13692.
Appliance for charging metallurgical furnaces. Gottlieb. 14027.
Arrangement for use in steam generators and water heaters to prevent corrosion and incrustation. Fry. 14513.
Reduction of metal ores. Sieurin. 14612.
Devices for controlling dampers for furnaces. Thwaites Bros., Ltd., and Bullock. 15016.
Furnaces. George Fletcher & Co., and Rudder. 15521.
Means for converting reciprocating into rotary motion and vice versâ applicable to engines and pumps. Williams. 16541.
Mechanical distant signal control for railways. Hellier & Gasson. 16662.
Purification of asbestos. British Thomson Houston Company. 16960.
Pulley blocks and hoisting gear. Priest, Millward, & Morrall. 17197.
Blow pipes. Fletcher, Russell, & Co., and Fletcher. 17320.
Roller bearings. Thompson. 17378.
Steam nozzles for heating liquids in vessels. Mooser. 17489.
Valve mechanism for internal combustion engines. Miesse. 17804.
Sliding stop valves. Kleinschmidt. 17885.
Valves and cocks. Bertrain. 17950.
Apparatus for charging blast furnaces. James. 17988.
Coal shipping machinery. Sir W. G. Armstrong, Whitworth, and Co., and Ridley. 18225.
Apparatus for carbonising peat. Edgeworth. 18393.
Manufacture of gas from coal. Rollason. 18741.
Lubricating packing. Drury & Stearns. 18800.
Rotary inferential water meters. Kennedy. 18905.
Method of connecting superheater tubes. Mannesmannrohren Werke. 20176.
Feed water heater for locomotive boilers. Schumacher. 20461.
Clutches or couplings. Heliot. 20450.
Tube expander. Clark & King. 21430.
Continuously operating annealing furnace for metals. Kugel. 22786.
Nut locks. Cheneau. 23582.
Valve mechanism for internal combustion engines. Rose, Sandbach, & Sandbach. 23711.
Sectional boilers. Gremmels. 24297.
Belt conveyers. Hildebrand. 25878.
Valves. Fisher & Peck. 26736.
Gas turbine plants. Akt. Ges. Brown, Boveri, et Cie. 29097.

1912.

A tilting Martin Siemens furnace. Ateliers de Constructions Electriques du Nord et de l'Est. 637.
Steam stop valves. Greatorex. 1137.
Ball cages for ball bearings. Kapper. 1462.

ELECTRICAL, 1910.

Self regulating dynamos. Vandervell & Midgley. 29493.

1911.

Gas detecting apparatus for portable electric hand lamps. Ralph and Holmes. 6364.
Variable speed dynamos for train lighting. Electric and Ordnance Accessories Company, Etchells & Price. 6611.
Incandescent electric lamps. Robin. 6856.
Electrodes for flame arc lamps. Oliver Arc Lamp, Ltd., Oliver and Pell. 6984.
Electric lampholders. Waterhouse. 7161.
Controllers for electric motors. Smith. 10219.
Intercommunication telephone systems. Sterling Telephone and Electric Company, and Bell. 11237.
Telephone signalling systems. Ellison & Jacobs. 12175.
Plug and socket electrical connections. Lundberg, Lundberg, and Lundberg. 12225.
Electrically operated or controlled indicating apparatus for use with signalling apparatus on railways. Johnson & O'Donnell. 12833.
Dynamos. Midgley & Vandervell. 15038.
Construction of electric plug connection. Price. 16081.
Automatic telephone exchange selector. McBerty. 16867.
Alternating current commutator generators. Siemens Bros. Dynamo Works, Ltd. 17040.
Starting switches for electric motors. Siemens Bros. Dynamo Works, Ltd., and Schupp. 18575.
Manufacture of electric metal filament lamps. Schwab. 20224.
Safety device for electric cables. Siemens Schuckert Werke Ges. 20995.
Luminescent tubes for rare gases. L'Air Liquide, Soc. Anon. pour l'Etude & l'Exploitation des Procedes Georges Claude. 24164.
Electric contact making and cut out devices for electrically lighting motor cars and rolling stock. Polkey. 24431.
Electric reading lamps. Burnham. 25211.
Electrodes for arc lamps. Beck. 25916.
Method and apparatus for the electric transmission of pictures. Tschörner. 27474.
Apparatus for lifting the brushes and short circuiting the rotor windings of alternating current dynamos. Bruce Peebles and Co., and Brookhouse. 28682.
Voltage regulators for electric generators. Olmsted. 28747.

1912.

Water tight terminal for electric cables. Robert Bosch. 3026.

METAL QUOTATIONS.

TUESDAY, APRIL 9TH.

Aluminium ingot	67/- per cwt.
„ wire, according to sizes, &c. ......from	102/- „
„ sheets „ „ ...... „	120/- „
Antimony ......£27/-/- to	£27/10/- per ton
Brass, rolled	7⅞d. per lb.
„ tubes (brazed)	10½d. „
„ „ (solid drawn)	8¼d. „
„ „ wire	7⅞d. „
Copper, Standard	£70/10/- per ton.
Iron, Cleveland	52/- „
„ Scotch	58/- „
Lead, English	£16/12/6 „
„ Foreign (soft)	£16/5/- „
Mica (in original cases), small	6d. to 2/- per lb.
„ „ „ medium	2/6 to 4/- „
„ „ „ large	4/6 to 8/6 „
Quicksilver	£8/12/6 per bottle.
Silver	26⅝d. per oz.
Spelter	£25/11/3 per ton.
Tin, block	£198/-/- „
Tin plates	14/3 „
Zinc sheets (Silesian)	£28/12/6 „
„ (Stettin; Vieille Montagne)	£28/5/- „

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The Physical Properties of Zinc.

ALTHOUGH zinc, owing to its low tensile strength, is rarely used as a stress-carrying member of a machine or structure, it is occasionally so employed, but its main use is as a constituent of other alloys and as a protective coating for iron and steel, or for positions in which its corrosive-resisting properties are important. Having regard to the extent of its employment for engineering purposes of one kind or another data respecting its physical properties is scanty. The scarcity of information appears to have been brought to the attention of the Engineering Experiment Station of the University of Illinois as the result of some questions submitted to it, and a series of tests of the strength of rolled zinc were consequently made by Mr. Herbert F. Moore, and the results of these which are of interest are embodied in Bulletin No. 52, which has just been issued. Previous available data were mainly based on tests by Dr. Oswal Meyer and Bauschinger. Meyer's tests showed that the stresses at elastic limit and yield point were both very low and not sharply defined, the former being an average of about 1,000lbs. per square inch and the latter 12,500lbs. A peculiar and unexpected feature of the results, however, was that specimens cut across the grain proved stronger and stiffer than specimens cut with the grain, *i.e.*, parallel to the direction of rolling, results which are not, so far as we are aware, characteristic of any other metal. The ultimate stress with the grain in these tests (made with thin sheets about $\frac{1}{20}$in. thick) was 30,400lbs., while across the grain it was 36,800lbs. This characteristic applied also to the elastic limit (determined by Hooke's law, *i.e.*, deformation proportional to stress) and yield point, these values being with the grain 710lbs. and 11,400lbs. respectively, while across the grain the figures were 1,280lbs. and 13,640lbs. On the other hand, the elongation of zinc under load followed the characteristics observable with iron and steel, being greater with the grain (27·2 per cent.) than across it (9·2 per cent.).

Bauschinger's tests were made with the object of finding the effect of rapidity of loading on tensile strength and disclosed a perceptible difference, the average ultimate tenacity in tests lasting 6 minutes being 29,100lbs., while in tests lasting 81 minutes it was only 23,300lbs. Some tests made by Martens with the object of determining the influence of thickness of plate and of temperature on strength confirms generally the results given above, and showed 300° Fah. (the melting point, it may be remarked, is 790° Fah.) as the most favourable temperature for rolling, as at that point the strength is low and the ductility a maximum. The results of the Illinois tests confirm generally previous ones, but as they were in some ways more exhaustive they permit of more specific conclusions. The ultimate tensile strength of cast zinc, for example, appears to depend on the temperature of pouring and other factors and varies within wide limits. In rolled specimens, zinc resembles other metals, the tenacity of thin plates being stronger than thick ones. For plates under $\frac{1}{20}$in. thick 24,000lbs. per square inch would seem to be about the value to be used for the ultimate tensile strength, and for plates over this thickness 21,000lbs., while the modulus of elasticity is about $11\frac{1}{2}$ million pounds per square inch. The Illinois experiments included some interesting tests on the resistance of zinc to punching and shearing with plates varying in thickness from 1in. down to about $\frac{1}{3}$in., and with flat-faced tools so as to make the applied stress as uniform as possible on all parts under shear. An examination of the results of these shows the average value of the stress on the area sheared, to be in punching 50,040lbs., and in shearing 43,270lbs., while the energy required in the punching tests was 25,200 inch pounds per square inch of sheared area, and in shearing 16,910 inch pounds per square inch. It is difficult to compare the ductility of different metals owing to the absence of any well-defined quantitative standards, but from the results of tests made it is manifest that zinc is much less ductile than wrought iron or mild steel, though it does possess a relatively high degree of plasticity. Where specimens do not exceed $\frac{1}{10}$in. in thickness bending tests do not show any difference either with or across the grain, but when a thickness of $\frac{1}{4}$in. and upwards is reached the difference is plainly perceptible, and hence, where zinc plates are required to be stamped or bent into shape, a severe cold bending test would appear to be a convenient one to apply in determining the acceptability of the material.

Joint Rings for Steam Pipes and Manhole or Mudhole Covers.

A Board of Trade Report (No. 2,071) just published calls attention to the fatalities that occasionally occur from the use of india-rubber packing rings for steam pipe and manhole joints, &c. The use of such elastic material between the flanges necessitates a gradual screwing up of the joint after the ring has been inserted to ensure continued steam tightness, as the material softens and undergoes lateral extension until a limit of compression is reached, when the tenacity allows no further extension and the joint becomes permanent and durable. Rubber rings used in this way often prove convenient where the joint surface is very uneven, but it is not an ideal material even in such cases; asbestos or other similar packing, which is not so liable to stretch or so perishable under heat, being far preferable, while for high pressures joints should, if possible, be made metal to metal, with only a coating of red lead between. This, of course, is not always feasible in the case of manhole and sight-hole covers on the curved surfaces of steam boilers, in connection with which, it may be also noted, many fatalities occur through the covers being a bad fit in the holes. As a result of this, the packing is only partially gripped between the joint surfaces, and is liable, if of rubber, to soften and be blown out under the steam pressure. Some years ago, accidents of this kind were very frequent and are still far too common, as we note from a glance at a batch of Board of Trade Reports recently issued.

IRON AND STEEL INSTITUTE.

THE annual meeting of this Institute will be held, by kind permission, at the Institution of Civil Engineers, Great George Street, Westminster, on Thursday and Friday, the 9th and 10th of May, commencing each day at 10-30 a.m. The following is a programme of the proceedings: Thursday, May 9th: General meeting of members. The council will present their report and the hon. treasurer the statement of accounts for 1911. The retiring president (the Duke of Devonshire) will induct into the chair the president-elect (Mr. Arthur Cooper). The Bessemer Gold Medal for 1912 will be presented to Mr. J. H. Darby. The president will deliver his inaugural address, after which a selection of papers will be read and discussed. In the evening the annual dinner of the Institute will be held in the Connaught Rooms, Great Queen Street, W.C. Friday, May 10th: General meeting of members. The Andrew Carnegie Gold Medal (for 1911) will be presented to Dr. P. Goerens (Aachen), and the award of Research Scholarships for the current year will be announced. A selection of papers will then be read and discussed. The following is the list of papers that are expected to be submitted for reading and discussion: (1) "Notes on the Solubility of Cementite in Hardenite," by Dr. J. O. Arnold and L. Aitchison (Sheffield); (2) "On the Chemical and Mechanical Relations of Iron, Vanadium, and Carbon," by Dr. J. O. Arnold (Sheffield) and Prof. A. A. Read (Cardiff); (3) "Notes on a Bloom of Roman Iron from Corstopitum (Corbridge)," by Sir Hugh Bell, Bart. (Middlesbrough); (4) "The Influence of Carbon on Corrosion," by C. Chappell (Sheffield); (5) "The Manufacture and Treatment of Steel for Guns," by General L. Cubillo (Valladolid, Spain); (6) "The Corrosion of Nickel, Chromium, and Nickel-chromium Steels," by Dr. J. N. Friend, J. Lloyd Bentley, and W. West (Darlington); (7) "On the Mechanism of Corrosion," by Dr. J. N. Friend, W. West, and J. Lloyd Bentley (Darlington); (8) "Sinhalese Iron and Steel of Ancient Origin," by Sir Robert A. Hadfield, F.R.S. (Sheffield); (9) "Modern Rolling-mill Practice," by J. W. Hall (Birmingham); (10) "The Influence of Heat on Hardened Tool Steels," by E. G. Herbert (Manchester); (11) "Improvements in Electric Steel Furnaces and their Application in the Manufacture of Steel," by Dr. H. Nathusius (Friedenshütte, Upper Silesia); (12) "A New Process for the Investigation of Fractured Surfaces of Steel," by F. Rogers (Sheffield); (13) "The Welding Up of Blowholes and Cavities in Steel Ingots," by Dr. J. E. Stead, F.R.S. (Middlesbrough); (14) "Note on Some Remains of Early Iron Manufacture in Staffordshire," by Prof. T. Turner (Birmingham).

Electric Traction on Railways.—A lecture on this subject was recently delivered by Prof. Gisbert Kapp at the Birmingham University. Prof. Kapp, answering the question as to whether there was any economy in electric traction, said that opinions differed even amongst electrical engineers. If a line were electrified on a large scale—not simply a few dozen miles—there would be an economy effected. Then there would be an increase in driving capacity, because an electric locomotive was able to exercise more power; it hadn't to carry its own source of power. In the generation of that power cheaper fuel could be used. The modern electric express locomotive could develop 30 h.p. for every ton of its own weight. The slow passenger, or fast goods train, could develop 22 h.p., and even a slow goods engine would develop about 10 h.p. or 12 h.p. Another advantage in electric motors was that the train could be started much more quickly than by steam. The overhead wiring was really the difficulty in electric traction.

BROWN'S FOUR-CYLINDER OIL ENGINE.

We illustrate herewith a design of internal-combustion engine of the valveless and sleeveless type, the joint invention of Messrs. David Brown & Sons (Huddersfield), Ltd., Park Gear Works, Lockwood, Huddersfield, and Mr. F. T. Burgess. The cylinder casing A is made integral or in one casting, a common combustion chamber R or S being provided for each pair of cylinders, which pairs of cylinders have no communication with each other. The crank shaft is journalled in bearings in the crank case, the arrangement being such that it can be drawn out bodily endwise from the crank case without removing the latter. On one of the crank discs to one pair of pistons adjacent the crank disc to the inner piston of the other pair of pistons is provided a facing which abuts against a corresponding face on a part surrounding and supporting the bearing for the intermediate portion of the crank shaft, to make a tight joint between same and isolate the portion of the crank chamber corresponding to one pair of cylinders from the portion of the crank chamber corresponding to the other pair of cylinders, and thus form separate crank chambers in which the cranks to each pair of pistons work. A further tight joint is made by an annular ground face on the part supporting the bearing engaging with an opposing ground face on the crank casing. This construction gives an air-tight joint between the two crank casings and prevents the passage of air from one chamber to the other. The several crank discs are hollowed out or recessed on the faces opposed to the bearings for the crank shaft, and in each of these recesses is an eccentric groove, the highest portion of which extends to a point in alignment with a bore through the crank pins, and is in communication therewith. Lubricant is forced into the recesses in the discs and is caused to enter the grooves and pass from the highest points thereof into the bores in the crank pins from whence it flows through channels to the outer circumference of the crank pins to lubricate same and parts connected therewith.

The adjacent cylinders B and C of the two pairs of cylinders are provided with inlet ports D E, and the outer cylinders F and G of the pairs are provided with outlet ports H and J. The inlet ports are equally distributed around the respective cylinders, the ports of each cylinder communicating through a passage K or L with an inlet M from the respective compartment of the carburetter. The outlet ports communicate with the exhaust passage P which is common to the two outer cylinders of the engine. This formation and arrangement of the inlet and outlet ports facilitates the admission of the combustible mixture to the cylinders and the clearing away of the products of combustion after each explosion. The pairs of pistons rise and fall alternately and, as the pistons of each pair rise, air is sucked into the respective crank chamber and the fuel is sucked through the jet. When the pistons of each pair descend on the charge being fired, the air in the respective crank chamber is compressed until the inlet port to the cylinder is uncovered, and then the compressed air rushes past the jet thereby becoming impregnated with inflammable vapour and entering the combustion chamber. The carburetter comprises a single casting divided into two compartments each containing a carburetting device as shown. Each chamber or compartment communicates through a passage O, with its respective portion of the crank case, and through its respective inlet passage K or L with the inlet ports. Both carburetting devices are controlled by a common throttle valve N. The carburetting devices are of the type in which the flow of air draws petrol through a passage T, the outlet area of which is controlled by a needle valve.

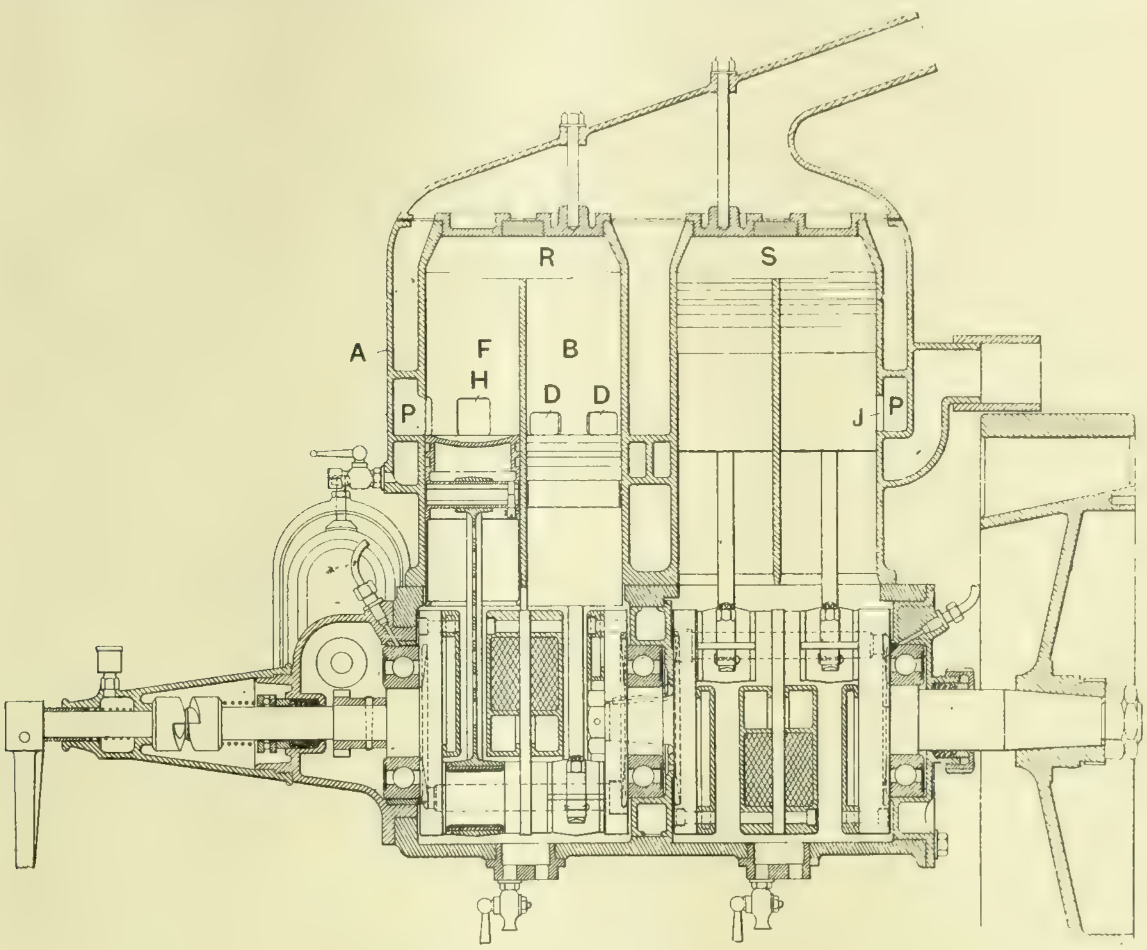


Fig. 1.

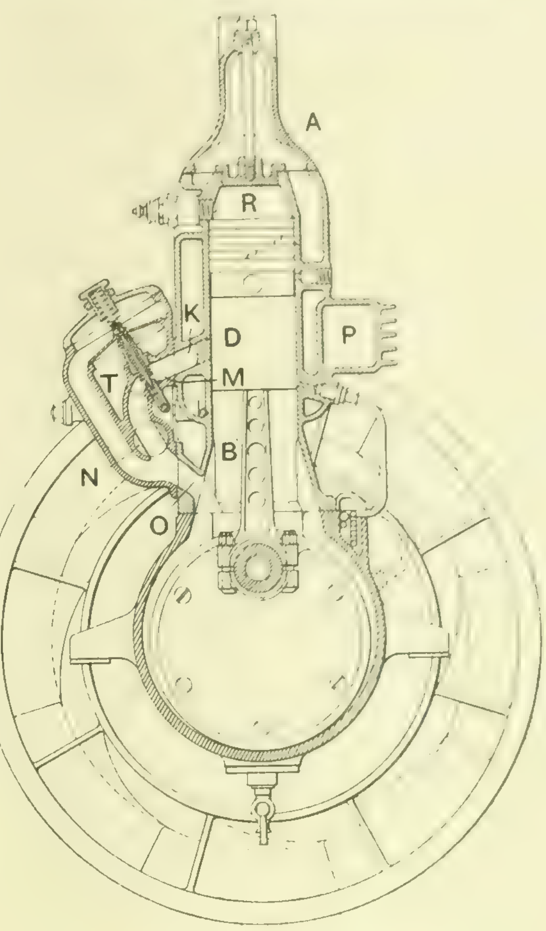


Fig. 2

Brown's Four-Cylinder Oil Engine.

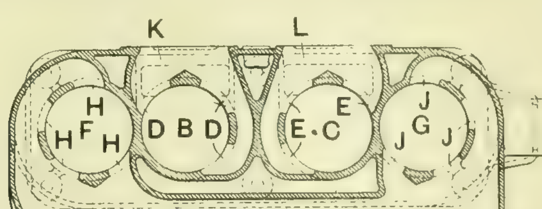


Fig. 3.

Fatal Steam Pipe Explosion. An explosion occurred on Tuesday last, at Hull, on board the Italian steamer "Pasquale P.," which was lying in the Albert Dock, about to proceed to sea. One man was killed, another is not expected to recover, and four other members of the crew were badly scalded. The men were in the engine room when the steam pipe burst, and they received severe scalp wounds, besides being scalded.

ON THE SOLIGNAC-GRILLE BOILER AND ITS APPLICATION IN FRENCH CHANNEL STEAMERS.*

BY G. HART.

THE Solignac-Grille boiler with small water tubes differs considerably from the boilers with tubes of small diameter heretofore in use. The principle adopted for circulating the water and passing the steam through the tubes is quite different in these boilers. It is based upon the introduction at the orifice of the tube, on the feed-water side, of a supplementary resistance preventing any tendency to reverse the direction of flow of either fluid. It is desirable, therefore, before considering

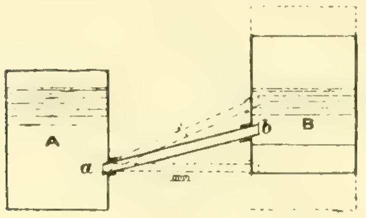


FIG. 1.

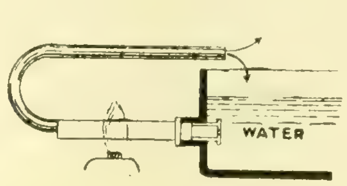


FIG. 2.

the Solignac-Grille boiler, to deal briefly with the theoretical and experimental reasons which have lead to the employment of a device adopted for ensuring a regular circulation.

If one considers a bubble of steam originating at the lower side of an inclined tube full of water, it is found that this bubble rises vertically until it reaches the upper side of the tube, against which it impinges at an angle depending on the inclination of the tube. The bubble then travels along the upper side and expands under the action of heat, while it also tends to escape out of the tube. But its escape is rendered difficult by the fact that there is, above the outlet of the tube, a pressure due to the head of water separating the tube from the water surface, and also that due to the pressure in the boiler. The escape cannot take place until the steam pressure which accumulates at the upper portion of the tube in the form of a steam pocket is sufficient to overcome the resistance, and it then takes place suddenly. It is followed immediately by a return of the water, in which steam bubbles are again formed, until a new steam pocket is formed. These sudden escapes of steam and consequent return of water give the steaming a tumultuous character, very liable to disturb the circulation and to produce priming, because the steam has, before escaping, to pass through the water surface. It results from this periodical escape of steam that the tube is not completely filled with water. Its upper portion is filled with steam, so that the metal is very unequally cooled, which frequently causes the tube to bend, and creates local deformations.

The hydrostatic force of the ascending steam bubble can be resolved into two components, one perpendicular to and the other parallel with the axis of the tube. It is this second force which causes the steam to ascend along the tube. If the entire length of the tube is exposed to the action of the heat, every cross-section of the tube is cut by a series of ascending streams which make both the water circulation and the escape of steam intermittent, so that both will depend mainly on the application of heat to the tube, and on its distribution. If the tube is unequally heated, it may even happen that, if for any reason, such as the rolling or pitching of a ship, its inclination to the horizon varies, the direction of the water circulation and steam escape is reversed, and that the steam escapes now at one, now at the other end of the tube. A variation in the distribution of heat along the tube or in the amount of friction which the steam has to overcome before it can escape causes the same result. Such reversals of the water circulation are found frequently in marine boilers with water tubes slightly inclined to the horizon, principally when the tubes are of large diameter. These boilers are subject to frequent reversals of circulation, and when the head of water above the tubes is considerable they are sometimes liable to very violent motions of the water.

Mr. Bellens, in the course of his investigations on water circulation in boilers, made a series of experiments, from which he has been able to ascertain the cause of such reversals of circulation. He observed, moreover, that the escape of steam was not continuous, but took place in jerks and in the form of very large steam bubbles. He also saw, by means of a sighting hole fitted with a looking glass, the water descending between two escapes of steam, by the path of this escape. It was in order to do away with such escapes of steam by jerks and reversals in direction that Mr. Solignac had the idea of fitting at lower end of the tube a diaphragm creating a supplementary resistance which should prevent any escape of steam at the lower end. He took as a basis for this design the results of the following experiments. Take two similar vessels (Fig. 1) placed in the same horizontal plane and connected by a suitable horizontal metallic tube. Now heat the tube, and you will see steam escaping intermittently from the two ends of the tube, whose heated portion becomes red hot, the water which it contains being transformed to steam. This steam does not escape except when its pressure is greater than the resistance caused by the pressure of the head of water above the tube. As soon as the former has become again less than the latter, the water once more fills the entire tube, and the operation recommences.

When the feed water is cold and does not as yet contain any trace of steam, one can hear a rapid hammering, when the water rushes into the tube, which decreases as the temperature of the feed water rises. If the water is cold and the tube somewhat long, this knocking is accompanied by the bending of the tube, whose convexity is turned on the side opposite to the application of the source of heating. If now, one of the two vessels is raised gradually so as to give more inclination to the tube, the phenomena are modified according to the inclination, the height of the head of water above the outlet of the tube being no longer the same. As long as the inclination is slight and does not exceed the diameter of the tube, the effects observed are nearly the same as when the tube is horizontal.

If, on the contrary, we increase the inclination of the tube, the escape of steam still takes place at both ends; but,

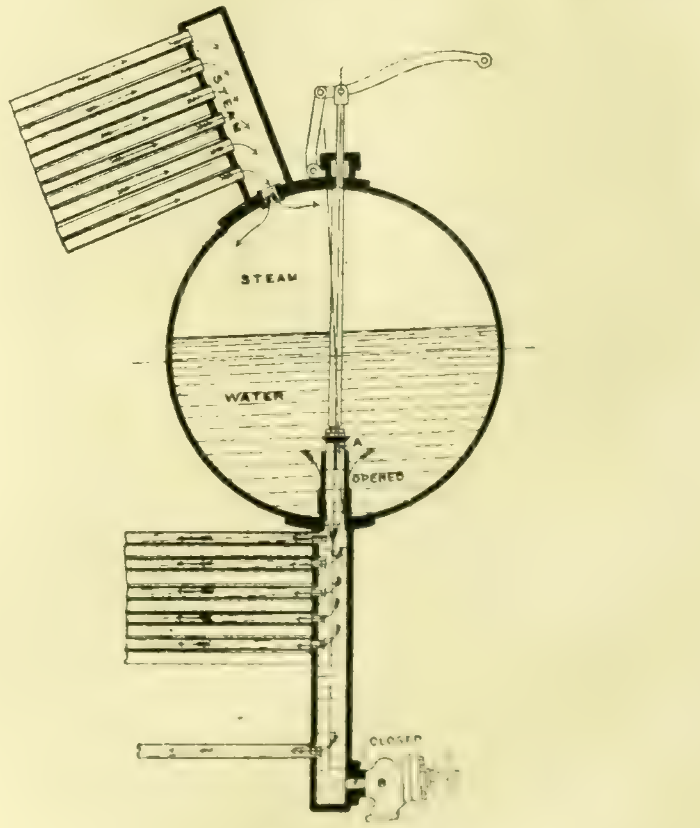


FIG. 3.

as the inclination increases, a larger quantity of steam escapes by the side of the upper end, while the water in the vessel on this side is also heated to a higher temperature. The escape of steam is, however, never regular. It has very variable periods of intensity, as may be ascertained by suspending from the upper end of the tube a little thin shutter, which is driven off or drawn on, according as the escaping steam is more or less active. While there is only an occasional escape of steam

* Paper read at the spring meeting of the fifty third session of the Institution of Naval Architects, March 28th, 1912.

by the lower end of the tube, you will, however, see a liquid film of viscous appearance escaping from it, with variable periods of intensity, corresponding with those of the steam discharge at the other end.

If, while retaining the same device, a reducing diaphragm is fitted at the lower end of the tube the phenomena of circu-

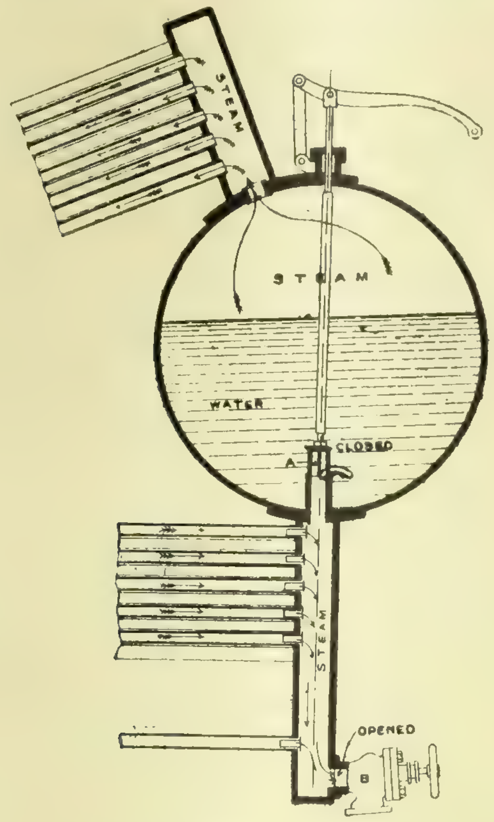


FIG. 4.

lation become quite different. Steam then escapes continuously from the free end; the tube no longer becomes red hot, and the water in the vessel on the diaphragm side remains cold, while the water in the corresponding vessel at the free end is heated rapidly. Finally, the level of the water becomes lower in the vessel on the diaphragm side, and rises in the vessel corresponding to the free end by a quantity which varies according to the inclination of the tube. This experiment was, moreover, supplemented by the following one:—

If a vessel (Fig. 2) is fitted with a pipe connected to a metallic tube passing through a joint, and a bent glass tube completes the circuit above the vessel, it will be seen that, when the metallic tube is heated, it rapidly becomes red hot in the heated portion, while the portions adjoining are at a high temperature. The level of the water varies above or below the level AB of the water contained in the vessel. The steam escapes by the end of the tube connected to the vessel, and hammering is heard in this at the moment when steam escapes and is followed suddenly by cold water in the tube. The temperature in the vessel rises after a time, and the tube, though it passes out under the water, becomes red hot throughout its entire length. If, on the contrary, we fit on to the end of the tube connected with the vessel a section-reducing diaphragm, we find that the water penetrates regularly into the tube, which does not become hot, and that the upper bent branch, after having emitted water and steam, lets the steam escape in a regular and plentiful manner. There is no more hammering due to the sudden return of water upon the red hot part of the tube, but as soon as the diaphragm is taken off it recommences immediately.

The diaphragm is, therefore, the proper regulating device which affords a continuous flow of steam. It performs a double duty. First it creates on the side of the feed water, a supplementary resistance which prevents any reversing in the direction of the steam outlet. Secondly, the diaphragm limits the flow of water into the tube to the quantity corresponding, after regulating the inlet orifice, to the quantity of water which can be vaporised. It follows that beyond this diaphragm the proportion of water to steam in the emulsion contained in the tube is lower than when the diaphragm is not in its place. There is, consequently, a decrease in the resistance to the escape of steam at the free end of the tube, on the one hand, and, on the other, an increase of resistance on the side of water. The sum of these two effects ensures a rapid and regular circulation. It is to be observed that in this arrangement the escape of steam takes place above the water level in the vessel, so that the steam is much drier and the carrying along of water is done away with, provided that the opening of the diaphragm is well under control.

It may be objected that, with such a device, as the tube contains only an emulsion of steam and water, and this latter being only in a limited proportion, the tube can be burnt more easily. But it must be remarked that in other water-tube boilers there is likely to be nothing but a mixture of steam and water, the former beginning to escape along the whole length of the tube, as the flow is interrupted, as stated above, by the ascending streams of bubbles. The only difference between these boilers and the one here described is that there is in them a *mixture* and not an *emulsion*, *i.e.*, steam and water pockets of very considerable size instead of a very fine emulsion of water and steam. It seems, therefore, that this is, on the whole, more advantageous, and it was, moreover, confirmed experimentally.

The regular circulation in the Solignac-Grille boiler is accounted for principally by the fitting of the reducing diaphragm on the side on which the water reaches the vaporising tubes. But this boiler, as now constructed, presents various other features which differentiate it from the generality of

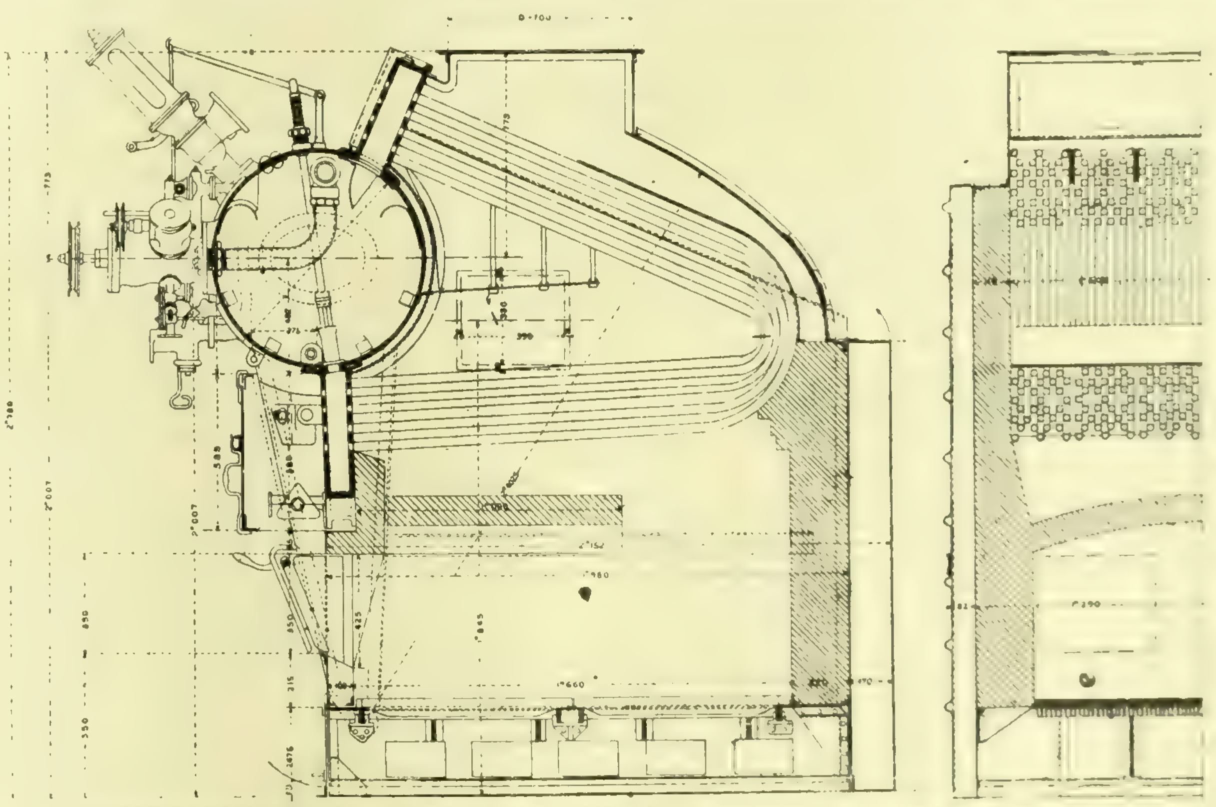


FIG. 5.—SOLIGNAC-GRILLE BOILER ON TORPEDO BOAT "KABYLE." LONGITUDINAL SECTION AND HALF CROSS-SECTION.

existing small tube boilers. The first and most important advantage is, next to the diaphragm, the facility for cleaning the inside of the tubes with a jet of steam under pressure proceeding in the reverse direction to the normal circulation.

This tube-cleaning by steam under pressure is of very short duration, since it is operated while the boiler is under steam and under fire; it ensures a thorough cleaning of the inside of the tubes, and carries away every trace of scale and sedi-

ment. It is of importance that it should not be prolonged beyond 30 seconds, in order that the tubes should not be deprived of water for sufficient time to become damaged by the effect of heat-radiation, and for this purpose the operating device is most simple and rapid. The cleaning is made still easier by the division of the tubes into several groups, each corresponding to an element of the boiler shell, the various elements having nothing in common but the steam and water chest.

Figs. 3 and 4 indicate, the first, the path of the steam when blown through for cleaning, and the second the normal steam circulation. It must be noted (Fig. 3) that one has

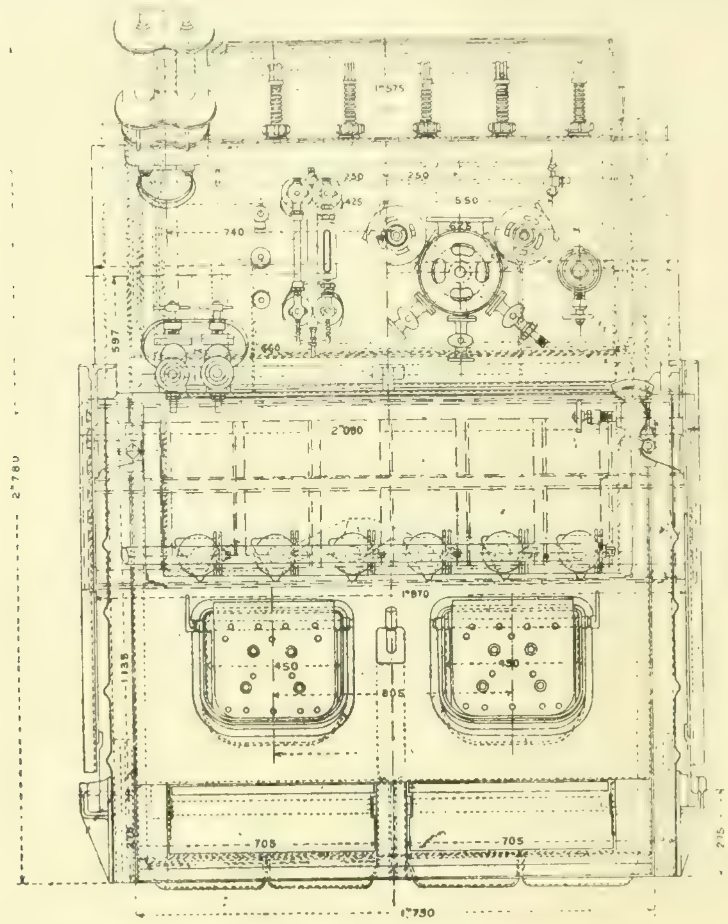


FIG. 6.—FRONT ELEVATION OF BOILER SHOWN IN FIG. 5.

only to pull the chain by which the valve A (which is open while steam is circulating normally) is closed, and to open the blow-off valve B, to reverse the direction of the steam and send into the tubes a very powerful steam-jet, which carries away any impurities they may contain.

Fig. 4, representing the normal circulation, shows that the steam, in order to escape into the upper steam chest and into the upper part of the general chest, is not compelled to cross the water surface, but escapes above it. Hence the steam generated is much drier than in boilers, where it has to pass through the water surface, and the proportion of water is very small, as was shown by measurements taken with the Rateau apparatus This proportion does not exceed the ratio of a few thousandths. Besides, this way of escape does away with the tumultuous ebullition and consequent rushes of water, and the more so as the water and the steam chests are only exposed to a very slight quantity of heat, and the return of the steam through the mass of water is made impossible by the presence of the diaphragm. Finally, it is a device which allows the whole boiler and the group of tubes to be opened up around a pivot for inspection, and for repairing the brickwork surrounding the boiler, which accounts for the excellent returns from the coal burnt and for the high efficiency per kilogramme of coal, the furnace working as a real gas producer.

Trials on an experimental boiler of the Solignac-Grille type were carried out in Paris in 1901, and at Loughborough (England) the following year. Subsequently more extensive trials on full-sized boilers of this type were made at Indret and Calais Maritime in 1903 and 1905, the details of which are too extensive to be given in the present paper, but some results obtained with a boiler of this type fitted in a French torpedo boat may be referred to before describing the installations that have been carried out in the Channel steamers between France and England.

In 1908, the French Admiralty, encouraged by the trials made at Indret, decided that the two Thornycroft boilers of the torpedo-boat "Kabyle" (of 125 tons, 1,700 i.h.p., and 20·5 knots of speed), which were at their extreme limit of wear, should be replaced by two Solignac-Grille boilers (Figs. 5 and 6), particulars of which are recorded below:—

Grate area	2·14 sq. m.
Heating surface	62·36 sq. m.
Tubes: Number	192
,, External diameter	30 mm.
,, Internal diameter	25 mm.
Working pressure	15 kgs.
Volume of water	725 litre
Volume of steam	620 litre
Weight of the boiler without water	7,225 kgs.
Weight of the boiler with water	7,950 kgs.

The small floor space required by the Solignac-Grille boiler, which gives a high rate of steam generation per square metre of space occupied, makes its use advantageous in many cases, especially on board ship. Before being fitted on the "Kabyle," the boilers were tested on land by extensive trials,

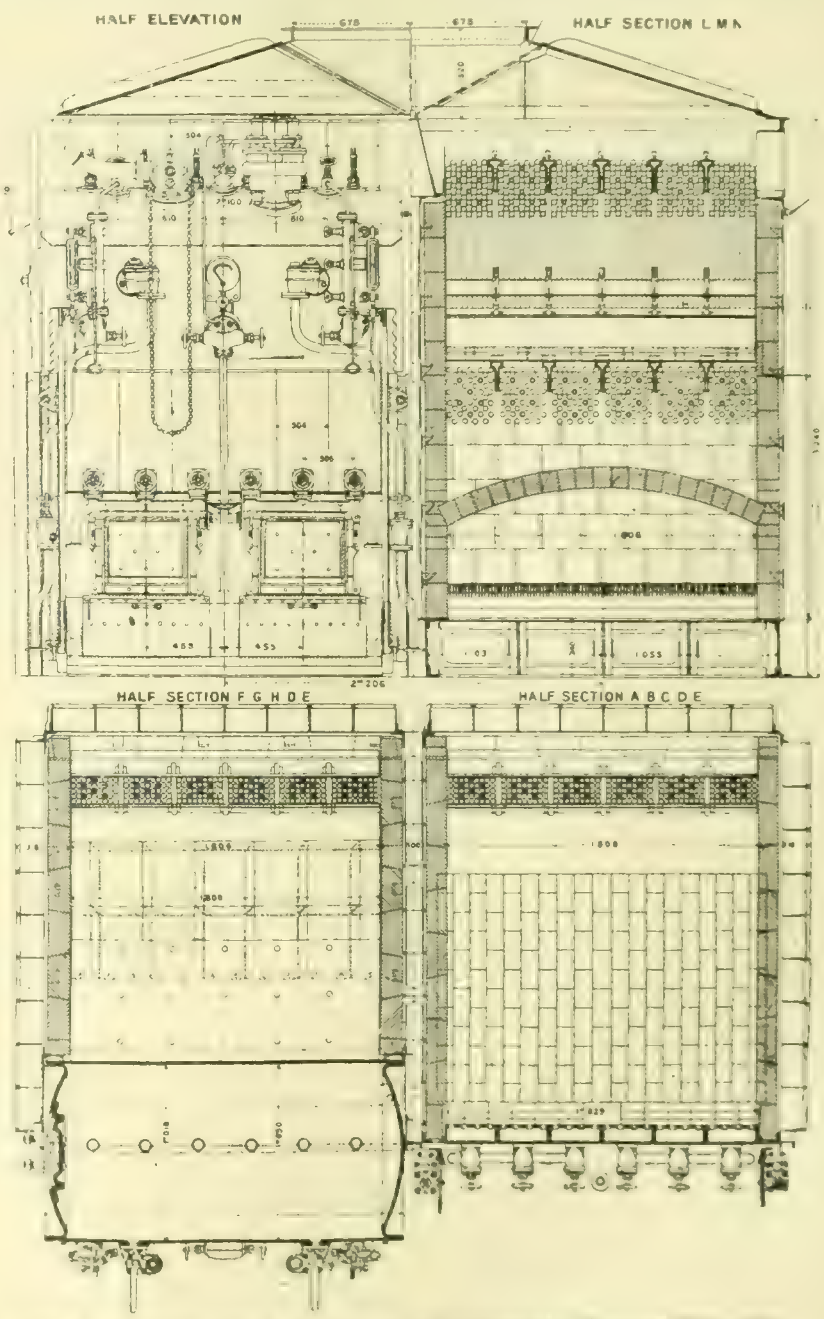


FIG. 7.—SOLIGNAC-GRILLE BOILERS IN PADDLE-WHEEL CHANNEL STEAMERS S.S. "LE NORD" AND "PAS DE CALAIS."

which showed that, with a rate of combustion varying from 98 kgs. to 295 kgs. per square metre of grate, a rate of evaporation varying from 9·662 kgs. to 8·668 kgs. per kilogramme of coal could be obtained, with feed water at 12° C. and a very low proportion of water (0·007 to 0·008). The temperature at the foot of the funnel fluctuated from 330° C. to 480° C. These satisfactory results obtained on land were confirmed by trials at sea, in the course of which the "Kabyle" attained her designed speed.

During the acceptance trials, 20 years ago, the coal consumption of the Thornycroft boilers was 1,600 kgs. per hour at 310 revolutions. During the trials at sea with the Solignac-

Grille boilers, the same speed was maintained during three hours with a coal consumption of 1·030 kgs. — a saving of 570 kgs. per hour, or about 35 per cent. Although the grate area was only 4·28 sq. m. as compared to 5·70 sq. m. in the Thornycroft boilers, the rate of combustion did not exceed 242 kgs. per square metre of grate.

With the high rate of combustion, the temperature at the foot of the funnel did not exceed 325° C., the air pressure in the stokeholds being 75 mm. of water. The temperature in the stokehold, recorded at 1 m. in front of the boilers, did not exceed 30° C., which is accounted for by the slight radiation due to the complete covering in refractory masonry with air circulation. The good effects of blowing steam through was shown by the expulsion of a large quantity of oil, resulting from insufficient filtering of the condenser water. During the inspection made after the trials, fatty deposits were found only on the surface of the brackets supporting the reducing diaphragms, on which a large quantity of grease had been projected during the blowings. The tubes and nozzles were found to be perfectly clean. The formal acceptance of the "Kabyle's" boilers was announced in the course of the year 1909. The ship was commissioned for the naval engineers' school. There is a great saving of weight and space by the use of Solignac-Grille boilers, which has enabled a cross coal bunker to be installed in the front of the boilers, so as to increase the radius of action of the ship, already enlarged by the saving of coal. The installation of two Solignac-Grille boilers in a steamer of the Gironde and Garonne Steam Navigation Company showed a saving of weight of 44 tons—the two Solignac-Grille boilers weighing 22 tons, while the two cylindrical boilers weighed 66 tons.

After these various trials, and on account of the proposed replacing of the boilers on the steamers for the French Mail Service between France and England, the Maritime Service of the French Northern Railway Company adopted a type of boiler with a grate area of 3·50 sq. m. to replace the Lagraffel and d'Allest boilers, which were troublesome on account of the high rate of combustion at which they had to be worked in order to supply the required power. The construction of four boilers for experimental purposes was decided upon, but it was understood that, before installing them on board in the aft stokehold of one of the steamships, they would be used on land for a series of experiments. These boilers, mounted on the "Pas de Calais" and the "Nord" (Figs. 7 and 8), were constructed at Hellemmes, in the works of the French Northern Railway Company, and also in the Ateliers et Chantiers de France, at Dunkerque.

After a series of trials made in 1908-1909, by which the results previously obtained were confirmed, both in respect of evaporation and of the efficiency of steam blowing, these four boilers were fitted, jointly with eight Lagraffel and d'Allest boilers, on board the "Pas de Calais." The latter were located in the forward stokehold, and the Solignac-Grille boilers in the aft stokehold, separated from one another by a watertight door and coal bunkers.

The principal dimensions and particulars of the two types of boilers are given below. As will be seen by referring to this table, the Solignac-Grille boilers, intended to work at a high rate of combustion, have only 3·49 sq. m. of grate area, while the Lagraffel and d'Allest boilers, for which the former have been substituted, had 4·20 sq. m. of grate area. This is a reduction of 12 per cent., which accounts partly for the saving in floor space

The Lagraffel and d'Allest boilers previously fitted being of three different sizes, the data of the intermediate group were taken as a basis of comparison. In normal working the rate of combustion is, in the Lagraffel and d'Allest boilers, of 120 kgs. per square metre of grate, and, in the Solignac-Grille boilers, of 160 kgs. However, in order to be able to continue working in case it should be necessary to put out of service a group of two Lagraffel and d'Allest boilers (which cannot be disconnected without difficulty), provision was made to raise the rate of combustion to 200 kgs. per square metre of grate. Working two stokeholds with different rates of combustion implies, as a matter of course, rather serious difficulties, since the two fans have to work simultaneously in the two stokeholds, and the fore stokehold has twice the grate area of the other one. After some trials, however, it was found that the air pressure could be properly controlled in the two stokeholds, but a closed air chamber had to be set up between the two stokeholds, in order to avoid air currents being set up.

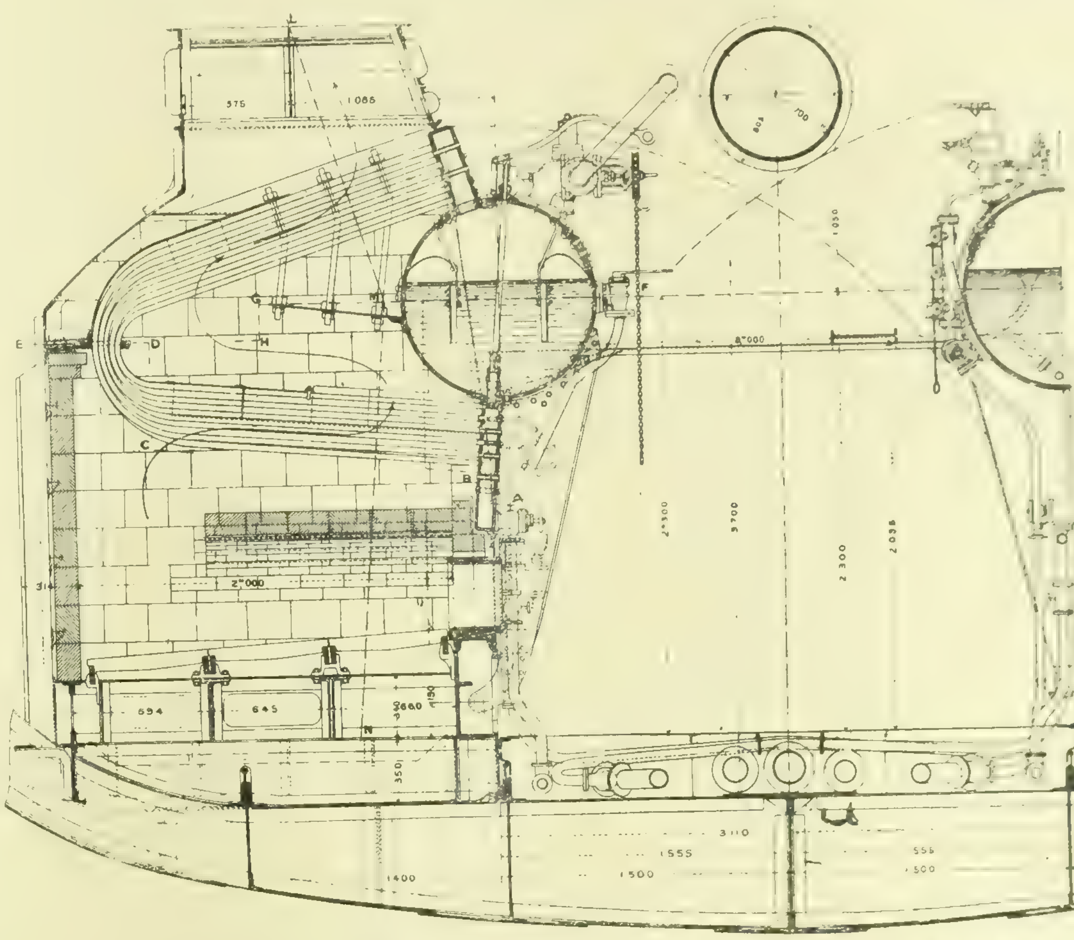


FIG. 8.—SOLIGNAC-GRILLE BOILERS IN PADDLE-WHEEL STEAMERS S.S. "LE NORD" AND "PAS DE CALAIS."

Particulars of the Boilers.		Lagraffel and d'Allest.	Solignac-Grille.
Working pressure	kgs.	15	15
Grate: Length	m.	2·00	1·932
Grate width	,,	2·00	1·806
Grate: Area	sq. m.	4	3·249
Tubes, Number		259	258
Tubes: Internal diameter	mm.	62 and 64	25
Tubes: External diameter	,,	70	30
Mean length of the tubes	m.	2·200	4·421
Heating surface in contact with the hot gases: direct ...	sq. m.	5·90	2·563
Heating surface in contact with the hot gases: tubular ...	,,	125·35	107·20
Heating surface in contact with the hot gases: total ...	,,	131·25	109·76
Ratio of heating surface to grate area		32·8	31·44
Volume of water	cub. m.	3·200	1·300
Volume of steam...	,,	2·380	0·913
Height of the chimney above the grate	m.	17	17
Section of chimney corresponding to one boiler	sq. m.	0·625	0·625
Required floor space	,,	6·80	[illegible]
Weight in working order (water included)	tons	17·5	13

The considerable difference between the weights of both types of boiler in working order may be noted in the preceding table. The Solignac-Grille boiler has the advantage both

as to weight of construction and as to volume of water contained. This latter is less than that of the d'Allest boilers by more than 50 per cent., but 45 per cent. greater than in Belleville boilers, and this reduction involves no inconvenience in the working of the boiler, since the feeding apparatus can be controlled according to the production of steam. There have been, during the past eight months' service, no difficulties due to this reduction, and the stokers have become well acquainted with the practical working of the Solignac-Grille boilers. In the course of the trials made after the repairs to the steamer "Pas de Calais," comparisons were made by running first with the four Solignac-Grille boilers, then with six of the Lagraffel and d'Allest boilers. It was not possible to run at exactly the same power, and consequently at the same speed, in both cases; but after the necessary corrections had been made, the following figures at equal power and speed were arrived to.

The four Solignac-Grille boilers working with a rate of combustion of 200 kgs. per square metre of grate correspond to six Lagraffel and d'Allest boilers working at 132 kgs. The coal consumption is 2,795 kgs. for the former and 3,120 kgs. for the latter, which represents a saving of about 12 per cent., despite the difference in the rate of combustion, which, with the highest rate of combustion, causes a reduction in the evaporative power per kilogrammes of coal. The evaporation should, therefore, be much better in the Solignac-Grille boilers than in the Lagraffel and d'Allest, and this is accounted for by the difference in the volumes of the combustion chambers. These results are lower than those given by the "Kabyle," where the conditions of the installation were entirely different. They were confirmed in actual service on the "Pas de Calais," which, although it has more steam available, shows a steam consumption less by about 8 per cent. than it was with only d'Allest boilers.

On the "Nord," fitted with 12 Solignac-Grille boilers, instead of four only, the speed is notably increased in spite of a greater displacement resulting from various causes. The boilers fitted on both the "Nord" and "Pas de Calais" are appreciably different from both the experimental boiler and from those fitted on the "Kabyle," as may be seen by referring to the plans.

The second steamer, "Le Nord," being fitted exclusively with Solignac-Grille boilers, continues on a more extensive scale the progressive experiment undertaken with these boilers. This steamer would have been completed more rapidly if reasons connected with the service had not made it necessary to postpone the replacing of the boilers till the year 1911. It is now in service, and the saving of weight due to the boilers themselves has fortunately compensated for the additional draught caused by loads added forward, and the speed is notably greater on the "Nord" than on the "Pas de Calais." The combustion rate is 166 kgs. per square metre of grate and the pressure (16 kgs. per square centimetre) is easily maintained, the level of the water being almost constant. The time for raising steam with the Grille boilers is one-half of that required with Lagraffel boilers, and when the ship starts with a low pressure and with fires in a bad state, in consequence of the late arrival of trains, the normal pressure is obtained in four or five minutes, while 10 or 12 minutes were necessary with the Lagraffel boilers.

On December 10th last, in a very heavy sea, the outlet valve of the centrifugal circulating pump being out of the water in consequence of rolling, the condensation was interrupted, and the steam of the low-pressure cylinder, escaping by the lifting of the condenser safety valve, invaded the engine and boiler rooms. No priming in the boilers nor any shocks in the cylinders were observed, in spite of the rolling having reached 35° from the vertical and the transverse position of the boilers in the ship, the steam being discharged above the water level. This would have been impossible with the former boilers, and the failure of the high-pressure cylinder, with all the consequences involved, would very probably have occurred. The working of the boilers was resumed after six minutes, although the stokers had begun to leave the boiler rooms, which were rendered uninhabitable by the escape of steam.

In conclusion, the advantages offered by the Solignac-Grille boilers may be summed up as follows:—(1) Considerable reduction in weight. In the case of the steamers of the mail service between France and England, this reduction affects the stokeholds placed forwards, and will involve an alteration in trim favourable to speed, or a reduction of the power required at the same displacement. (2) Reduction of the floor space, which while ensuring an easier installation of the boilers, and a more convenient access to their various parts, will allow the installation of some auxiliaries whose economy will add to that of the boilers. (3) Notable saving in coal. This saving may be estimated at 6 or 8 per cent. (4) Economy in coal resulting from the external covering of the boilers acting as a gas producer. (5) Greater flexibility in steam production of the boiler. The economical rate of combustion with a maximum output seems to be 150 kgs. per square metre of grate approximately, but this rate may, without too great a variation in the output, be increased to 170 kgs. or 180 kgs., and, with a very light reduction of efficiency, to 200 kgs. per square metre of grate. (6) Economy of maintenance. The maintenance cost is very slight, if the periodical cleaning of the tubes by a steam jet is carefully done. (7) Reduction of priming and production of dry steam, the escape of the steam generated taking place above the level of the water. These two last advantages will become specially valuable where steam turbines are used as motors. (8) Easy internal cleaning, by reversal of the steam jet. (9) Easy working. The level of the water varies only very slightly in the water gauges if the apparatus is properly controlled and the production of steam is very regular, without any priming at all. (10) Safety for the personnel, because the fracture of a tube, the only damage that can happen, cannot have any serious consequences, even if the stokers are only very imperfectly acquainted with the boiler. In order to obtain altogether satisfactory results, the stoking must, of course, be worked methodically, as is usual on board the steamers of the French mail service.

THE PREVENTION OF ACCIDENTS IN FOUNDRIES.*

BY W. H. CAMERON.

All accidents due to negligence are largely preventable. The means of prevention lie in the direction of (1) proper design and construction of plant and appliances, (2) care on the part of employers and employés, and (3) the use of safety devices. It must not be overlooked that in the past employers have concentrated their attention on the machinery and equipment of their plants and overlooked the most important element of all, the care of the human machine. Although considerable stress will be laid in this paper upon the proper design and installation of protective devices, it is believed that at least two-thirds of the accidents which happen in any plant are due to carelessness on the part of the worker and negligence for which the employer and employé are responsible.

It is an easy matter nowadays to secure information from the current journals of the details of organisation for carrying out elaborate plans for safeguarding employés, involving the expenditure of large sums of money; but while it is believed that the underlying principles of both large and small organisations are essentially the same, it is the intention of this paper to give the experience of one of the smaller corporations in its efforts to prevent accidents and protect its workmen to the maximum.

Up to 17 months ago the American Steel Foundries followed the usual custom of protecting itself from money losses due to accidents under employers' liability policies. Investigations were made several times with a view to ascertaining the probable cost and risk of carrying its own insurance; but on account of the hazardous character of its work, the insurance was continued until it came to the realisation of the economies of safeguarding. It then became apparent that the company could control to some extent at least the frequency of accidents among its employés, and this assumption has been borne out by actual experiences. As in other pioneer work, the simplest method was first followed. A general inspection was made of the equipment and buildings at the plants, and recommendations were made for the protection of the most dangerous places. When these recommendations

* Paper read before the [illegible]

were approved the master mechanics at each plant were asked by the managers to supervise the making and installation of the guards, and to report monthly the necessity, if any, for additional guards. This method was only partly successful. The master mechanics were busy men, and more or less calloused by frequent contact with carelessness and indifference on the part of the workmen. As will be shown later, the initial efforts to protect the men were not received kindly, and it seemed futile to foist upon them what they looked upon as handicaps in their work.

The next step in furtherance of the safety work was the appointing of working-men's and foremen's committees. Three men were selected from three different departments of the plant and instructed to make four whole-day inspections during the month. Men were selected who were not only old employés and familiar with all parts of the plant, but who were known to be conscientious and not afraid to report what they saw. These men were carefully instructed in their work and informed that the company did not obligate itself to accept any of the suggestions or do any work. They were paid full wages while engaged on their inspection duties and $5 each upon presentation of their reports at the end of the month.

These working-men's committees revealed the immense possibilities at each plant for protection. We received during the first month in all about 1,000 suggestions, and at two of the larger plants approximately 300 each. These recommendations were described carefully in writing, numbered numerically, and submitted to the three foremen in charge of the departments from which the men were selected, and they acted as a jury in approving or disapproving the suggestions made. The jury of foremen visited and inspected all of the dangerous conditions pointed out by the working-men's committee, so as to be in a position to say "Yes" or "No" to the recommendations. Only a small percentage of the suggestions were rejected as impracticable. The combined reports of the working-men's and foremen's committees were then submitted to the plant managers, and they expressed their opinion of the reports. The result of the careful consideration of each recommendation from three different standpoints was a warranty to the officials of the company that the final recommendations were probably worthy of acceptance. These committees were continued during the following month and with about the same results. They were then discontinued for the reason that each plant had so much work to do that it seemed impracticable to pursue the subject further until the recommendations already made had been carried out. Since then, however, similar working-men's committees have been appointed, with continued good results, and it is believed that the workmen in the plants, familiar with every working condition and having the interest of self-protection in view, can be as productive as any other agency in calling attention to the hazards of the industry. By changing the committees monthly the attention of a number of workmen will in time be especially directed to the subject of safety, and this nucleus will help to leaven the lump of the disinterested mass of workers.

The next thing was to find a means of following up the work economically, and at four plants, employing approximately 1,500, 900, 700, and 500 workmen, safety inspectors have been engaged to devote all their time and efforts to safety, including the inspection of machinery or equipment for broken or worn-out parts, the continued use of which may cause an accident, such as flask trunnions and flanges; the inspection of buildings for loose bricks; inspection of pillars; of boards and loose material stored overhead; cranes and crane runways for loose parts; the use of gongs on cranes; improper riding of workmen on loads being carried by cranes. They are also to be on the look-out for slippery places on floors and stairways, for holes, broken boards, and protruding nails in boards; to make regular inspections of railroad tracks for guards at frogs and switches, holes about tracks, piling of material too close to tracks, and riding on engines and cars without permission, and also to inspect hoisting cables for broken strands and rust. They are to oversee the use of scaffolding for painting or making other repairs, and to be on the look-out for loose sleeves while operating machinery; to inspect for the proper and constant use of safeguards; to report narrow escapes from injury and the causes therefor, and to recommend discipline for workmen or recommendations for additional protection, as well as to report all other conditions about the plant which might be considered hazardous and likely to result in injury to workmen or damage to the company's property. These inspectors are required to attend all meetings of foremen, to call attention to unsafe conditions about the plant, and to suggest improvements in the method of handling the work from a safety standpoint.

Reports of serious accidents and the causes therefor are also discussed at the meetings of the foremen and the heads of departments. It is exceedingly important to bring constantly to the minds of foremen the necessity for caution and care in the habits of the workmen. The burden of stimulating the foremen and heads of departments rests almost entirely upon the management of the plant. The managers' and foremen's attitude towards the prevention of accidents will be reflected by the workmen just as accurately as their attitude towards the production of castings is reflected. If the manager treats the subject lightly, his assistants will look upon it in the same way. If he shows a determined desire to avoid accidents, and have the rules of the plant obeyed, if he makes prevention of accidents one of the most important features of his department, then the foremen will reflect his attitude towards the work, and will see that the men take the precautions which are known to be necessary for the prevention of accidents.

The result of the committees' investigations were forwarded to the central office of the company, and all the plants have received the benefit of all the recommendations made. The central office keeps in constant touch with the inspectors on safety matters, and when an accident occurs showing carelessness or unnecessary risks taken, or where the use of a safeguard would have avoided the accident, a sketch and a safety bulletin are sent to all of the plants, with recommendations as to the avoidance of similar accidents. The central department also has charge of the care and compensation of all injured employés under a voluntary relief plan; receives full reports of all accidents, and when it is apparent that repetition of such accidents can be avoided by cautionary measures, recommendations are made to all of the plants, so that each one receives the benefit of the experience of the other.

The organisation of the safety work, therefore, has been conducted through the efforts of committees at each plant, a supervising safety inspector, and the general dissemination of the experience of all plants through a central office. For the smaller collective groups of plants, this plan will be found effective and inexpensive. The safety inspector in a plant employing from 500 to 600 workmen will have ample time to attend to the full investigation of all accidents and the preparation of all reports, as well as to the visitation of injured workmen, and to represent to them the interest of the company in their welfare and speedy recovery. He also can assist the company in reporting workmen who are inclined to magnify their injuries and make fictitious claims against their employers.

My further remarks will be confined largely to the work which has already been done by the American Steel Foundries for the prevention of accidents at its several plants. It is obvious that the industrial plant that can seriously follow up a plan of accident prevention must undertake (1) to provide and maintain proper working conditions and efficient safeguards, and (2) to educate its employés and inculcate in them habits of caution.

Probably 75 per cent. of the accidents in steel foundries affect the eyes of workmen. It became apparent at the start, therefore, that it was necessary to provide all grinders, chippers, floggers, sand blasters, machinists, ladlemen, and others with eye protectors which would be suitable and comfortable and not impede the work or injure the eyes of the workmen. An investigation of the use of spectacles and goggles in other industries showed that not one had been entirely successful in educating the workmen in the use of any style of spectacles. It was found, however, that the old-fashioned type of grandfather's glasses has successfully protected the eyes of men working at emery wheels; and with these glasses as a foundation to build on, the spectacles now in use are worn by about 98 per cent. of the employés mentioned. The present design of spectacle is equipped with mesh screens at the sides and heavy lenses. The total weight

is about 1oz. per pair. A case is provided with each pair of spectacles, as well as a specially prepared cloth and paraffin pencil, used by automobilists to keep their glasses free from moisture and dirt.

The next problem was to have the glasses worn by such workmen as chippers and floggers, and it was found that these men would not voluntarily use the spectacles. An effort was then made by one of the plants to have the spectacles worn under the supervision of a watchman, who had time to circulate constantly among these workmen, and stimulate them in the use of the spectacles. Since the employment of safety inspectors this duty has been delegated to them. As an additional stimulus to wear the spectacles, every cleaning-room workman was asked to sign a contract with the company, under the terms of which he agreed to wear the spectacles constantly, and in the event of injury to his eyes happening while at work without spectacles the company is absolutely free from responsibility for the accident. When spectacles have been broken by flying chips, photographs have been made of them and posted on the bulletin boards about the plants to illustrate the hazardous nature of the work. It is believed that supervision and education along the lines described will have to be adopted in all foundries employing a large number of chippers and floggers, for the reason that these men will not protect themselves voluntarily, and the foremen and their assistants are usually too busy to give special attention to the use of the spectacles.

I have a collection of 78 pairs of spectacles, the lenses of which have been damaged by flying chips over a period of less than three months. Fifteen pairs of these spectacles were received from one plant in one month. Only one eye has been lost in all of the plants of the American Steel Foundries over the period of 17 months by workmen using these spectacles. In this one instance the piece of steel penetrated the lens with great velocity and entered the eye of the workman. If the spectacles had not been worn we believe that a much more serious accident would have resulted.

Another means adopted by our company to protect workmen while cleaning castings is to provide screens made of canvas, mounted on supports, to be placed between the men as they work. The screens have been effective in preventing flying chips from striking fellow workmen, but they are not as complete protection to the individual workman as the use of spectacles.

We require also emery wheels over 8in. diam. to have a safety taper of $\frac{3}{4}$in. to the foot, and be protected with safety collars. This means that the wheels will be convex in shape, while the collars will be concave, and should the wheel break in service, it being thicker at the hub than at the face, the pieces will be held in place. All emery wheels are also protected with cast steel hoods with plates bolted at one side, and the emery wheels used by the workmen grinding tools are provided with plate-glass shields to protect the eyes. Care is also taken to keep tool rests closely adjusted to the wheels, so that castings cannot be jammed between the wheels and rests.

Emery wheels often break through mistakes made by repairmen in not changing the speed limits when placing new wheels on spindles. Our safety inspectors are required to test the revolutions per minute of all emery wheels once per week and check up the speed limits. Wheels are often run at speeds far too great for their diameters. The belts and pulleys of all emery wheels are also protected by metal guards.

Sand blasters are protected with helmets and respirators, and arc welders with aluminium helmets and rubber aprons covered with asbestos.

Accidents occur in all foundries by feet being burned by slopping metal. It is very important that workmen wear whole shoes, and that these be so constructed that they may be slipped off quickly. We urge upon our workmen the necessity for wearing such shoes, and we have undertaken to keep a stock of them on hand at all plants, which are sold to the workmen at wholesale prices. The result is that the workman buys the shoes and protects himself from accident, and the company benefits from keeping the workman constantly at his job and by a reduction of the accident expense account.

All overhead cranes should be provided with walks on both bridge girders, extending the entire length of the crane. Each crane should be provided with a safety switch installed on the bridge, which will cut off all power, making it impossible for an absent-minded operator to forget that men are working above and start the machinery from the cab. Each crane should also be equipped with guards extending out from the truck wheels, the purpose being to warn any person who may be resting his hand on the runway of the approach of the crane, which he might fail to notice because of other noises. A number of accidents happen every year to persons working on scaffolds on crane runways. A workman may rest his arm or leg thoughtlessly against the runway and fail to notice the approach of the crane and be run over, with the loss of one arm or leg.

All trolley gears and truck drive gears should be guarded. The floor should be completely covered in so that loose parts will not fall through the openings in the bridge girders of the trolley carriage. This is important both from a safety standpoint and from an operative point of view.

Cables and chains should be inspected regularly. The exposure of crane chains to the prolonged action of the radiant heat of metal in the ladle seems to cause a molecular change in the metal of the links. It is not safe to call this a crystallisation; but such broken chain links always show a short and lustrous fracture which is called crystalline, whether it is really so or not. Frequent inspection, annealing, and renewals after a certain period of time are the only safeguards against this.

Every crane should be equipped with a foot gong. When these gongs were first suggested, objection was made that the gongs would not be heard above the other noises in the foundry; but experiment soon proved the value of the warning and all cranes have since been equipped with gongs. These gongs are also guarded by wire nets to prevent the gongs from falling on the heads of workmen, should they become disconnected or break in pieces. Of course, as a general part of the equipment of cranes, foot brakes should be provided, as well as boxes for oil cans and tools, so that the latter will not be laid around carelessly, and fall on the heads of workmen. Steel ladders should be provided to enable cranemen to reach their cranes safely. These ladders should be made of angle iron, not pipe.

Band saws should have a hinged guard covering the top and front of the saw to prevent the saw flying should it break, and a head guard extending down from the saw to prevent the workman's head from accidentally coming in contact with the saw. The saw below the table should be encased. We are now trying out a wooden guard, designed in one of our pattern shops, which we expect to prove satisfactory. We also believe that all pulleys and belts in the pattern shop should be guarded, if there be any danger of timbers being caught in them.

It is also important that the knives of wood jointers be guarded. We have adopted an aluminium guard for this purpose, and it has been found to be satisfactory in every way. It is equipped with a strong spring to keep the guard constantly in position. We have equipped all of our planers with safety cylinders, which, instead of pulling the man's hand into the knives, throws it out from the machine, and instead of losing his fingers or his hand he sustains comparatively slight injuries. We have not had a report of a serious injury to pattern shop workmen from the use of the planers since the adoption of safety cylinders and the use of the guard referred to. Rubber matting in front of all pattern shop machines is recommended.

All gears and pulleys should be encased in metal guards. The standard requirements for gear guards are that the gears shall be covered on the side as well as on the face; that the guards shall cover the gears to such an extent that the danger of being caught between the end of the guard and the cog of the wheel will be eliminated; and openings should be made, with sliding covers, to enable oilers to do their work.

There is a danger of having the limbs caught and sheared off between the table and the ribs of the planer bed. Workmen, contrary to all rules, ride on the tables of these machines, and a guard placed over the bed eliminates this danger. When the beds are left open they are used frequently as a receptacle for tools, oil cans, &c.

All counterweights should be enclosed by metal guards with door openings, so that the weights can be easily removed should they fall, without detaching the entire guard.

Switch box doors should be equipped with latches and

repairmen and others supplied with locks, so that workmen can protect themselves by locking up switches to avoid the danger of machinery being started while repair or other work is being done upon it.

The ends of piston rods extending beyond the cylinder heads should be guarded, the purpose of the shield being to prevent the men getting so close to the cylinder that they will be struck by the rod. All flywheels should be guarded either with plate or wire net guards. All points on engine beds where oilers may have occasion to walk should be provided with screen or plate guards to a height of 5ft. from the pillar blocks.

There will be an opportunity in almost all foundries to apply protection to such machines as charging cars, where it is found necessary to provide guards for the truck wheels. Where a railroad track runs close to a building, railings should be placed at the corner of the buildings to prevent men suddenly stepping from the buildings on to the tracks.

Considerations of economy often lead to the overcrowding of machinery, *i.e.*, too many machines are placed in a given space. The width of the passageways between the machines is thus reduced to the point of danger. Any undue curtailment of space interferes with the proper handling of the machines and adds to the risk and probability of accident, owing to the operator being exposed to contact with gears, pulleys, belts, and other moving parts, or even where guards are provided in fullest measure it is really impossible to eliminate absolutely all danger. The space should not be held of more value than safety.

Cleanliness about the shop and yards cannot be too strongly urged, as there is no question as to its being a factor in causing men to be more cleanly about their work, and in preventing accidents due to untidy conditions. It is also true that shop windows should be cleaned at regular intervals, and illumination generally may be greatly improved by whitewashing the walls of a dark room at least once a year. This also saves much on the cost of artificial illumination. Mention may be made of the risk of permitting unsuitable clothing to be worn. Leather leggings for the use of belt repairers will minimise the risk of accident, as there is considerable danger of these workmen having their trouser legs caught in moving machinery. Gasoline should not be carried in open cans. This is frequently done by careless workmen, but it is the avoidance of such accidents as these that assists in the improvement of the accident record.

I suppose there is no one who has ever had anything to do with the operation of a foundry who has not heard of the danger in protruding set-screws. Nevertheless these will be found in every plant, and they should be countersunk to make the working conditions safe. Slippery floors are also a menace to unsuspecting workmen, and, if necessary, rubber matting should be provided to prevent accidents.

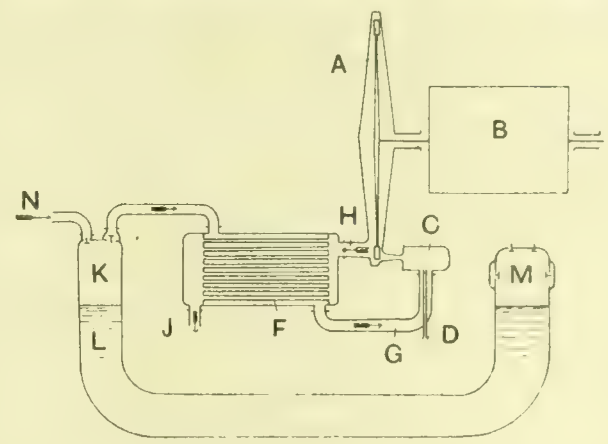
The insistence on rules and regulations is emphasized by all persons having anything to do with the prevention of accidents, but we believe that these should be used sparingly and be as brief as possible. They may give legal protection in damage suits for accidents, but they are practically worthless if no attempt is made to enforce them. We believe that a few effective rules insisted upon by educated foremen, in sympathy with the full protection of their workmen, will be far more effective than a long list of works rules which few will read and none will remember.

We believe that money and effort expended for the protection of workmen in foundries will be amply returned in the form of a better and more stable organisation, and an actual saving in the accident expense account.

BROWN, BOVERI'S GAS TURBINE PLANT.

According to the processes heretofore proposed for working gas turbines, the preliminary compression of the motive medium is effected in piston or revolving compressors. The use of such compressors renders the entire gas turbine installation complicated. Further, in such installations the amount of energy consumed in the preliminary compression is very considerable, compared to the new output of the gas turbine, so that it very greatly reduces the total efficiency of the turbine. This amount of energy is further very considerably increased by the comparatively low efficiency of the actual compressor, and in by far the majority of cases also by the efficiency of the gas turbine which drives the compressor. Owing to these circumstances, the total efficiency of the gas turbine installation is extremely low in all cases. Attempts have been made to increase this efficiency by aiming at the production of as complete as possible isothermic compression of the motive medium. For this purpose, however, the suggested means constitute a further and considerable complication of the gas turbine.

The arrangement diagrammatically illustrated in Fig. 1, the invention of Brown, Boveri & Co., Baden, Switzerland, has been designed with a view to enable gas turbine plants to be worked in such a manner that their total efficiency is no longer injuriously affected unduly by the compression of the motive medium, to dispense with the use of complicated apparatus for the purpose of compressing, and to effect nearly perfect isothermic compression. It consists in the compression by the action of a water column to which kinetic energy has been imparted, without the co-operation of the gas turbine. The gas turbine A is directly coupled to a dynamo B. The gas turbine is provided with a combustion chamber C into which are led a fuel supply D and an air pipe G, leading from a regenerative air heater F the passages or tubes of which are fed from the air compression space K above a water column L, the air being led into the space by a suitable lead N. The passage around the pipes of the air heater is connected at one end H to the gas turbine.



Brown, Boveri's Gas Turbine Plant.

and at the other to a suitable exhaust J. At the end of the water column remote from the air compression space is provided an explosion chamber M.

In operation, explosions are caused to take place in the chamber M whereby energy is imparted to the water column L, and air is in turn sent in at N, compressed in the space K, forced through the pipes of the heater F and the passage G to the combustion chamber C where, with the fuel supplied by the pipe D, the mixture is formed for driving the turbine. The exhaust gases leave the turbine at the part H and flow in a counter current through the heater F, whereby on their passage to the exhaust J they impart heat to the air supply. A compression according to this process can, it is claimed, be effected *per se* with high efficiency, and especially in all cases independently of the efficiency of the gas turbine. Consequently the total efficiency of the gas turbine installation is considerably increased thereby. At the same time the action of the water column produces an almost complete isothermic compression without any complicated apparatus for this purpose. Special advantages may, however, be obtained as regards the efficiency, by carrying out the improved process by imparting kinetic energy to a water column by the explosion or combustion of a combustible medium and utilising this kinetic energy to compress the motive medium or any part of the same for the gas turbine.

Colliery Cage Mishap.—A cage accident occurred at Felling Colliery on the 10th inst., which fortunately resulted in no loss of life, although it was at first believed that lives had been killed. When a third cage of men was going down, the winding gear went wrong, and the cage ran to the bottom of the shaft, the occupants being thrown together with violence. The most serious injury was a broken leg sustained by one of the men. The men were brought to the surface by another shaft.

A STEAM BOILER BURST BY ICE.

An instructive, though not by any means unknown, source of boiler failure is recorded in the April issue of our contemporary "Vulcan," the failure not arising, as boiler failures usually do, from the expansive force of steam, but from another even more irresistible, though happily not dangerous, namely, that of ice. The boiler in question was of the ordinary vertical type, 3ft. 6in. diam., and 8ft. high, with an

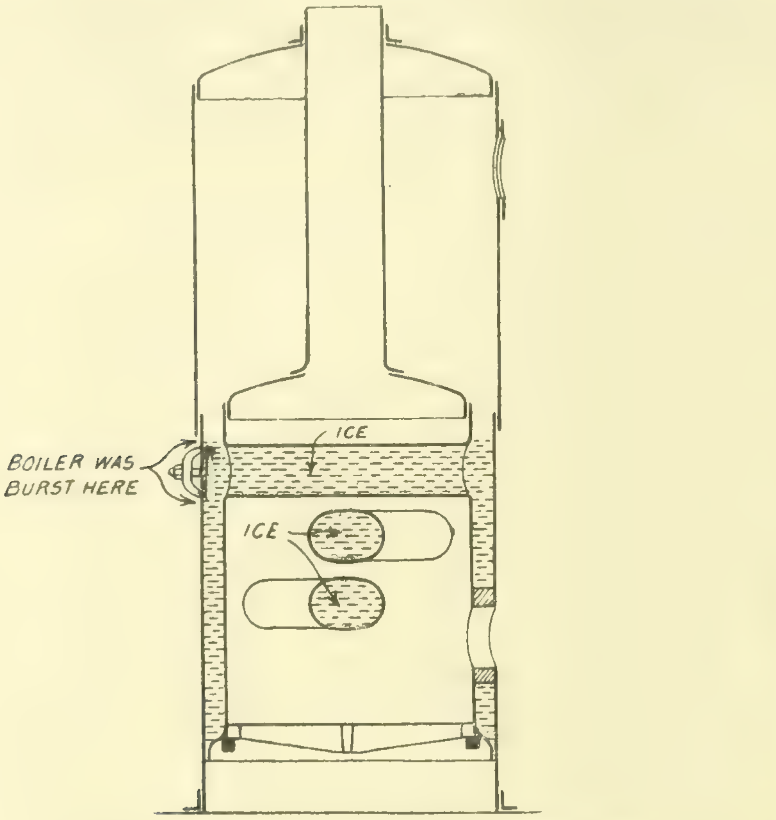


Fig. 1.—Sectional View of Boiler Burst by Ice.

internal firebox having three cross tubes welded into it. The shell was formed of two belts of ⅜in. steel plates double riveted longitudinally. The photographs show the damage sustained by the boiler at the cleaning holes cut in the shell for the purpose of access to the insides of the cross tubes. The shell plate was completely ruptured for a length of about 6in. or 7in., starting upwards and downwards from the edge of three of the cleaning holes, which, it may be remarked, were not fitted with a compensating ring. At the widest part the rent gaped open over $\frac{3}{16}$in., and the plate was bulged outwards sufficiently to give it a permanent set of over ¾in. The damage was caused solely by the freezing of the water in the cross tubes, which formed bars of ice about 8in. diam. and 3ft. 6in. long, and when it is realised that a column of water 3ft. 6in. long would, if frozen, and if the sectional area remained constant, increase in length by over 3in., the destructiveness of the force exerted will be readily seen. Such a bar of ice would be sufficiently strong to burst the boiler, even assuming that the water between the firebox and the shell was not frozen solid. It will be seen from the sectional sketch that the expansion of the ice would be greatest along the axis of the cross tube, a vertical plane through which would also intersect the boiler shell along its weakest section, owing to the cutting of the cleaning hole without fitting a strengthening ring. The moral of the accident is, of course, in frosty weather either to keep the fire going or to empty the boiler. In the present case the boiler was damaged to such an extent that it was obviously not worth repairing, but it is quite possible, as our contemporary observes, for a boiler to be seriously strained by frost without actual rupture, and so dangerously weakened that the ordinary working pressure would be sufficient to complete the destruction commenced by the ice.

International Association for Testing Materials.—The sixth Congress of the International Testing Association will be held at New York, from Tuesday, September 3rd, to Saturday, September 7th, 1912. The president of the congress will be Prof. H. M. Howe, of Columbia University. A large number of papers will be read and discussed, and arrangements are being made for visits and excursions to other cities in the United States.

THE DISINTEGRATION OR "DECAY" OF METALLIC TIN.*

BY PROF. ERNST COHEN.

The chief of a commercial firm informed me in 1868 that many blocks of Banca tin belonging to the same consignment had decayed in the store of the custom house. I remembered dimly that some years previously a large number of cast tin buttons for military uniforms which had been kept in one of the Crown magazines had been found to have decayed into a shapeless mass when inspection took place, and that an enquiry into the cause had been opened at that time. I did not know whether this enquiry had any results. I, therefore, at once examined a new case of tin decay at the spot and ascertained that while a certain number of blocks had completely preserved their normal appearance, others had suffered a profound change in their structure.

From the very first I had the opinion that the cause of the change in structure was the exceptionally low temperature of the winter 1867-1868 at St. Petersburg (on January 26th the thermometer had gone down to 36 below zero Fahrenheit). I, therefore, in May, 1869, submitted tin to artificially produced low temperature below the freezing point of mercury, and I had the satisfaction to observe that tin, at this low temperature, soon underwent a change in structure entirely corresponding with that found in February, 1868. Enquiries also acquainted me with other additional circumstances. One firm informed me that another portion

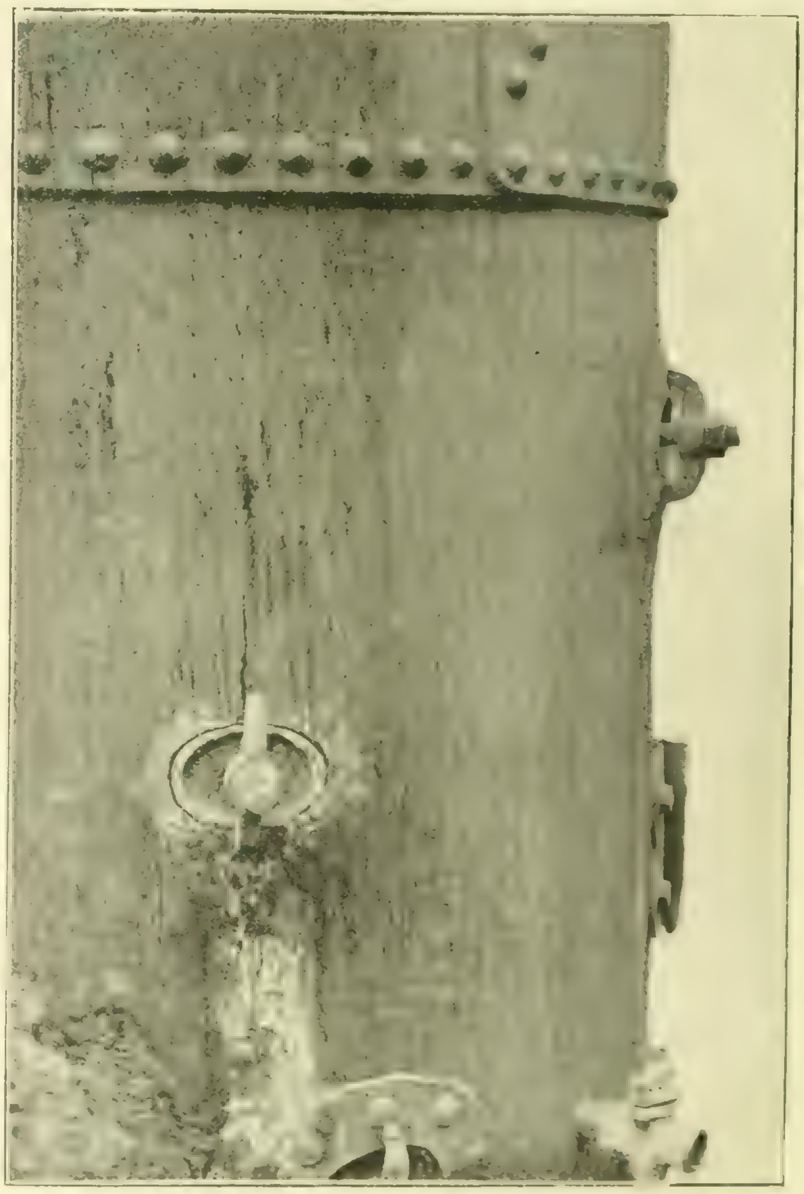


Fig. 2.—Vertical Boiler Burst by Ice.
View showing fracture and bulging at cleaning holes

of Banca tin had suffered in the same way during the winter 1867-1868 and that this decay of tin at extreme cold was well known in their establishment, especially to the men employed in tin stores. They had, indeed, a special name for this tin, a Russian word, which might be translated "Tin that can be scattered about." The chief of a Russian drug house, whom I met here, told me that he had himself seen the decay of Banca tin several times during very cold weather in the winter fair at Irbit; the tin would swell and develop warts

* Abstract of [illegible] read before the Faraday Society.

and drops which would adhere to a copper wire, as if they consisted of mercury. This he considered an incontestable proof that Banca tin contained mercury.

After this historical introduction, I pass to a description of the special condition in which I found the altered tin. Whilst, as already stated, some blocks had remained entirely unchanged, others had undergone a more or less radical alteration. These latter blocks had assumed a brittle consistency. Isolated spots at the surface with warty swellings were at once recognisable, or swellings extending from a larger portion of the surface which still retained some cohesion, more or less deeply into the interior. Other blocks had lost their metallic lustre completely; they either looked dull, of a radical, fibrous texture throughout their mass, or the surface had alone turned crystalline, while the interior had retained its metallic appearance. A saw-cut displayed these differences at once. The completely changed blocks had partly turned into a grainy, powdered mass, like sand; other portions formed lumps of various dimensions up to the size of the fist, of loose cohesion and fibrous texture. In the specimens that had been exposed to artificial cold, the effect of the cold had apparently started from certain spots and spread under development of a warty extumescence of a coarse, fibrous texture. The appearance suggests a rough, mosaic structure and could be separated at the fissures.

The colour of this modified tin is decidedly grey, and distinctly different from the ordinary bright metal. When the tin is heated, this colour undergoes a very striking change. When hot water is poured over it, the dark grey becomes much lighter, almost like that of ordinary tin. It is immaterial whether dry or wet is applied, and neither the water or the aqueous vapour takes any part in the colour change. When a glass stoppered bottle, filled with sandy, dark-grey tin was heated on a water bath until the colour became lighter, I noticed not an inconsiderable diminution in volume. I then exposed this tin to the temperature below the freezing point of mercury, with the curious result that the colour became dark again. The sandy mass would not run out of the bottle and had apparently increased in volume again so that the grains pressed against one another which impeded their gliding over each other.

When the grey tin is heated up to melting, a certain portion of it remains behind in an oxidised state. This again, is a consequence of its broken-up structure. The fused tin regains on cooling entirely the appearance of ordinary tin, and when exposed to a low temperature, it undergoes the same changes as before, provided it has not been contaminated with other metals.

A badly-corroded block of Banca tin, originally 35 kilos in weight, had been returned by a Moscow firm to Rotterdam because an adulteration was suspected. The tin had turned grey, and the powder was still dropping from the blocks. Analyses proved that the tin was very pure; it did not contain more than 0·05 per cent. impurities.

A long time ago an antique dish was found near Appleshaw, in Hampshire. It is now in the British Museum. The composition by analysis is: Tin, 94·35 per cent.; lead, 5·06 per cent.; traces of copper, oxygen, carbonic acid. The extraordinary molecular change which the metal has undergone is of more interest to the physicist and metallurgist than to the antiquary. The metal is not much oxidised, yet it is so exceedingly brittle that it can be broken with the fingers. The effect of time has resulted in a complete alteration of the molecular structure, the mass of the alloy being converted into an agglomeration of crystals, and to this the brittleness is due. On melting and casting a small fragment I found that the crystalline structure disappeared and the metal regained its original toughness. The vase dated from 350 B.C. and had probably been lying in Hampshire for about 22 centuries. The mean annual temperature of this locality, I am informed, lies below 18° C.

I applied to several directors of museums in Holland and other countries for information in regard to the decay of tin. They confirmed the statement without being able to supply specimens. A few years ago I obtained possession of a tin medal which was badly affected by the "tin pest" on both sides. The warts of grey tin had reached a height of several millimetres. The medal was cast about 1692 by the Leiden medal maker, Johannes Smeltzing, and the disease has thus had two centuries to develop.

We are thus confronted with a museum disease of universal occurrence which can only be prevented by maintaining the temperature of the rooms above 18° C. In winter the rooms will have to be heated. Visits to the stores of dealers in antiquities have entirely confirmed my views. Many of the tin objects found there are more or less affected with the disease. That our church organs are badly subject to the "tin pest" may be imagined. Organ builders have so far not risked to utilise the material of old pipes for the manufacture of new pipes. The old pipes need only to be melted down under an addition of coal to regain white tin good for new pipes. If the deterioration of church organ pipes is to be prevented, the temperature will have to be kept above 18° C.

You see that our scientific researches on the transformation of tin have taken us over into the domain of technics. I could add several more examples of technical interest, bearing on other technical problems with which I have become acquainted within the last few months. As I am not permitted to publish details, however, I will refer to a point of

FIG. 3—VERTICAL BOILER BURST [illegible]
View showing fractures at one of the [illegible]

historical interest. In the work of Aristotle the following passage occurs. Translated it reads: "They say that the Celtic tin melts much more easily than lead. A proof of the fusibility is that it melts even in water. It is, apparently, very sensitive to exterior influence. It melts also in the cold, when there is frost, because, it is said, the warmth which is in the tin is imprisoned in the interior and compressed, owing to its weakness."

The author carried out a series of investigations in order to reproduce the decay of the tin in an artificial manner and was not only able to cause the change from white to grey tin by maintaining at a low temperature, but found that the white tin could actually become infected by coming in contact with the germs of the diseased tin or grey powder. The whole was kept at 5° below zero Centigrade for several weeks and developed the disease. To this disease he has applied the name of tin pest and assumes that the grey tin is simply an allotropic form of tin or, in other words, it is tin in another physical condition just as the diamond is another form of charcoal.

THE THERMAL EFFICIENCY OF INTERNAL-COMBUSTION ENGINES.*

BY DUGALD CLERK, F.R.S.

BRITISH engineers engaged in the invention, design, and construction of motive power engines have struggled for more than 150 years to obtain motive power from fuel in the most economical manner. Long before thermodynamics emerged as a science, James Watt and the other engineers of his time, developed economical and reliable heat engines using steam as the motive fluid. Even before the steam engine became thoroughly established—about the beginning of the 19th century—many engineers perceived the possibility of increasing economy, first, by the use of the hot-air engine, and, later, by its development into the internal-combustion motor. Through the whole period of the development and perfection of the steam engine engineers were ceaselessly occupied with attempts to produce more economical internal-combustion engines. Thermodynamics may be said to have begun as a science when Carnot published his immortal paper in 1824. It had no real application, however, to motive power engineering until the discoveries of Joule about 1843. In the next few years the work of Joule, Macquorn, Rankine, Thomson, and Clausius supplied new light upon motive power problems, which engineers were not slow to use. This work from that time had a great effect upon the development of the steam engine, and right up to the present time scientific thermodynamics has aided the development of the steam turbine and the reciprocating steam engine, as well as the rival system of internal combustion.

Internal-combustion engines in various forms have been in commercial use since 1860, and their theory has been under careful scrutiny for at least 50 years. British engineers were fully alive to the high efficiencies possible. The present writer, for example, made the following statement to the Institution of Civil Engineers in April, 1882:—

"The gas engine is as yet in its infancy, and many long years of work are necessary before it can rank with the steam engine in capacity for all manner of uses; but it can and will be made as manageable as the steam engine in by no means a remote future. The time will come when factories, railways, and ships will be driven by gas engines as efficient as any steam engine, and much more safe and economical of fuel. Gas generators will replace steam boilers, and power will not be stored up in enormous reservoirs but generated from coal direct as required by the engine.

"The steam engine converts so small an amount of the heat used by it into work that, although it was the glory and honour of the first half of the century, it should be a standing reproach to engineers and scientists of the present time, having constantly before them the researches of Mayer and Joule."

In the same paper the writer also stated:—

". . . . it may be accepted as probable that an engine of about 50 i.h.p. could be made to work on 12 cub. ft. of coal gas per indicated horse-power per hour, or a duty of about 32 per cent."

The forecast made over 28 years ago has proved to be correct. The present indicated thermal efficiency of the internal-combustion motor in the form of a 60 h.p. engine using coal gas is as nearly as possible 35 per cent., according to results of the Institution of Civil Engineer's tests. Another engine was found by Hopkinson to give 37 per cent., and as much as 40 per cent. has been claimed by the makers of the "Diesel" oil engine.

In considering thermal efficiency it is better perhaps to base it upon brake horse-power rather than indicated power, because the mechanical efficiency of different types of engine varies considerably. The following tables show the slow change of indicated and brake efficiency from 1882 to the present time, in 4-cycle and 2-cycle engines.

It will be noted that the mechanical efficiency of the Diesel engine is lower than that of most of the other 4-cycle engines, so that the brake efficiency is not so high as that given in Hopkinson's test. Generally it may be taken from these numbers that a first-class internal-combustion engine will give a brake thermal efficiency of 30 per cent.

With regard to the future, it is possible in a large engine to increase the indicated thermal efficiency to about 50 per cent., but in such an engine the mechanical efficiency would probably fall to some extent and the brake thermal efficiency obtained would be about 40 per cent. The smaller gas engines do not give quite such good results, but the falling off is not great. The Institution of Civil Engineers' tests showed for a 5 h.p. gas engine a brake efficiency of 26·7; for a 20 h.p. gas engine, 28·3; and practically 30 per cent. for a 60 h.p. engine. The indicated thermal efficiency of a first-class motor-car petrol engine may be taken as about 28 per cent. at its highest; that is, with 80 per cent. mechanical efficiency, 22·4 brake thermal efficiency. Large gas engines are not found to increase notably in brake efficiency. As good results from the thermal point of view can be obtained with a 50 h.p. as with a 1,000 h.p. engine.

Indicated and Brake Thermal Efficiency of 4-cycle Engines from 1882 to 1908.

No.	Mech. Effiey.	Names of Experimenters.	Year.	Dimensions of Engine.		Ind. Thermal Effiey.	Brake Thermal Effiey.	Type of Engine.
	Per cent.			Diam.	Stroke.	Per cent.	Per cent.	
1	87·6	Slaby	1882	6·75in. ×	13·7in.	16	14	Deutz
2	84·2	Thurston ...	1884	8·5in. ×	14in.	17	14·3	Crossley
3	86·1	Soc. of Arts.	1888	9·5in. ×	18in	22	18·9	Crossley
4	80·9	Soc. of Arts.	1888	9·02in. ×	14in.	21	17	Griffin (6 cycle)
5	87·3	Kennedy ...	1888	7·5in. ×	15in.	21	18·3	Beck (6 cycle)
6	82	Capper	1892	8·5in. ×	18in.	22·8	17·4	Crossley
7	87	Robinson ...	1898	10in. ×	18in.	28·7	25	National
8	83	Humphrey.	1900	26in. ×	36in.	31	25·7	Crossley
9	81·7	Witz	1900	51·2in ×	55·13in.	28	22·9	Cockerill
10	85·5	Inst. C.E. ...	1905	14in. ×	22in.	35*	29·9	National
11	76·6	Longridge...	1905	22in. ×	29·5in.	39·9	31·2	Diesel 2 cycle
12	77·1	Burstall ...	1907	16in. ×	24in.	41·5†	32	Premier
13	87·5	Hopkinson..	1908	11·5in. ×	21in.	36·8	32·2	Crossley

* The value 35 per cent. is deduced by the author from the Inst. C.E. Committee's values.

† This value is, in the author's view, too high; probably due to indicator error.

Indicated and Brake Thermal Efficiency of 2-cycle Engines from 1884 to 1908.

Mech. Effiey.	Names of Experimenters.	Year	Dimensions of Motor Cylinders	Ind. Thermal Effiey.	Brake Thermal Effiey.	Type of Engine
Per cent.			Diam. Stroke.	Per cent.	Per cent.	
84	Garrett	1884	9in × 20in.	16·4	14	Clerk-Sterne
—	Stockport Company	1884	—	—	11·2	Andrews & Co.
83	Clerk	1887	9in × 15in.	20·2	16·9	Clerk Tangye
--	Atkinson	1885	7½in.	—	15	Atkinson
75	Meyer.....................	1903	26¾in. × (2 × 37½in.)	38	29	Oechelhauser
75	Mather & Platt	1907		30·6	23	Koerting

The use of internal-combustion engines has steadily increased, and the smaller powers, operating with the coal gas supplied by towns, have almost entirely displaced the small steam engines formerly used. Coal gas is used for these engines up to about 100 h.p. Below that power many engines are operated with producer gas made from anthracite or coke, so that coal gas and producer gas engines overlap as to powers. Above 100 h.p. practically no coal gas is used. Suction producers are used up to about 400 h.p. Above that power pressure producers are applied. For the highest powers of all blastfurnace gases are utilised. Altogether at present about 2½ millions of horse-power are developed by stationary gas engines below 500 h.p. units. Large gas engines above 500 h.p. up to about 5,000 h.p. (which is the present maximum), develop something over a million horse-power. Motor-car engines also may be taken as developing about 2 million horse-power using petrol as the fuel.

So far internal-combustion engines have been most successful in displacing the smaller steam engines; but in future the competition with steam will become keener and keener. At present considerable study and work is required to perfect the large cylinder gas engines. So far, these large cylinder engines have proved most expensive to build and considerable difficulties have been experienced to maintain them in reliable continuous operation. During the last few years many of these difficulties have been overcome and the large cylinder engine is making most satisfactory progress. It has not yet, however, attained the position as to reliability held by large steam engines of the reciprocating and turbine types. Strenuous effort, however, is being devoted to overcome the remaining difficulties, and the early future will see it competing more and more strongly with large steam engines both for stationary and locomotive land work, and for the propulsion of ships.

Internal-combustion motors are largely used for boat propulsion, but in only comparatively small units. The marine

* From report of British Science Guild on "Natural Sources of Energy."

problem, however, is receiving attention, and very shortly large marine gas and oil engines will be applied to ships of considerable dimensions. Steam engines of the reciprocating and turbine type are in some ways more easily handled than internal-combustion engines, but all steam engines are greatly inferior in thermal efficiency. Mr. Parsons gives an absolute thermal efficiency of about 20 per cent. for a 10,000 h.p. steam turbine working with 200lbs. steam pressure superheated to 300° C., and exhausting into a vacuum of 1in. absolute of mercury. Such an economy, however, is very unusual in steam engine work, as he points out. Such steam engines as are in ordinary use up to 100 h.p. will not give a greater thermal efficiency than 10 per cent.; that is, 10 per cent. of the lower calorific value of the fuel converted into indicated work. Even large and well-made mill machines of quite modern type rarely attain a 15 per cent. efficiency on this basis.

From what has been shown it will be seen that the internal-combustion motor broadly may be taken as twice as efficient as the steam engine; that is, the average internal-combustion engine of over 50 h.p. will always give at least 30 per cent. of the heat of combustion of the gas supplied. In engines fed with producer gas the producer efficiency is usually about 85 per cent., so that the over-all efficiency from fuel to brake power is about 25 per cent. The larger producers consuming bituminous and semi-bituminous fuel have a slightly lower efficiency—usually about 80 per cent.—but the coal used is generally of a cheap type. Suction producers using bituminous fuel are still in the early commercial stage. Three different makers, however, have now succeeded in reaching the market, and a very great development of this type of producer will undoubtedly result in a great further extension of the field of the internal-combustion motor. Gas for these engines is now made from coal, coke, anthracite, pit shale, wood, charcoal, sawdust, spent tan, and many other carbonaceous materials, and mineral oil, gas and wood tar hydrocarbons, paraffin oil, alcohol and other inflammable liquids are used directly within the cylinders of many types of inflammable vapour engine. The waste gases from many industrial processes, too, are being used in these engines. Nearly all the large gas engines, for example, amounting to about one million horse-power consume the waste gas from the blastfurnaces. A very large amount of power can still be obtained from the blastfurnace gases evolved at British iron works. Assuming 10 million tons of pig iron to be made in Britain per annum, and allowing for the free gas available after heating the blast, about 700,000 h.p. could be continuously developed in Britain without burning any additional fuel. Some of this gas is used for motive power, but the greater part of it is still wasted. The gases evolved in modern coking processes can be collected and used for motive power. From this source it is possible in Britain to obtain about 140,000 h.p. continuously. Engineers are busily engaged at present in attempting to utilise all sources of motive power, and at no previous time have they paid greater attention to waste gases and waste heat than at present. The waste heat carried away in the exhaust gases of gas engines is utilised in many cases for raising steam, and about 2½lbs. of steam at over 100lbs. per square inch pressure can be obtained per hour per brake horse-power. The exhaust steam, too, from rolling mill engines and other engines using little expansion is being largely applied to operate low-pressure steam turbines. Practically all the waste heat from gas engines, amounting to about 50 per cent. of the total heat of combustion, could be utilised in some such manner.

From what has been said, it is evident that if steam power could be entirely replaced by power obtained by means of internal combustion the fuel consumed would be reduced to one-half. It may be asked then by scientific men, why not legislate so as to enforce the use of gas power by law? Apart from the varied monetary interests which would make it impossible to carry any such law, the law even if carried would be of most doubtful benefit. Great industrial inventions cannot be perfected in a few years, and any attempt to force the rate of progress usually ends in financial disasters which discredit the rising industry. The monetary reward of successful competition with steam for all purposes is so great that engineers may be trusted to do everything possible to forward the application of the new form of motive power.

THE ALLOYS OF ALUMINIUM AND ZINC.*

BY DR. WALTER ROSENHAIN AND S. L. ARCHBUTT, OF THE NATIONAL PHYSICAL LABORATORY, TEDDINGTON.

General Introduction. — The Ninth Report to the Alloys Research Committee contained an account of the influence of manganese upon the alloys of copper and aluminium; the consideration of manganese was regarded as the first step in a general investigation of the ternary alloys of copper and aluminium with other metals, and the Alloys Research Committee decided that the next step in this investigation should deal with the effect of zinc. As it had been found, however, that the previous Reports dealing with the useful alloys lying at both ends of the copper aluminium series were undesirably bulky, it was decided in the first place to confine the investigations to alloys consisting principally of aluminium, which may be conveniently grouped under the term "light alloys."

Before the systematic study of the ternary alloys of aluminium, copper, and zinc could be undertaken it was, however, necessary to investigate the new base-line of this system, namely, the alloys of aluminium and zinc. In practice the investigation of the binary alloys and of the ternary alloys derivable from them has been carried on side by side, but the well-known difficulty which arises in all investigations of ternary alloys from the large number of combinations which have to be studied has made it desirable to publish the results of the investigation of the binary alloys without waiting for the completion of the study of the ternary system. The present Report, therefore, deals principally with the constitution and properties of the binary alloys of aluminium and zinc. At the same time the investigation of the ternary system has already been carried to a considerable extent and has revealed the existence of a group of alloys which promise to be of considerable practical value.

The alloys of aluminium and zinc have been the subject of a considerable number of experimental investigations. As regards their constitution they have been studied by Heycock and Neville,† Shepherd,‡ Ewen and Turner,§ and D. V. Plumbridge,‖¶ while as regards some of their mechanical properties important papers have been published by C. R. Carpenter,** W. D. Bancroft, †† Ewen and Turner and M. Portevin.‡‡

From the point of view of practical use, the aluminium-zinc alloys have received considerable attention. For casting purposes the fact that an addition of zinc to aluminium facilitates the production of sound castings is widely recognised; at the same time, these alloys are credited with undesirable properties in two important directions. The first of these is the tendency which they are said to possess to crack in cooling, particularly if the castings are of a shape liable to that form of defect. Further, the alloys are generally regarded as being liable to rapid corrosion, and actual examples of such corrosion have come under the notice of the present authors in the case of industrially-prepared alloys. The experience of the present authors, however, in dealing with these alloys does not confirm these widely-held views of their properties; the authors have had no difficulty in avoiding the cracking of castings which is said to be due to the tenderness of these alloys when hot. As regards corrosion, the experiments and tests described below indicate that the alloys as prepared by the authors are by no means liable to the severe and excessive corrosion which the general reputation of the alloys would lead one to anticipate. The authors supposed—and experiment has justified the supposition—that the rapid corrosion (particularly in moist air) of many commercial samples of aluminium-zinc alloys is due to the presence of impurities derived from the spelter employed in their manufacture. The authors' alloys, prepared from pure zinc, behaved in a much more satisfactory manner.

* Summary of the 10th report to the Alloys Research Committee of the Institution of Mechanical Engineers, presented April 19th, 1912.

† Heycock and Neville, "The Freezing Points of [illegible] another Metal." Journal Chemical Society, Vol. LXXI [illegible]

‡ Shepherd, "Aluminium Zinc Alloys." [illegible] page 504.

§ Ewen and Turner, [illegible] Metals Journal, September, [illegible]

‖ D. V. Plumbridge. [illegible]

¶ A brief preliminary account [illegible] has been given in the annual report [illegible] and 1910, and [illegible] W. R[illegible]

** C. R. Carpenter. [illegible]

†† W. D. Bancroft. "The M[illegible]

‡‡ Portevin. "Revue de M[illegible]

With regard to the mechanical properties of the aluminium-zinc alloys, the statement is sometimes found that they are particularly weak under the action of vibratory stresses and of shock. Here again the results of the present research do not confirm this previously held view; the exhaustive tests under shock and alternating stresses described in this Report clearly show that these alloys are not abnormally weak in this respect, and that in effect they exhibit properties in these circumstances which are in normal correspondence with their general mechanical behaviour.

As regards the general mechanical properties of the aluminium-zinc alloys, the outstanding result of the present research is perhaps to be found in the very large effect produced upon them by hot work. It has been found possible to roll out into bars and even to draw into wire an alloy containing as much as 25 per cent. of zinc in spite of the fact that this same alloy in the sand-cast condition shows no perceptible ductility. This alloy attains its maximum tensile strength when in the condition of rolled bar 1¼in. diam., the maximum stress being 27·5 tons per square inch. It is very interesting to find that rolling down the same alloy to ⅞in. diam. while hot, so far from improving the properties of the material, brings about a reduction in the tensile strength of several tons per square inch, and similar phenomena are met with throughout the whole series of alloys. It may be added here that by the addition of a small percentage of copper to these aluminium-zinc alloys the tensile strength of the hot-rolled material may be raised to 32 tons per square inch while retaining a reasonable degree of ductility. In the form of wire the maximum tensile strength obtained is 34 tons per square inch. The specific gravity of alloys having these high tensile strengths lies in the neighbourhood of 3·2, so that they may still fairly be regarded as light alloys; in comparison with other light high-tensile alloys containing magnesium, the present series have the advantage that no special heat treatment or quenching is required to develop their special properties.

Both the binary and ternary alloys just referred to differ in one important respect from the majority of non-ferrous alloys by the fact that in the rolled condition they exhibit a definite and well-marked yield point, their behaviour in the testing machine showing the sudden dropping of the beam which is familiar in the testing of mild steel. This behaviour may perhaps justify greater confidence in the properties of these alloys than that which engineers usually repose in materials having a gradual indefinite yield.

If the results of the present investigation are viewed in the light of current practice in the application of aluminium-zinc alloys, the most important point is that the alloys richer in zinc, namely, those containing from 15 to 25 per cent. of zinc (with or without the addition of copper), are deserving of much closer attention and of more widespread use as compared with the lower alloys, containing less than 15 per cent. of zinc, which are much more widely used in present practice. If dynamic as well as tensile tests are taken into consideration, the outcome of the present Report is to show that the alloy containing 20 per cent. of zinc is the most generally useful of the simple binary alloys.

In this brief notice of the outstanding results of the investigation mention must now be made of what is probably the most serious defect of this group of alloys, namely, their great sensitiveness to rise of temperature in relation to their tensile strength. Thus the alloy containing 25 per cent. of zinc, whose tensile strength at the ordinary temperature is 27·5 tons per square inch, at a temperature of 100° C. has a tensile strength of only 18·5 tons per square inch, and the rapidity of this drop in strength with rising temperature increases as the temperature is further raised. When very hot the alloys are accordingly very weak, but while they are brittle to shock and cannot therefore be forged at temperatures much above 400° C. (752° Fah.), in the testing machine they still exhibit an exceptional amount of ductility. It is this somewhat abnormal behaviour which makes it possible to roll into bars alloys which are brittle in the cast state, but at the same time it renders an accurate control of the rolling temperature an essential condition of success.

SUMMARY OF THE PRINCIPAL RESULTS.

The principal results obtained in the investigations described in the present Tenth Report to the Alloys Research Committee are briefly summarised as follows:—

(1) **The Constitution of the Alloys.**—This is only briefly dealt with in the Report, since a full account of the metallographic study of the aluminium-zinc system has already been published elsewhere. The new equilibrium diagram arrived at by the authors shows the occurrence of reactions and the formation of a definite compound (Al_2Zn_3) whose existence had not previously been established. From the equilibrium diagram it appears that all the alloys containing more than 40 per cent. of zinc undergo transformation at a temperature of 256° C. (493° Fah.). As regards the alloys at and near the aluminium end of the series, the new equilibrium diagram establishes their "solidus curve" or temperature of complete solidification, and also exhibits certain minor transformations which, although shown not to be due to a change in the pure aluminium-zinc system, always occur in commercial alloys at temperatures near their melting point. The alloys containing less than 40 per cent. of zinc are shown to be simple homogeneous solid solutions, although it is possible that the inversion at 256° C. also occurs at this end of the series. When cast in chill moulds, the microstructure of these alloys exhibits the sharply "cored" structure usually found in rapidly-cooled solid solutions having a long range of solidification. In sand castings this coring is less sharply defined and the whole microstructure is on a larger scale. The "cores" are entirely removed by prolonged annealing at such a temperature as 400° C. (752° Fah.), but they are removed rapidly and completely by the rolling process. Photomicrographs of the hot-rolled alloys, especially after annealing, containing up to 25 per cent. of zinc exhibit the typical polyhedral structure of a perfectly homogeneous solid solution, although the scale of the crystals varies considerably according to the exact mode of treatment which the material has undergone.

The Study of the Cast Alloys.—The tensile strength of sand castings shows a steady increase up to a concentration of 50 per cent. of zinc, when an ultimate stress of 18·7 tons per square inch is reached; there is then a slight fall of strength with further increase of zinc content, followed by a rise to a second maximum near 75 per cent. of zinc, a concentration which corresponds approximately to the composition of the compound Al_2Zn_3. The highest ultimate stress reached is 18·9 tons per square inch. The results of tests on chill castings shows three maxima, namely, the first at 30 per cent. of zinc with an ultimate stress of 17·9 tons per square inch, the second at 50 per cent. with 21·6 tons per square inch, and the third at 75 per cent. with 20·1 tons per square inch.

In discussing the results of tensile tests on the present series of alloys the authors have used the term "Specific Tenacity," to denote a quantity which is proportional to the tensile strength and inversely to the specific gravity; this has been calculated by dividing the ultimate stress of a given alloy in tons per square inch by the weight of a cubic inch in pounds. The quotient is the breaking load in tons of a bar of the material whose cross-section is such as to make the weight of the bar 1lb. per inch length. From the point of view of tensile strength alone this figure may be regarded as representing the value of any structural material, and allows of comparisons on a correct basis between materials of widely different specific gravity, such as these light alloys and steel. In the cast alloys the specific tenacity is found to reach its maximum for both sand and chill castings in an alloy containing approximately 26 per cent. of zinc. The value attained is just over 150, as compared with a maximum value of 126 reached by the light alloys described in the Ninth Report. In the light alloys of aluminium with copper alone the specific tenacity of castings does not exceed a value of 99.

Compression tests on a number of chill and sand castings of the alloys, including some of higher zinc content, have been made. These tests show that in general terms the behaviour of the castings under compression is approximately proportional to their behaviour under tension. The highest yield stress under compression was obtained with alloy No. 55 in the chill cast condition, giving a stress of 22·96 tons per square inch. It is curious to find, however, that the chill castings are decidedly inferior to the sand castings until a zinc content of about 50 per cent. is passed.

The question of the possible "ageing" or even gradual spontaneous disintegration of the aluminium-zinc alloys has also been studied in connection with the sand-cast material, tensile tests on some of the alloys being repeated on specimens

which had been kept for over 15 months, but no signs of any change were observed.

Study of the Wrought Alloys.—Billets of the alloys containing up to and including 26 per cent. of zinc were cast at the laboratory and were rolled and drawn to various sizes, including wire and sheet, at the Milton Works of the British Aluminium Company. Hot rolling was found possible with all these alloys, but not with an alloy containing 30 per cent. of zinc.

Tensile tests on a representative series of alloys lying between the limits of composition just named were made on material in the form of (1) bars hot rolled to 1¼in. diam., (2) bars hot rolled to ⅞in. diam., (3) bars hot rolled to ½in. diam., (4) bars cold drawn to 1 3/16in. diam., (5) bars drawn with annealing to 1 3/16in. diam., (6) cold-drawn wire 0·1285in. diam., and (7) sheet of 0·14in. and 0·07in. thickness. In addition, the material in the form of ⅞in. bars hot rolled, 1 3/16in. cold drawn, hot rolled ½in., and wire, as well as sheet of both thicknesses, was also tested after annealing for one hour at 400° C. The tensile tests on all the hot-worked material gave very uniform and consistent results which can generally be represented by reasonably smooth curves when the data are plotted against zinc content. The yield points in these tests, as contrasted with those on castings, are well defined and as regular as the results for ultimate stress.

In the form of 1¼in. hot-rolled bars, the alloy No. 26, Table I., attains a tensile strength of 27 tons per square inch, with a yield point of 25 tons per square inch and an elongation of 16·5 per cent. on 2in. Both the tensile tests on 1¼in. and on ⅞in. hot-rolled bars give curves of ultimate stress plotted against zinc content which are very similar to one another, but it is a striking feature of these alloys that the curve for the smaller section lies above that for the larger only up to a zinc content of about 12 per cent.; above that concentration the 1¼in. bars give higher ultimate stresses than the ⅞in. bars. The results of tests on still smaller sizes of material, even including the hard-drawn wire, show corresponding results, although the crossing point of the respective curves differs from one size of material to another. The general conclusion is demonstrated that the beneficial effect of "work" on these alloys diminishes steadily with increasing zinc content, until the 25 and 26 per cent. alloys are reached in which we find that the highest ultimate stress is always given by the 1¼in. hot-rolled bars. These alloys, richer in zinc, therefore present the unusual property that cold-drawing a bar from 1¼in. to 1 3/16in. diam., although it raises both yield point and elastic limit and lowers elongation and reduction of area, actually reduces the ultimate stress.

The condition (excluding wire) of highest tensile strength, together with the yield stress and elongation corresponding to that condition, are given for a series of typical alloys in the following summary table:—

TABLE I.

Number of the Alloy (also per cent. Zn).	Conditions for Highest Ultimate Stress.	Ultimate Stress. Tons per Square Inch.	Yield point. Tons per Square Inch.	Elongation on 2in. Per cent.
5	⅞in. hot-rolled bar	8·94	7·4	26
9	⅞in. hot-rolled bar	11·17	6·98	38*
11	½in. hot-rolled bar	13·78	9·42	35*
13	1 3/16in. cold-drawn bar	14·73	12·80	19·5
17	1¼in. hot-rolled bar	19·85	13·20	22
20	1¼in. hot-rolled bar	22·64	17·3	20·5
26	1¼in. hot-rolled bar	27·09	25·00	16·5

* On 1in.

The tensile tests on annealed material were undertaken principally to ascertain whether the peculiar effects of "work" mentioned above persisted after annealing, and the results are discussed with reference to the resulting microstructures. It was found that the "hot-rolled" materials exhibited a considerable amount of deformation in their constituent crystals and that this deformation was entirely removed by annealing, although the scale of the resulting structure differed widely according to the treatment which each specimen had received. In general terms it was found that the tensile strength of the annealed materials was not strictly proportional to crystal size, but that the more severely worked material always exhibited better results after annealing than less severely treated metal. The highest ultimate stress in annealed material of the present series of alloys was obtained from alloy No. 20 in the form of annealed cold drawn wire, the value being 21·1 tons per square inch, but it must be noted that the higher alloys of the series (Nos. 25 and 26) were not included in all the tests on annealed material.

The tests on wire and sheet gave results which have already been referred to in connection with the effect of work and of annealing. Sheets were rolled from alloys Nos. 15 and 20; the former rolled well, but the latter cracked somewhat at the edges. The tensile tests show considerable variation as regards yield points between longitudinal and transverse tests, although these are obliterated to a considerable extent after annealing. The yield stresses, however, gave very erratic results, and this is probably to be ascribed to slight surface cracking of the metal. In the cold rolled condition, alloy No. 20, in the form of sheet 0·07in. thick, gives an ultimate stress of 23 tons per square inch, but there is little or no elongation in this condition. After annealing the ultimate stress falls to 18 tons per square inch, but the elongation reaches 10 per cent. on a longitudinal and 6·25 per cent. on a transverse test.

As regards the tests on the alloys in the form of wire, it was found possible to obtain even alloys Nos. 25 and 26 in this form, but the results given by these were disappointing, since they were lower than the tests obtained with 1¼in. hot-rolled bars. In the annealed condition, however, these wires give results which appear to be promising; thus No. 19 gives an ultimate stress of 21 tons per square inch with 17·7 per cent of elongation. It is interesting to note that the tests on annealed wire exhibit a well-defined maximum in tensile strength at or near a concentration of 20 per cent. of zinc.

Tensile tests at high temperatures were made on a series of the alloys in order to ascertain the effect of zinc content on the rate of loss of strength of these alloys with increasing temperature. Most of the alloys were tested up to 200° C. (392° Fah.), but in two cases considerably higher temperatures were employed (up to 595° C.). In every case it is found that there is a rapid fall in the yield stress and ultimate stress with rising temperature, even 50° C. producing a marked effect. The rate of loss of strength varies according to the composition of the alloy; thus at 100° C. the alloys containing up to 13 per cent. of zinc have lost about 36 per cent. of their tensile strength at the ordinary temperature; the alloys containing from 15 to 17 per cent. show a loss of 44 to 52 per cent., but this figure again diminishes to 26 per cent. for alloy No. 26. These relative rates of loss are confirmed at higher temperatures. At still higher temperatures the strength of the alloys becomes exceedingly small, but they exhibit a remarkable degree of ductility as measured by elongation and reduction of area; the latter in some cases is so great that the fracture is drawn down to a sharp point, while the elongation in one instance reached 133 per cent. Forging tests, however, show that this extreme ductility exists only under "static" loads, and that the alloys which draw out to fine points in the testing machine are broken into small fragments if struck sharply with a hammer at the same temperature.

The elastic properties of the alloys have been determined both for the hot-rolled and cold-drawn materials. They exhibit a satisfactory elastic behaviour and show well-defined elastic limits, which increase regularly with the zinc content and consistently with the ordinary yield point determinations. The elastic moduli of all the alloys are almost identical, lying near the value 9×10^6, a low value which may prove a disadvantage for certain possible uses of the alloys.

Autographic stress-strain diagrams have been taken from 8in. specimens; the diagrams show well-defined yield points and they also exhibit the stepped appearance which is typical of the mode of plastic extension of many non-ferrous materials.

Torsion tests have been carried out on specimens cut from the alloys in the form of 1¼in. hot-rolled bars; comparison of the results with those of tensile tests shows that the torsional strength, although it increases considerably with increase of zinc content, yet does not increase as rapidly as the tensile strength. The ratio of the maximum stresses under the two forms of test falls from 1·10 for alloy No. 9 to 0·76 for alloy No. 25.

The hardness numbers of the alloys, again in the form of

1¼in. hot-rolled bar, have been determined by the Brinell method under loads of 1,000 kg. and 3,000 kg. respectively and by the Shore scleroscope. The proportionality between the hardness numbers and tensile strength is found in these alloys to be only of a general kind, the shapes of the respective curves being notably different.

Compression tests have also been made on the wrought alloys. The results are in strict conformity with those of tensile tests, although the compression yield stresses are always slightly higher than those found in tension.

Dynamic tests have been carried out on the alloys both with the machines designed for that purpose at the National Physical Laboratory under the direction of Dr. T. E. Stanton, and also by the kindness of Prof. J. O. Arnold at the University of Sheffield. The tests made at Teddington include direct alternations of stress, repeated-bending impact, and single-blow impact.

The tests in alternations of direct stress give a series of results for the safe range of alternating stresses for the alloys, and this curve lies considerably below that of the static elastic limits. These ranges, although low when compared with the ordinary tensile test results, yet indicate a very decided advance on other light alloys which have been described in the Ninth Report. The best of those alloys (of aluminium with copper and manganese) showed a safe range of 9·4 tons per square inch, while the best of the present series has a range of 12·0 tons per square inch.

Alternate-bending impact tests were made with a weight of tup of 4·71lbs. and heights of fall of 1·0in. and 0·71in. respectively. Both sets of tests give curves of very similar shape which show that after 15 per cent. of zinc the resistance to this test is strictly proportional to the zinc content of the alloy. Of the present alloys, No. 9 shows a resistance practically equal to that found in the best of the light alloys described in the Ninth Report (about 600 blows with a fall of 0·71in.), while the best alloy of the present series (No. 25) required 3,400 blows for fracture. This power of resisting repeated impact is particularly noteworthy in view of the fact that the aluminium-zinc alloys are frequently spoken of as being weak under shock.

Single-blow impact tests, made on the Izod machine, show that the work absorbed by fracture reaches a maximum for a zinc content lying between 15 and 20 per cent. This is in accordance with the fact that such tests are affected by both tensile strength and ductility, so that the increased tensile strength of the alloys containing more than 20 per cent. of zinc is more than outweighed by their lower ductility so far as this test is concerned. As compared with the light alloys previously studied, the present series are decidedly superior, although the difference is not so marked as under some of the other tests.

Under Prof. Arnold's alternate-bending test, the alloys gave remarkably uniform results, but the curve of number of alternations endured falls rapidly with increase of zinc. Prof. Arnold remarks that the resistance of these alloys to his test varies from ⅛ to ¼ that of heat-treated best mild structural steel. It is interesting to note, in comparing the results of the three last-mentioned forms of dynamic test, that the curves representing their results are closely related to the curves of ultimate stress and elongation or reduction of area as shown by tensile tests. Thus the repeated-bending impact tests give a curve which is closely proportional to that of ultimate stresses, while the results of Prof. Arnold's tests are proportionate to the ductilities of the alloys as shown by elongation or reduction of area. The single-blow impact tests, on the other hand, appear to be proportional to the sum of these two properties.

In view of the results of all the mechanical tests the authors arrive at the conclusion that an alloy containing about 20 per cent. of zinc probably represents the best combination of properties obtainable in the simple binary aluminium-zinc series.

Corrosion tests on specimens of these alloys exposed to the sea have been carried out for a period of over 500 days, and the results show that the rate of loss of weight under such exposure increases with increasing zinc content. The actual rate of loss, however, is not as great as might have been anticipated, varying, when allowance for the difference of density is made, from 1½ times that of Naval brass to 1½ times that of Muntz metal. The authors, however, regard their corrosion tests as purely preliminary, since the alloys were used in the cast state, while subsequent study suggests that annealed material would show considerably less corrosion. The method of measuring corrosion by loss of weight is also regarded as inadequate for the study of these alloys, and further corrosion tests are being undertaken.

A general feature of some importance in connection with all the alloys described in the present Report, and particularly with those containing from 10 to 30 per cent. of zinc, is the great facility with which they can be worked by machine tools of all descriptions, in most cases without the use of any lubricant. Turnings of exceptional length and strength have been obtained from several of these alloys. The machined surfaces retain their brightness in the air of the laboratory for many months without protection of any kind.

The authors, in an appendix, give a preliminary account of the properties of a ternary alloy of aluminium with zinc and copper (alloy No. 25/3) containing approximately 25 per cent. of zinc and 3 per cent. of copper. This alloy, which can be rolled hot, although some special care is required in dealing with it, gives remarkable results under mechanical tests. An ultimate stress of 34 tons per square inch has been attained with this material, while its resistance to repeated-bending impact is over 4,500 blows, as compared with 3,400 of the best of the binary alloys.

OIL BURNING IN BOILER FURNACES.*

BY PROF. E. W. KERR.

In general, it may be said that boilers using oil as fuel have higher efficiency than those using coal. This is due to the greater ease of burning the former without the losses which are more or less unavoidable in coal burning. These losses consist mainly of those due to incomplete combustion and excess air. In coal burning there is also danger of incomplete combustion, due to the fact, even when "excess air" is supplied, that there are still portions of the fuel bed so inaccessible as to not get sufficient oxygen for the formation of CO_2. In oil burning, there being no thick bed of fuel and with the fuel thoroughly atomised, there is every facility for perfect admixture of all the air admitted and so complete combustion with the least possible "air excess" is secured. It is interesting to note that all of the high records have been accompanied by very low excess air. The following table gives the results of tests showing the performance of a number of oil-burning plants:—

Type of Boiler.	Calorific Value of Oil.	Water Evaporated per Pound Oil	Boiler Efficiency.
1. Horizontal return tubular	19,456	15·32 (Aver. of 8 tests)	78·5
2. Water tube	—	15·4	79·8
3. Water tube (Redondo plant, Cal.)	18,184	15·15 (Aver. of 8 tests)	80·47
4 Water tube	17,953	14·42	78·53
5. Water tube	17,425	14·61	80·97

The above figures, reproduced here from data given in various engineering journals, show performances better than the average and are given to show what may be accomplished by carrying out the proper principles in the design and operation of oil-burning plants. Most of them are averages of a number of tests made by reputable engineers.

The all-important question is: What conditions must be met in order to secure the highest possible efficiency? Among the factors affecting the question may be mentioned the following: (1) Completeness of combustion, (2) quantity of air in excess of that theoretically required, (3) type of burner, (4) form and volume of combustion space, (5) cleanliness of the heating surface.

At a recent meeting of the American Society of Mechanical Engineers, in San Francisco, the subject of oil burning was discussed very fully, 10 papers being read upon the subject and some 20 engineers entering into the discussion. It is interesting to note the great stress laid upon the matter of reducing the excess of air to a minimum. In fact, it would

* Abstract from Bulletin No. [illegible] [illegible] State University.

seem that the increased efficiency possible in oil burning may be attributed to this, and that most of the factors enumerated above have their importance in the manner in which they affect this one item.

In general, any burner will atomise the oil if sufficient steam is supplied to it. On the basis of an equivalent evaporation of 15lbs. of water per pound of oil, steam for atomising equal to 5 per cent. of that generated would be equivalent to $15 \times 0{\cdot}05 = 0{\cdot}75$lb. of steam per pound of oil fired, and similarly for other percentages. In the tests made by the United States Naval Liquid Fuel Board in 1904 the steam required for atomising varied from 1·75 per cent. to 10·81 per cent. of the total generated. In these tests a large number of different burners was used. Average good practice seems to be in the neighbourhood of 3·5 per cent. to 4 per cent. for atomising, although the best practice ranges from 1·5 per cent. to 3 per cent. At the Redondo plant in California the average steam for atomising in seven tests was 2·15 per cent. of the total generated. It should be said that the steam used for this purpose will vary greatly with the same burner.

So far, the effect of the type of burner on efficiency has been discussed only from the standpoint of its effect upon the amount of steam it requires for atomising. It is evident that that burner which atomises the oil and divides it most finely will facilitate most the thorough mixture of the air and the burning oil and that this, in turn, will result in a minimum excess air. In fact, the oil must be vaporised—that is, converted into a gas—before it is burned, and, of course, the finer the division accomplished in the atomising process the more speedy the gasification.

This vaporisation may be aided by either or both of two methods, viz.: preheating the oil before it is delivered to the burner or by preheating the air used in combustion. The former is a common practice, especially where the heavier crude oils are used, and during cold weather. By heating the oil its viscosity is reduced and this, in turn, aids in atomisation and vaporisation. The heating is generally done by means of a heater similar to that used for heating feed water, with exhaust steam from the oil pump.

The writer has been unable to secure trustworthy experimental data upon the economy effected by preheating the oil or the air. Preheating the oil, if the temperature is raised too high, will cause a decomposition of the oil and result in deposits of carbon in the piping and the burner. This will give much trouble. If, however, the heater does not raise the temperature of the oil above the flash point there will be no trouble from this source. Thus the fuel oils, from which the more volatile oils have been removed, may be preheated to higher temperatures than crude oil without trouble from carbon deposits in the supply pipe.

Beaumont oil (fuel oil) used in the tests by the Navy Liquid Fuel Board had a flash point of 216° Fah. Average crude oil from the same fields has a flash point of 180° Fah. California oil (fuel), used also in the Navy tests, had a flash point of 311° Fah., and a residuum mixture of California and Texas oils a flash point of 270° Fah.

The type of burner, however, has little to do with the economy of oil burning compared with the design of the furnace. In the first place, a large volume of furnace is necessary. No matter how well the atomising process is accomplished by the burner, a certain amount of time is required for gasification and a mixture of the air and the particles of fuel. By enlarging the volume the time of passage through the combustion space is lengthened.

The combustion space may be enlarged by increasing the cross-sectional area or by increasing the length. Theoretically, these two methods fulfil the requirements equally well, provided the volume is the same. In other words, a short furnace with a large cross-sectional area would produce the same effect as a longer furnace with a small cross-sectional area. The velocity of the current would, however, be greater in the long narrow furnace, and more draught would be required with this arrangement. In the case of horizontal tubular boilers, where the under side of the boiler shell constitutes one wall of the combustion space, the long narrow arrangement will bring a larger proportion of the gases in contact with water-cooled heating surface prior to combustion, a thing always to be avoided when possible. On the other hand, the entire combustion space is more likely to be effective in the narrow furnace—that is, there is less likely to be short-circuiting of the gases across portions of the furnace. It may be said, however, that the latest practice tends to approve the short and wide arrangement.

With very wide furnaces, in some cases, baffle walls and arches have been built in for the purpose of compelling a thorough filling of the entire combustion space, the former by scattering the flame and the latter by holding the flame in the front part of the setting. Present practice seems, however, not to favour these adjuncts, the burner being depended upon, by its fan or cone-shaped flame, to diffuse the gases through the entire space. It is important in designing an oil furnace to arrange so that the flame is well distributed over the heating surface and that no part of the latter is subjected to intense local jets of flame, as it is very easy to injure the metal materially in this manner. This, in fact, is one of the harmful effects which result from the baffles and walls mentioned above.

One of the most effective and satisfactory arrangements is to have the floor of the furnace gradually slope upward from the front of the furnace to the bridge wall, in some cases paved and smooth and in other cases made of brickbats piled loose. Either of these constructions throws the flame to the heating surface and at the same time at such a small angle as to ensure against local impingement of flame. This arrangement aids also in fulfilling another requirement for efficient oil burning, viz.: that the combustion takes place in a space surrounded with firebrick. This brick becomes incandescent and the heat radiated from it aids materially in the gasification of the fuel in the quickest possible manner.

Having a properly designed furnace will not secure the highest efficiency unless the air supply to it is carefully regulated. In fact, it would seem that this is of most importance. The front of the furnace—in fact, the whole setting—should be air tight with air openings so arranged as to be easily regulated. If the air is admitted through the draught doors their position should be carefully adjusted so as not to give too much or too little air, the greatest cause of loss being in the former.

Many—in fact, most—of the smoke stacks used with oil burners were formerly used for coal burning, the height of the stack being made to suit that fuel. The result is higher stacks and greater draught than is necessary for good economy. One expert in oil burning cites a case where the stacks in a large plant were blown down, only 35ft. being left, and yet the load was easily carried. One authority states that a draught of 0·1in. of water in the last pass of a water-tube boiler is sufficient for the best economy, and that with 0·5in. draught a loss of at least 10 per cent. in fuel may easily result.

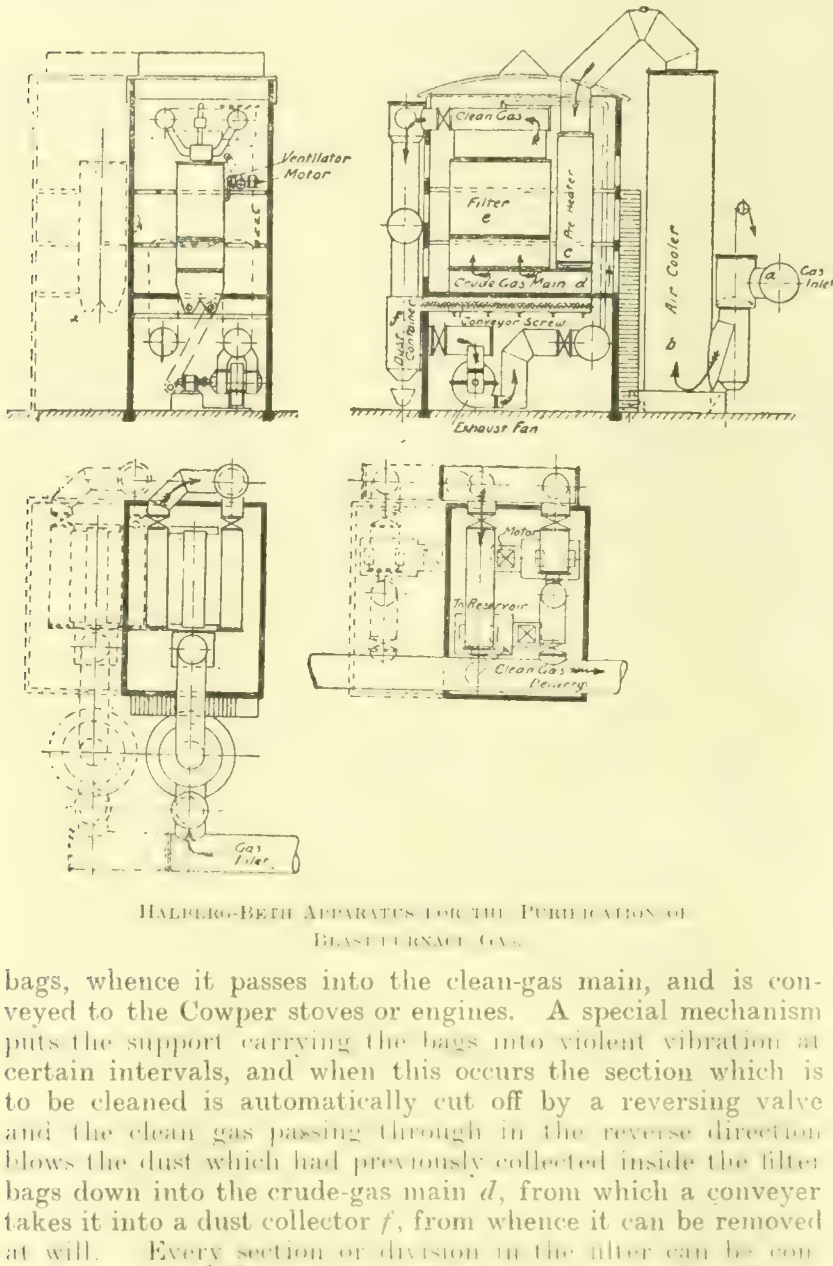
To summarise, there are three main essentials for the best results in oil burning, viz.: (1) a furnace with proper design as regards volume of combustion space and distribution of gases on the heating surface; (2) complete control of the air supply; and (3) thorough atomisation and gasification of the fuel as early in the process as possible.

Vanadium in Tool Steel.—In a recent publication issued by the American Vanadium Company, Pittsburg, it is stated that the first vanadium was only added to high speed steel in amounts of 0·2 to 0·3 per cent., but it was found that larger percentages produced still better results, and as much as 0·75 to 1 per cent. is now generally used. The increase in efficiency may be stated either in the relative speed at which the tools will last a specific time, or in the relative length of time the tools, under test, and under similar conditions, will cut without re-sharpening. Results show that 0·3 per cent. of vanadium permits a 10 per cent. increase in speed, or the removal of 10 per cent. more metal in the same period; 0·6 per cent. of vanadium permits of 20 per cent. increased speed, and 0·9 per cent. of vanadium permits of an increased speed of 30 per cent. Stating the effect in terms of increased time between grindings, 0·3 per cent. of vanadium doubles the time between grindings; 0·6 per cent. quadruples the time, and 0·9 per cent. of vanadium cuts eight times as much metal between grindings if the same speed and feed are employed in each operation.

THE PURIFICATION OF BLAST-FURNACE GAS.

Numerous attempts have been made to effect a cheap and easy method of purifying blastfurnace gas. One of the latest processes is the "Halberg Beth" as carried out by the Dinglersche Maschinenfabrik A.G., of Zweibrücken. This system is shown in plan and elevation in the annexed figures, for which, along with the following description, we are indebted to "The Iron and Coal Trades Review."

The crude gas enters the plant from the blastfurnace main pipes through the opening *a* into the air cooler *b*, which is of the vertical type, and has at its lower end a water seal. In this cooler the gas is brought down to a temperature close to its dew-point. Leaving the cooler, the gas passes to a receptacle *c* where the temperature necessary for the efficient working of the subsequent filtering operation is obtained and regulated by means of a steam coil. It then passes to the filter apparatus, which is installed in the compartment *e* and which consists of a number of sections in which linen bags are fastened by their lower and open ends to the floor of the chamber, while the top ends are closed and carried by means of suitable supports. A fan exhausts the gas from the linen



Halberg-Beth Apparatus for the Purification of Blast-furnace Gas.

bags, whence it passes into the clean-gas main, and is conveyed to the Cowper stoves or engines. A special mechanism puts the support carrying the bags into violent vibration at certain intervals, and when this occurs the section which is to be cleaned is automatically cut off by a reversing valve and the clean gas passing through in the reverse direction blows the dust which had previously collected inside the filter bags down into the crude-gas main *d*, from which a conveyer takes it into a dust collector *f*, from whence it can be removed at will. Every section or division in the filter can be controlled and cut off separately, while a small exhausting fan is specially provided in order to draw away the gas in case it should be necessary for any person to enter the section after it has been cut off. The main and ventilator fans are usually driven electrically, as shown.

It will be seen that the process is a dry one, which is an important advantage if the gas is to be used for Cowper stoves or boilers. The temperature at which the gas is filtered is some 10° or 20° above dew point, thus avoiding condensation of water vapours in the filters or the subsequent exhausting plant. The purified gas goes at this temperature to the gas utilisation plant and does not require to be cooled down. The saving in cooling water thus obtained is considerable, and there is also further economy in the reduced horse-power required for water pumping and in first cost, as no tanks, &c., are used.

In a trial plant with a capacity of 200,000 cub. ft. per hour, which has been working for over 19 months, the gas being utilised to drive a blowing engine, the efficiency of the system for cleansing blast-furnace gas containing up to six grammes of dust per cubic metre, down to 30 milligrammes and less after the gas has passed to the filters, has been proved. Cooled down to about 20° to 25° C. after it has passed the filters, it is then found that the gas contains only from five to 10 milligrammes of dust per cubic metre. Results such as these should establish the claim of the system as a valuable adjunct to gas-engine plant operating on blast-furnace gas. The working of the plant is automatic, requiring very little attendance. Experience has shown that the filtering fabric lasts from six to 12 months, and a complete section can be changed without stopping the plant in about two hours. Means are provided to control the working of the filters and to detect any defective ones without stopping the whole plant. A further saving claimed is that the horse-power required for working the plant is considerably lower than that required for alternative types. The figure given for the best of the existing plants dealing with gas for use in gas engines is about 9 h.p. for 1,000 cub. metres per hour, or if the gas is only cleaned for Cowper stoves or boilers, from 4 h.p. to 7 h.p. As against this, it is claimed that the "Halberg-Beth" process only requires 3 h.p., showing a saving of 50 to 60 per cent. on the usual figures for power. Further than this, it is claimed that the total working costs of the process as compared with wet processes show a saving, including depreciation and interest on capital, of about 50 per cent.

PERFORMANCE ON SERVICE OF THE CHANNEL STEAMER "NEWHAVEN."*

By P. Sigaudy.

Speed, regularity of service, and rapid manœuvring are the most important qualities for passenger steamers crossing arms of the sea and establishing communication between neighbouring continents, especially on short-trip services. From this point of view, we think it interesting to communicate the service results of the steamer "Newhaven" during the first five months on the route between Newhaven and Dieppe. Briefly the dimensions of this vessel are: Length between perpendiculars 292ft., length over all 302ft., beam 34ft. 7in., depth 22ft. 2in., maximum draught 9ft. 8in. Accommodation is provided for 1,000 passengers.

The machinery consists of three Parsons turbines: one high-pressure turbine driving the centre screw, and two low-pressure turbines driving the two wing screws. The reversing is done on the two wing screws. The boilers are of the water-tube type. The starting platform is on the main deck level in a roomy and well-lighted position, in which all the controls are assembled. The main regulating valve, the two manœuvring valves, the by-pass, the heating-through valves, and the lubricating system are all handled from this central position. The change over from ahead to astern, or the contrary, is effected in four seconds, and the vessel can be stopped in a distance of 295ft. from a speed ahead of 12 knots.

The contract trials consisted in a double crossing between Dieppe and Newhaven, at a time of tide to be selected by the owners in order to neutralise the effect of currents. The duration of the run from Dieppe to Newhaven was 2 hours 43 minutes 51 seconds, and from Newhaven to Dieppe 2 hours 43 minutes 5 seconds, giving a mean speed of 23.85 knots, the distance from light on pierhead to light on pierhead being 65 nautical miles. These trials were carried out on May 26th and 27th, 1911.

The "Newhaven" was put in service on June 2nd, and ran till October 20th inclusive, being then withdrawn for inspection at the expiry of guarantee period. Between the above dates she made 126 crossings, the mean time of which was 2 hours 51 minutes 25 seconds, corresponding to a mean speed of 22.70 knots. The fastest trip occupied 2 hours 43 minutes (slightly less than the trial runs) with a favourable tide. The slowest trip took 3 hours 6 minutes, in bad weather. The mean coal per trip was 29 tons 4 cwts., includ-

* [illegible] Institution of Naval Architects, March [illegible]

ing that consumed in raising steam and maintaining the fires in harbour. Although I have not been able to obtain exact information, I estimate that this quantity of coal may be divided as follows: 5 tons $1\frac{1}{2}$ cwts. for raising steam and losses on arrival, 24 tons $2\frac{1}{2}$ cwts. for the trip from pierhead to pierhead.

These results are notably better than those anticipated by the owners, who stipulated that the crossings should be made in 3 hours on the official trials. We attribute them in the first place to the turbines of the Parsons type, further to the special arrangements adopted for the auxiliary machinery, which was worked out on a destroyer basis, though with additional scantlings to ensure long-continued wearing qualities. For instance, the steam valves are of cast steel, the air pumps of gun-metal, the condenser shells of steel plate, &c. As a matter of fact, the inspection at the end of the guarantee period proved that all the parts were in perfect condition, and showed no signs of fatigue; no damage was found, and everything was closed up again without repair or renewal.

It may now be recognised that there is no disadvantage in employing for such vessels the same mechanical arrangements as for destroyers. Why not also for the boilers? Why not fire them with liquid fuel? Mr. Milton, in his paper on "Diesel Engines for Sea-going Vessels," read at our meeting of April 5th, 1911, clearly demonstrated the considerable advantages of liquid fuel for ships: Evaporative effect 50 per cent. greater, less space required, and greater facilities for stowing the fuel; more perfect combustion and better utilisation of the boiler heating surface; absolutely regular production of steam at a constant pressure; finally, handling of the fuel reduced to its simplest expression, since shipping, stowing, and feeding to the fires are carried out mechanically by means of pumps.

Further, we ought to take into consideration that Channel steamers have to start under a full head of steam, with the fires already forced, that they must keep this head of steam up to the moment of arrival, and that the waste of coal is reproduced at each departure and arrival, which may be several times a day. Now, with liquid fuel, these wastages at each arrival and departure do not exist. In fact, one can compare under these circumstances the firing of a boiler with the management of a lamp, which one lights, turns up and down, or on and off, without waste of oil. Briefly, the economical advantages of this system of firing are the greater the less the duration of the trips, and the greater their number.

Were our Institution an association of owners, I might complete this short note by a balance-sheet comparing the two fuels, based, for instance, on trips of 25 nautical miles, with four crossings daily; but I will confine myself to giving the consumption of fuel and the number of firemen in the case of coal fuel and in the case of oil fuel, based on the results of the "Newhaven." In the case of coal fuel, the consumption per trip would be 14 tons 6 cwts., including that used for raising steam and losses in port. With liquid fuel this figure would be 8 tons 13 cwts. only. For coal firing, 18 firemen and 2 leading firemen are necessary. For liquid fuel, 4 firemen and 2 leading firemen are sufficient.

I will only point out to engineers how attractive is the solution. Certainly, liquid firing for boilers is the complement to turbines for ship propulsion. The plant works without dirt, noise, or apparent fatigue, with complete flexibility, and without assistance from the human hand, under the control of a few intelligent mechanics who watch the pressure gauges and regulate the valves from time to time.

AUTOMATIC CONTROLLING VALVE FOR STEAM ENGINES.

STEAM engines of the type in which steam is admitted at one or both ends of the cylinder and exhausts through ports located at or near the end of the travel of the piston, the ports being controlled by the piston, are sometimes provided with additional clearance spaces, communication between which and the cylinder ends is controlled by valves that can be opened and closed by hand, according to whether the engine is to be worked non-condensing or condensing, or in starting or in ordinary running; in some cases such valves also act as relief valves. With a view to protect condensing engines of this type against damage due to excessive compression pressure in the cylinder such as might occur through loss of vacuum when the condensing plant fails to act, the arrangement illustrated herewith has been designed and patented by John Musgrave & Sons, Ltd., Globe Iron Works, Bolton. The engine is provided with an automatic exhaust valve on its exhaust pipe and with a suitably proportioned additional clearance space, communication between which space and the corresponding cylinder end is controlled by a

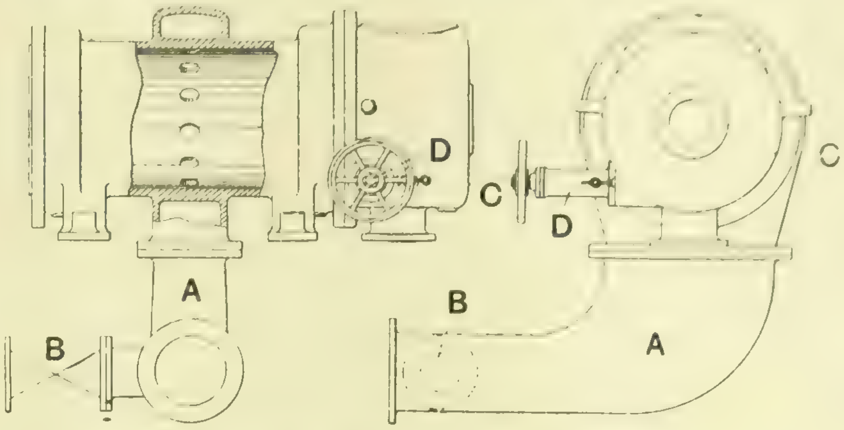


FIG. 1. FIG. 2.
AUTOMATIC CONTROLLING VALVE FOR STEAM ENGINES.

valve that is always free to be opened by excessive pressure in the cylinder, and which when so opened is automatically held open; on excessive pressure arising the automatic exhaust valve and the valve controlling communication with the clearance space open, and the engine then continues running but works as a non-condensing engine, the additional clearance space ensuring a sufficiently low compression pressure.

Referring to Figs. 1 and 2, which are diagrammatic sectional side and end views of part of an engine, and Fig. 3 a section of one form of automatic valve controlling communication with the additional clearance space, the exhaust pipe A is fitted with a valve B leading to the atmosphere and adapted to be opened by the exhaust pressure should this be above atmospheric pressure owing to failure of the condensing

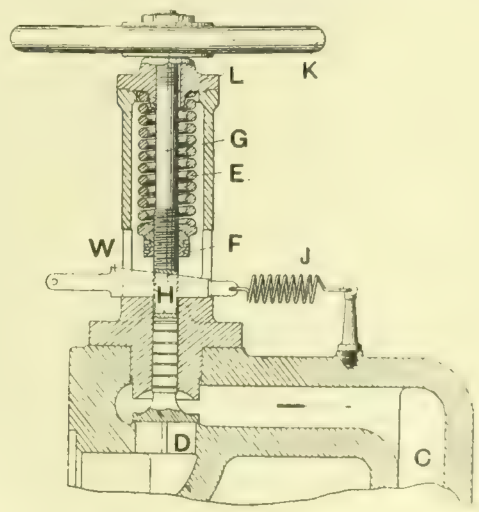


FIG. 3. SECTION OF AUTOMATIC CONTROLLING VALVE FOR STEAM ENGINES.

plant, but otherwise to be held closed, whilst between each cylinder end and an additional clearance space C is fitted a valve D adapted to be opened by excessive compression pressure and then be held open. The valve D (Fig. 3) is pressed against its seat by a spring E that is set, by an adjustable nut F on the valve spindle G, to a pressure of, say, 10lbs. above the boiler pressure and the spindle G is slotted at H to receive a sliding wedge W connected to another spring J so arranged that, when the valve D is forced open, the wide part of the wedge is moved into the slot and the valve thus held open. The outer end of the valve spindle is fitted with a handwheel nut K that abuts against a fixed part or frame L and can be manipulated to positively withdraw the valve from its seat when required.

International Congress of Applied Chemistry. — The eighth International Congress of Applied Chemistry will be held in Washington and New York, from September 4th to 13th. The hon. president of the congress is Prof. E. W. Morley, Sc.D., and the president, Mr. W. H. Nichols, Sc.D. A preliminary pamphlet has been issued and may be obtained from C. G. Cresswell, Society of Chemical Industry, Palace Chambers, Westminster, London, S.W.

AGGLOMERATING FINE IRON ORES AND FLUE DUST.*

BY N. V. HANSELL.

THE last few years have shown an increasing interest in the subject of beneficiating iron ores in all iron-producing countries. In the United States this movement has been slower than in certain of the European countries, the obvious reason being the abundance and relative cheapness of the Lake Superior iron ores which have been an effective hindrance to the development of enterprises that have for their object the preparation of low-grade ores for the iron industry. Gradually conditions have changed. The world's consumption of iron is increasing enormously. Being in 1900 about 40,000,000 tons, in 1910 it was already 60,000,000 tons. And there is no reason to doubt that in the near future the increase in the iron consumption will continue at the same rapid rate, especially with the development of such parts of the world as China, certain parts of Africa, and others, which have hardly been touched yet by modern industrialism.

It is therefore not surprising that concern is felt that the known available iron ore resources of the world are gradually being depleted. Signs of this feeling are the recent investigations under the direction of the Geological Survey of the iron ore resources of the United States, and particularly that by the last International Geological Congress of Stockholm, Sweden, of the iron ore resources of the world. These investigations have emphasized the fact that the known high-grade ore deposits are limited in their extent and that they will at no distant future be exhausted, compelling the iron industry to depend for raw material on the enormous deposits of low-grade ore which are distributed over almost all the world. The fact that new deposits of high-grade ore will be discovered in countries not yet thoroughly explored will not materially change the prospect. The rôle such new deposits will play in the future can, of course, not be forecast. Transportation difficulties will probably exclude a great part of them from being used at present centres of the iron industry.

In view of these facts it is no wonder that great interest is displayed in the subject of making useful such ores as have heretofore been discarded because in their natural state they are not suitable for blastfurnace operations. Among such ores are, in the first place, those whose low iron content precludes their direct charge in the furnace, so that they have to be crushed and concentrated, giving in result a finely granulated product with high iron content; in the second place, those which, although their iron content is sufficiently high, by either their physical or chemical character are less desirable.

Modern blastfurnaces with their high stacks and high blast pressure make difficult the employment in the burden of too high percentage of dusty or finely granulated ore, as, for instance, some of the fine Mesaba ores. At some furnaces conditions compel the management to use 60 per cent. or 70 per cent. of such ores; indeed, I am told of furnaces using 100 per cent. fine ores. But the manager will without incitement tell his woeful tale of unavoidable losses of the charge in the form of flue dust, of scaffolding in the furnace, and frequent explosions. The fine ore, descending more quickly than the rest of the charge, reaches the smelting zone only partly reduced. This causes disturbance in the furnace operations, with frequent casts of off iron. Therefore, if it can be economically done, it is highly desirable to convert to a lump form all such fine ores, whether they have been obtained in the form of fine concentrates in the separation of low-grade iron ores or mined as natural soft and fine ores. A high sulphur content in the fine ore is often an additional reason for a preparation of it by agglomerating, as usually thereby the sulphur content is reduced and the ore is made doubly attractive to blastfurnace managers.

The real impetus to the development of processes of agglomerating fine iron ores has not been the desire to make useful such fine ores as just mentioned, but rather the necessity of finding some method of preparation of such waste products as flue dust, pyrites residues, &c., for blastfurnace use. The most important of these is the flue dust, of which it is stated that between 2,000,000 tons and 5,000,000 tons are annually produced in the United States. A part of this is recharged into the furnace after a thorough wetting, which is supposed to prevent its being directly blown out again. That this practice is not very satisfactory is evident from the vast and growing piles of this material around furnace plants in the Middle West, where a high percentage of soft ores is used in the burden. This waste is especially great when a furnace has been long in the blast and begins to be somewhat rough in the lining. The flue dust contains from 35 per cent. to 45 per cent. metallic iron, with 5 per cent. to 20 per cent. of coke.

So also with the pyrites cinder, of which material yearly about 500,000 tons is produced; and on account of its usual pulverous condition and high sulphur content has been thrown away or perhaps at the best used for reclaiming land or building roads, although it frequently contained as much as 55 per cent. or 60 per cent. of iron. The modern methods of making useful for the iron industry through agglomeration either these waste products of these low-grade ores, in their natural state unsuitable for blastfurnace operation, certainly form a not unimportant phase in the present movement for the conservation of natural resources.

Methods of Agglomeration.—The many methods that have been proposed or are now being employed for the agglomeration of fine iron ores can properly be subdivided into three classes, the bases of the classification being radical differences in the processes themselves, and also to some extent in the nature of the products: (1) Nodulizing in revolving kilns; (2) Blast roasting; (3) Briquetting with or without binder, usually followed by a heating of the briquettes.

(1) Nodulizing gained early prominence in the United States. There are at present a number of plants in operation. Among these is the pioneer one at Hackensack Meadows, N.J., treating pyrites cinder. Others like the ones at Lebanon, Pa., Benson, N.Y., and Standish, N.Y., treat ore concentrates. Others again, like the Hubbard plant in Ohio, treat flue dust. The most modern plant of the kind is at Felton in Cuba. In Germany, similar methods are being used for the roasting and sintering of carbonates, and in Canada a plant of four kilns is now being erected for the same purpose. For such ores as decrepitate and shrink considerably in roasting, the method is especially valuable. The product is, however, seldom uniform. Occasionally they are nodules are vitrified and very dense, occasionally they are loose and brittle, producing much dust in handling. Difficulties in keeping the kilns free from scaffolds or rings, necessitating shut-downs every eight or 10 days, tend to make the cost of production higher than a first investigation of the merits of the process seem to indicate.

(2) It is not necessary to dwell at any length on blast roasting. The product is spongy and forms undoubtedly an excellent raw material for blastfurnace operations.

(3) At a meeting of the Iron and Steel Institute in 1910, Chevalier C. De Schwartz, of Liege, read a paper on the briquetting of iron ores. In this he gave as conditions for successful briquetting:—

"1. The iron ore briquettes must have a certain resistance against mechanical influences. They must resist a pressure of not less than 2,000lbs. per square inch, and when dropped from a height of 10ft. on a cast-iron plate they must not fall into dust, although they may break into pieces.

"2. They must resist heat. Heated to 900° C., they may commence to sinter, but they must not disintegrate into small fragments.

"3. They should be capable of being placed in water for a certain time without softening.

"4. They must resist the influence of steam at 150° C., without crumbling.

"5. They must possess a certain amount of porosity in order to allow the carbon monoxide in the blastfurnace to penetrate the interior of the briquette, and to exercise its beneficial reducing influence.

"6. The binding material, if any is used, should not contain noxious substances (sulphur, arsenic) to such an extent as to be injurious to the quality of the pig iron produced.

"7. The cost of producing briquettes should not exceed the difference in the prices between lump ore and fine ore."

In other words, the briquettes must be able to stand

* Paper read at the New York meeting of the American Institute of Mining Engineers, February, 1912.

handling, transportation, and storing in the open air without too much disintegration, and to withstand conditions as they exist in the upper part of a blastfurnace without crumbling into dust. In addition, they ought to be easily reducible. If a binder is used, it ought to be of such a nature that it adds no deleterious elements and it ought not to lower the iron content of the material too much. On the question of the cost of operation any process will stand or fall. In figuring this, it must be recognised that the value of a process cannot be determined by the briquetting cost alone. The value of the finished product and its influence on the cost of pig iron manufacture must be taken into consideration. For the preparation of a briquette which is easily reducible with a low consumption of coke, one can afford to pay more. Really, therefore, the question has a wider scope than at first appeared. The use of an easily reduced briquette makes possible a greater output of the blastfurnace. Presently, I will give figures which will verify this statement and will show that it is not enough to convert the fine ore into lump form and consider in selecting a method only the direct cost of the briquetting.

Various Methods for Various Conditions.—Of the great number of methods which have been devised, several of which have gained commercial prominence, some are better adapted to certain classes of ore than others. This is natural, as the processes have originated and have been worked out at places where necessity has called for them. Mr. Schwartz in his paper describes a briquetting process used at Kertsch, Russia, and Ilsede, Germany, where the ores are of a clayey nature, with 6 per cent. to 8 per cent. of hygroscopic moisture. The ore is pressed into bricks at a low pressure, 4,000lbs. to 5,600lbs. per square inch, and heated to a temperature of only 75° C. The use of higher pressure would make the briquettes too dense. Parallel cases can be cited from other places. A high sulphur content in the ore, for instance, gives prominence to a method by which the ore in the briquetting is heated sufficiently for an effective roasting.

To describe even the main features alone of the various briquetting processes that have come into commercial use in Germany, for instance, would take me too far away from the real subject of my paper. I refer anyone interested to G. Francke's "Handbuch der Brikettbereitung" (Stuttgart, 1910). But I wish to mention some of the more successful in order to compare them with the Gröndal method, which it is my intention to describe.

The Problem of a Binder.—The various briquetting processes can advantageously be classified as those that use a binder and those that do not. It is a very practical distinction. There can be little question that a binder used to cement together the ore grains fills the voids between them, producing a briquette with low porosity. This must have an unfavourable influence on the action of the briquettes in a blastfurnace. The more porous an ore or a briquette is, the less coke is required to reduce it. This is obvious, as in the upper part of the blastfurnace the ascending gases penetrate the porous briquette, and deposit fine carbon through dissociation throughout it, causing a direct reduction of it before it has reached a great depth in the stack. The binder also lowers the iron content of the briquette. In most cases 8 per cent. to 10 per cent. of the binder is employed. That the smelting and slagging of this material increases the fuel consumption and makes the pig iron more expensive is quite natural.

Of the various binders, those most in use seem to be of the nature of hydrosilicates, which are hardened either by exposure in air a long time or by being treated with steam under pressure. Deutsche Brikettierungs Gesellschaft advocate a method of this kind. They form with the binder a silicate of lime. The Scoria Gesellschaft of Dortmund uses 8 per cent. to 10 per cent. basic blastfurnace slag, or a mixture of 4 per cent. slag with 4 per cent. CaO. The ore is ground with the binder, pressed into briquettes, and hardened in steam. The Weiss method is to mix the ore with 5 per cent. or 6 per cent. of hydrated lime, form the briquettes at a pressure of 4,500lbs. and expose them to the influence of CO_2 gases, first cold and then hot, at 300lbs. pressure. The Tigler process (Duisburg Meiderich) employs a binder consisting of 6 per cent. to 8 per cent. of slaked lime, sometimes with an addition of 1 per cent. of blastfurnace slag. The Schumacher process for flue dust utilises the hydraulic properties of the flue dust which, like cement, contains lime, alumina, and soluble silica ready for combination. By the addition of a small amount of chloride of magnesium, chloride of calcium, or certain other salts, good briquettes can be obtained. The flue dust ought to be used hot direct from the dust catchers.

Among organic binders many have been tried, but few have been satisfactory. Trainer uses 4½ per cent. zellpech, which is a waste lye resulting from the manufacture of sulphide of cellulose. This and similar binders coke in the upper part of the blastfurnace stack, and thus continue to hold the fine ore together until a reducing zone in the furnace is reached. They are, however, generally too expensive to be used.

Of methods without binder, I will mention the one known under the name of Ronay. For the binder is substituted high pressure in hydraulic presses. The process has been more used for metal filings, &c., than for ores. The briquetting of clayey ores without a binder has already been mentioned. In reality the clayey constituent of the ore serves as a binder.

The Gröndal Process.—The only process of importance that remains to be spoken of is the Gröndal, which consists of the briquetting of fine ore at a medium pressure and the burning of the briquettes at a high temperature in a specially-constructed channel furnace. It was in 1899, when Dr. Gustav Gröndal was manager for Pitkaranta Iron Works in Finland, that he built his first channel kiln for the briquetting of iron ore concentrates. Similar kilns had been used previously for the burning of clay bricks, but for the adaptation of the process of the treatment of iron ores and for the gradual development of a modified type of kiln suited to this special purpose, the honour belongs to Dr. Gröndal.

The first kiln at Pitkaranta was an entire success. It was followed by one at Bredsjö, Sweden, built in 1902. From that time on, a great number of kilns have been built both in Europe and in this country. At present, there are 16 plants in Sweden with together about 35 kilns and a briquetting capacity of about 400,000 tons a year. In Norway, there are three large plants: Sydvaranger with eight kilns, Salangen with four kilns, and Dunderland with four. In England 12 kilns have been built, all treating pyrites residues and "blue billy." Italy has one plant, Spain has two, and in the United States there are six plants in operation or construction. In Canada the first one is being built by Moose Mountain, Ltd., for the treatment of magnetite concentrates.

The Gröndal furnace can briefly be described as a channel furnace, through which the ore, pressed into bricks, is transported on flat cars, which form a continuous movable platform through the furnace. The furnace is heated by means of gas introduced through the raised arch at a distance from the entrance end of about two-thirds of the furnace length. The flat cars are usually built of structural steel with firebrick tops and are furnished on each side with flanges dipping into sand troughs. They are often built with overlapping ends so that when they are pushed against each other in the kiln, they separate completely the upper part of the kiln, through which the gases pass, and the lower part, in which are the trucks and the wheels. The furnace walls are built double, with an outside wall of red brick and an inside one of firebrick; the two being separated by an air space, which assists in lowering heat losses by radiation, and at the same time permits the walls to move independently of each other in expanding and contracting on account of changes in kiln temperature when the furnace is started and stopped.

For obtaining the necessary temperature, almost any kind of fuel that has sufficient calorific value can be used. In Europe, the rule has been to use producer gas, except at some places in Sweden where the furnaces are built at iron works. There a mixture of blastfurnace gas and producer gas is burnt. Blastfurnace gas alone is too diluted, so that the high temperature required for the reaction cannot be obtained unless it is enriched by some producer gas. When it is available, however, it is economical, as the coal consumption in the gas producer can thereby be cut almost in half. In the United

States crude oil is used at two plants and natural gas at two. Local conditions govern the choice of fuel.

For different fuels and for different ores the construction of the kiln must be somewhat modified, although broadly the design is governed by the same principles. In the first third of the kiln the briquettes are preheated by the escaping combustion gases; they pass through zones of increasing heat as the cars are pushed forward. In the combustion chamber the heat is maintained at about 2,500° Fah. When the briquettes have passed the combustion chamber, they gradually pass through the cooling chambers, into which cooling air is blown by means of a fan. When they leave the furnace they are cooled off sufficiently to be unloaded directly into railroad cars. The arch over the cooling chamber is double, and in some installations it is made of corrugated cast-iron plates. Through the space between the double arches the air that is to be used directly for the combustion passes. On reaching the burners or the combustion chamber it has a temperature of 400° Fah. to 600° Fah. The outgoing combustion gases, when reaching the stack flue generally have a temperature of 300° Fah. to 500° Fah. It can be seen that the furnace is built on the regenerative principle and that its heat efficiency is good. The walls, as has been said, are double, and the arch is usually covered with 8in. or 10in. of sand, so that radiation losses are low.

Having thus given the general principles in the design of the furnace, I wish to describe the chemical reactions which take place during the passage of the ore through it, before giving details of the practical operation. As a rule, regardless of their original composition, the briquettes are discharged as a peroxide of iron (Fe_2O_3). If the ingoing ore is a hematite it is gradually dissociated to Fe_3O_4 as the ore passes towards the combustion chamber. In a nearly white hot condition, it is here met by a current of highly heated air. This gives the ideal conditions for a rapid conversion from Fe_3O_4 to Fe_2O_3. Here lies the secret of the Gröndal process. Briquettes at a temperature of 2,400° Fah. or 2,500° Fah. are met by air of high temperature. The oxidation is almost instantaneous. Thereby an appreciable amount of heat is liberated, to the benefit of heat conditions in the combustion zone. A quick oxidation of the Fe_3O_4 produces a blue crystalline Fe_2O_3. A slow oxidation will give a product that is earthy, amorphous and reddish in colour. From this it is clear that it is necessary to keep a high temperature in the combustion zone. The colour and condition of the discharged product tell whether the furnace is run properly. Dark blue, firm and strong briquettes indicate a right temperature; loose and reddish briquettes, a temperature too low. When the ingoing material is a magnetite, it is probably oxidised to a certain degree on its way toward the combustion zone. This oxidation is probably followed by a dissociation as the briquettes enter the hotter part of the furnace; but the Fe_3O_4 so formed is again oxidised to Fe_2O_3 before being cooled off and discharged. This last re-oxidation is so complete that analyses usually show over 90 per cent. Fe_2O_3 of the total iron oxide in the briquette.

It is probably these chemical reactions which account for the agglomeration and the great strength of the briquettes. The material is not rolled together when in plastic state, as in the nodulising process; nor fused together as in the blast roasting, which gives a sintering product usually of little strength; but in the re-oxidising of the lower oxides of iron, diminutive crystals of hematite are formed, growing out on the surface of each ore grain in the briquette. These small crystals interlace with each other or grow together, forming a strong bond between the grains. If the ore is not crushed fine enough or consists of rounded pebbles, the intergrowing effect may not be obtained, and consequently the resulting briquettes will be loose and easily disintegrated. Such was the case in tests with the concentrated product from St. Lawrence magnetic sands. It was found necessary to pass a part of the iron sand through a grinding mill in order to get some fine material to fill the voids between the larger pebbles. With pyrites residues there has been the same experience. It is futile to try to briquette cinder from lump pyrites without first grinding it so as to pass, say, 20 mesh, if strong briquettes are desired.

It has been mentioned that the briquettes in passing through the furnace are desulphurised. The conditions in the furnace are favourable to a complete desulphurisation: a high heat, a strongly oxidising atmosphere, and a porous material consisting of finely granulated ore particles, permitting the gases to reach every diminutive ore grain. In addition, the material stays in the hot zone for several hours, permitting a gradual oxidation of the sulphur, which escapes in the form of dioxide with probably a small amount of trioxide. At Bayonne, N.J., cinder with 2 per cent. or 3 per cent. sulphur is discharged with about 0·03 per cent.

A number of tests on Gröndal briquettes have been made in order to ascertain their suitability for blastfurnace and open hearth use. I mention the results of only a few of them. Last year a low-grade magnetite was crushed and concentrated in a large commercial test. A part of the concentrate was briquetted at Bayonne. Of the product about seven tons was shipped in an open bottom dumper car to Youngstown, Ohio. Here they were dropped, in unloading from a trestle 30ft. high, on an iron floor. A screening test of the unloaded material gave through a ¼in. screen 8·84 per cent. of the total mass. These fines gave the following results at the sieve test:—

On 8 mesh	69·70 per cent.	
On 20 mesh	16·66 per cent.	
On 40 mesh	4·55 per cent.	
On 60 mesh	0·81 per cent.	
On 80 mesh	0·80 per cent.	
On 100 mesh	0·60 per cent.	+ 0·06 per cent.
Through 100 mesh	6·66 per cent.	+ 0·16 per cent.
Total	99·78 per cent.	+ 0·22 per cent.

This shows that the total amount of fines passing through 40-mesh after the briquettes had been dropped 30ft. on the iron floor is only 0·8 per cent.

A regular compression test on the same briquettes showed that they would withstand a pressure of 5,221lbs. per square inch. That in handling they form a very small amount of dust was shown by the following test. A number of briquettes were crushed to ¼in. and less in a Gates crusher. A sieve test of the crushed material gave only 10 per cent. through the 100-mesh sieve, and very little on the other fine sieves.

The porosity of the briquettes, being the ration of voids to the total volume of the briquette, is always over 20 per cent. This is a strong point in their favour, as it aids in making them easily reducible in blastfurnace operations.

The Use of Briquettes.—Recently I noticed a paper read by John Jermain Porter at the meeting of this Institute of last June on "The Fuel Efficiency of the Iron Blastfurnace." He said among other things:—

"The great desirability of having an ore which is easily reduced by carbon monoxide rather than by solid carbon, and in addition is reduced at such low temperature that the resulting carbon dioxide has no solvent power, has been frequently pointed out. The importance of carbon deposition in this connection does not, however, seem to be so generally appreciated. It will be recalled that this reaction, $2CO - CO_2 - C$, begins at about 430° and ceases entirely at 900°. That is, it takes place near the top of the furnace. It is probable that very little of the carbon resulting from this reaction ever reaches the hearth, but it does useful work in reducing the carbon dioxide of the limestone and in removing that portion of the oxygen of the ore which has not been removed by carbon monoxide higher in the furnace. From this point of view it appears that the ability of an ore to induce carbon deposition is equally important as the ease with which it loses its oxygen. . . . Every pound of carbon deposited means a saving of a pound of fuel for the hearth."

He also gives some numerical factors of reducibility for various classes of ores to be used in formulas for finding the fuel efficiency of the blastfurnace. These figures indicate that the Mesaba ores are most easily reduced. In his list thereafter appear brown hematite, soft red hematites and roasted carbonates, hard red hematites, Clinton "hard red" ore and magnetites and mill cinders, the last two being those that require most coke for their reduction.

By my description of the physical and chemical character of the briquettes produced by the Gröndal method, I think I have been able to show that the briquettes have all the quali-

ties of an ore that can be reduced in the blastfurnace with the least coke. The briquette is porous, so that by the dissociation of the carbon monoxide in the upper part of the stack the fine carbon is deposited throughout its mass. Furthermore, the briquette is a hematite and therefore does away with the usual and, as can be seen from Mr Porter's figures, well-founded objection by blastfurnace managers to the use of a too large percentage of magnetite in the burden.

The Saving from Briquetting in Sweden.—It is the rapid reduction of the briquettes in the blastfurnace that has made them so popular in Sweden. From 25 per cent. to 50 per cent. of briquettes in the burden of charcoal blastfurnaces of that country has been demonstrated to reduce the charcoal consumption per ton of pig iron by 15 per cent. to 25 per cent. Fifty per cent. of briquettes in the burden gives the best charcoal economy. In Sweden 500,000 tons to 600,000 tons of pig iron is produced yearly. As 300,000 tons to 350,000 tons of briquettes are reported for the same time, containing in average 64 per cent. iron, which corresponds to about 200,000 tons of pig iron or about one-third of the total pig iron production of the country, this means a yearly saving for the country of 400,000 cubic metres of charcoal, an item of importance in these times of increasing scarcity of wood suitable for charring. If such a tremendous saving can be made in charcoal furnaces, it is not too much to believe that an appreciable saving in coke furnaces can be obtained.

I have figures from a furnace in Belgium which has been using imported Swedish concentrate briquettes in a mixture with calcined Bilbao Spathic ore. With 70 per cent. of briquettes and 30 per cent. Bilbao ore in the burden, the coke consumption was reduced to 1,760lbs. per ton of pig iron. With all Bilbao ore it had been 2,398lbs. The iron content of the Bilbao was 50 per cent.; of the briquettes 65 per cent. The output of the furnace was increased 20 to 25 per cent., with a corresponding saving in wages and general charges.

For use in open-hearth furnaces the briquettes are eminently fitted, being rich in iron, free from noxious substances, in lump form and of sufficient weight to sink through the slag cover.

The Moisture Content of the Ore.—The fine ore to be briquetted has to have such a moisture content that it maintains its brick form after pressing. Too much moisture affects badly the work of the presses; too little makes the briquettes dusty and causes considerable spilling in pressing. The proper percentage of moisture varies with the hygroscopic qualities of the ore. Concentrated magnetites have to be dewatered to 8 or 9 per cent.; fine pyrites cinder can have 15 to 18 per cent. and still give good results. The tempering is done in the simplest manner by a sprinkling pipe or a water hose. The man who watches the feeding of the presses soon learns by the feeling of the ore whether it has the right moisture content. The delivery of the ore to the presses is in modern plants made by mechanical means at a small expense. In most of the present installations, drop presses of a Dorstener type developed by Dr. Gröndal are used, but on account of their usually rather high upkeep cost, toggle presses of heavy construction will probably be substituted in new plants.

Sizes of Briquettes.—The standard size of the briquettes is 6in. by 6in. by 2½in., and two tiers are loaded edgewise on each car, so that the load stands 12in. high. At the Duquesne plant, briquettes are made 2½in. by 4½in. by 8in. and are loaded three or even four tiers high. In loading them on the cars care is taken to place them so that the gases can penetrate the load and heat the bottom row as thoroughly as the top one. The loading is done by hand, and constitutes the only hand labour around the plant. This is, however, so laid out that the work is as much facilitated as possible. The pressman removes the briquettes as they are delivered by the press and places them on the car, which is pushed close to him. He does not need to move from his place during his work, and although he handles only 10lbs. or 12lbs. each time he turns, he can place 30 tons in a 12-hour shift. The press delivers from 12 to 16 briquettes each minute, so that enough idle time is allowed for changing cars.

Kiln Construction and Practice.—The loaded cars are pushed through the furnace at intervals, one car being admitted at a time. This pushes the others forward so that the first one is discharged from the furnace. The pushing is done either by an hydraulic ram or some similar contrivance: it requires exceedingly little power. The discharged car is unloaded either by being pushed under a plough, which scrapes the briquettes over the sides of the car or by being tipped endwise. Either arrangement can be made entirely automatic, so that in a 4-kiln plant two men take care of all the cars as they come out, unload them, and send them back to the presses viâ a return track with endless chain haulage. The frequency with which the cars are charged depends upon the nature of the ore. If it has a high sulphur content it may be necessary to charge them at a slower rate than if the sulphur content is lower. At Mayville cars are charged every 10 minutes. The furnaces there are 195ft. long and the cars 6ft. 6in. Each furnace therefore contains simultaneously 30 cars, which require, as one is pushed in every 10 minutes, 5 hours to pass through. At Bayonne, the furnace is only 143ft. long. One car is pushed in every 18 minutes, so that it takes 6½ hours to pass through.

The length of the furnaces, which is quite different in the Mayville and Bayonne plants, depends upon the nature of the ore to be briquetted. The width has been gradually increased. To begin with, it was not more than 3ft. In the United States both 5ft. and 6ft. furnaces are used, and foundations are now laid for two having an inside width of 10ft. Plans are drawn for furnaces even 15ft. wide, and I see no reason for not having even a greater width than this. A wide furnace with a capacity of, say, 300 tons of briquettes per 24 hours, will show a still greater heat economy than present plants. The developments of the process are going in this direction.

Simultaneously improvements in the design of the kiln are introduced in every new installation, in order to strengthen details that in previous plants have been found unsatisfactory and in order to reduce upkeep cost. Good results in these respects have been attained. The kilns themselves will stand for years without the walls or the arch having to be touched; the repair cost on cars amounts to only a few cents per ton. Mechanical labour-saving devices are introduced everywhere, so that labour cost is being lowered.

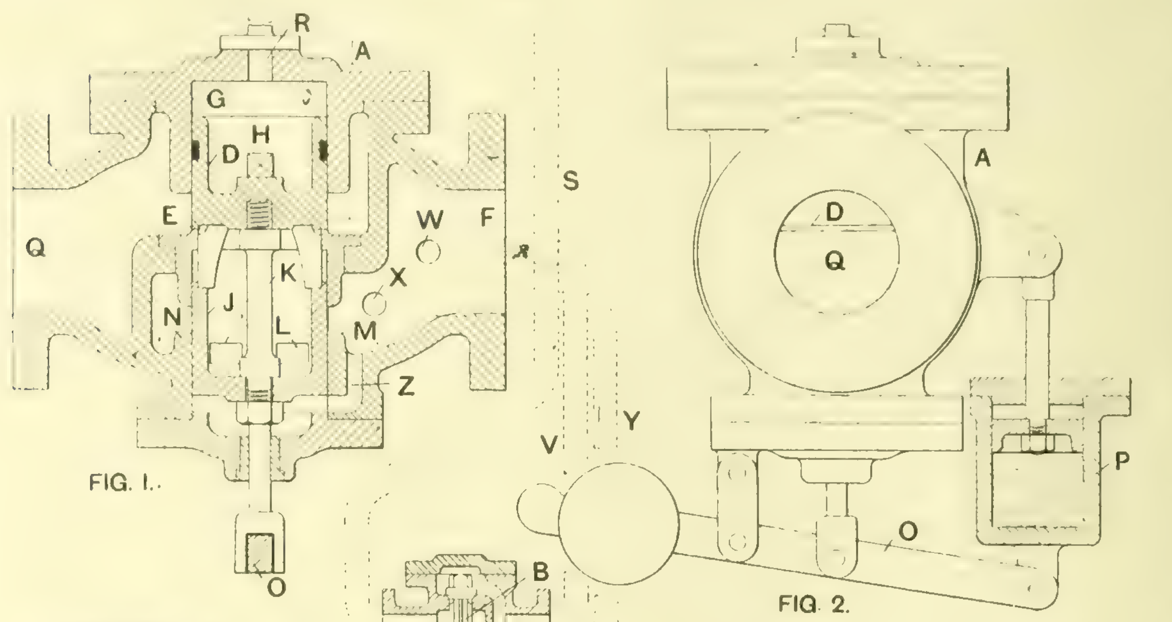
Fuel consumption is low. In plants treating magnetic concentrates, the amount of coal used in the gas producers averages 7 per cent. of the weight of the briquettes, and there are plants in Sweden using as little as 5 per cent. At a plant in the United States where pyrites residues are briquetted and crude oil is used as fuel, the oil consumption is stated to be 15 galls. per ton, which corresponds to approximately 10 per cent. It is obvious that if the ore is heavy, as magnetic concentrates are, the relative percentage of fuel used will be lower than when ore that contains a great amount of combined water and other volatile matter is treated. With such ore, a shrinkage in weight of 15 to 20 per cent. has to be taken into consideration.

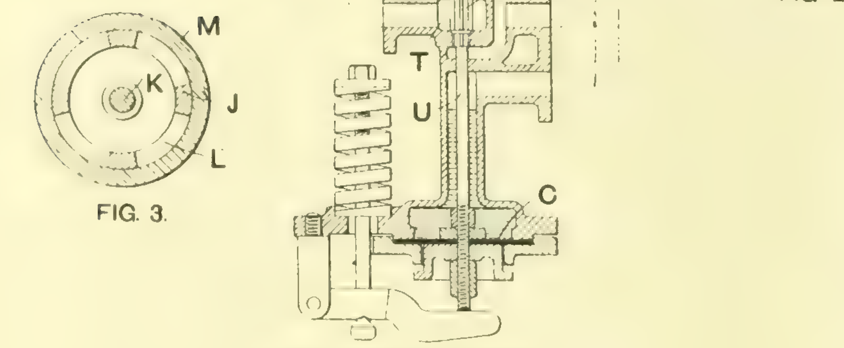
Junior Institution of Engineers.—On Saturday afternoon, April 27th, at 3 p.m., a visit of the members of this Institution will be paid to the engineering workshop and laboratory and electrical laboratory of "The Polytechnic," 307-311, Regent Street, London.

Application of Electricity to the Shale Oil Industry.—At a meeting of the West of Scotland branch of the Association of Mining Electrical Engineers, held recently at Glasgow, an interesting paper was read by Mr. James R. Laird on "Electricity Applied to the Scottish Shale Oil Industry." Mr. Laird, whose paper was illustrated by a set of lantern views, explained that until 1901 oil works in Scotland had not their power centralised or running economically, and it was often difficult to discern the nature of the work because of smoke and steam emanating from so many small steam plants. In 1901, however, the pioneer scheme for electrifying oilworks was carried out by Messrs. J. Wishart and A. C. Thomson, of the Oakbank Oil Company, Ltd. Many were sceptical, but the justification of the scheme is that nearly the whole of the Scottish oil companies have centralised their power and adopted electrical distribution. This has revolutionised the industry, and enables the local firms to compete with more fortunate oil companies in Russia, America, Galicia, &c., who have not to do any mining or retorting, but simply to bore for the oil.

AULD'S REDUCING VALVE.

THE accompanying illustrations show a design of pressure reducing valve fitted with a relay or regulating valve, the invention of D. Auld & Sons, Ltd., Whitevale Foundry, Rochester Street, Glasgow. The reducing valve A is actuated by the relay or regulating valve B, fitted with a diaphragm C and loaded by a spring and lever to the desired pressure and passing steam from above a balancing piston D, which is





AULD'S REDUCING VALVE.

formed in one with and over the main valve E to the delivery chamber F. The main valve E is fitted with a balancing piston D over it in the form of an open-ended cylinder working within a cylinder G and forming a chamber H, to which the high-pressure steam enters by leaking past the balancing piston D and presses down the valve E until the steam is relieved by the opening of the relay valve. A balancing piston J, formed as a cylinder closed at the lower end and working in a cylindrical part M of valve casing, is fitted below the main valve and connected to it by a spindle K. The outer diameter of this balancing piston J is equal to the outer diameter of the face of the valve E, so that its effective area is equal to that of the valve, when open. This lower balancing piston is formed with gates or openings L, which are closed by its cylinder wall M when the main valve E is shut, but are raised when it is opened until they coincide with an annular passage N at the top of the cylinder leading to the low-pressure or delivery side F of valve. The lower end of the lower balancing piston J is acted on by a beam lever O, loaded by a weight or spring, and jointed to the valve casing by a link and fitted at its other end with a dashpot P to control and steady the movement of the main valve E. The duct Z allows any steam leaking past the lower balancing piston to escape to the delivery chamber F.

The action is as follows The high pressure steam from the inlet branch Q leaks past the upper main valve piston D into it and the chamber H in which it works, and tends to press down to its seat the main valve E. It also passes by a port R and pipe connection S into the chamber T of the relay valve B. Insufficient pressure in the outlet branch F or delivery of main valve allows the spring to raise the central spindle U of the relay valve B and so open the same. On the relay valve being opened the steam imprisoned in the chamber H within and over the upper balancing piston D escapes by the port R and pipe S through relay valve B into outlet or delivery side of main valve by the pipe connection V and port W. The pressure on main valve being thus removed, it and its upper and lower balancing piston D and J are raised. Initial fluid pressure is now discharged through the main valve E into the chamber within the lower balancing piston J. The main valve E and piston J being now in perfect balance are moved up further by weighted lever until the gates L are opposite the annular passage N, when steam is discharged through the gates and annular passage into outlet chamber F. On the steam in the outlet branch F attaining a predetermined pressure, which pressure is adjusted by the spring pressure applied to the relay valve, the steam passing by the port X and pipe Y acts on the diaphragm C of the relay valve to close it. Steam being thus imprisoned between the relay valve B and the chamber H above upper balancing piston D by fluid pressure leaking past piston, the main valve E is pressed firmly down on its seating or face and remains closed until the pressure on outlet begins to fall below normal, when the same cycle of automatic operations is repeated. In place of the lever O and weight being used to open up main valve, a spring loaded lever or a direct spring or deadweight may be used with or without a dashpot attachment. With this arrangement it is claimed that action of the valve is rendered easy and chattering prevented.

THE USE OF COMPRESSED AIR IN BOILER SHOPS.*

BY THOMAS ALDCORN.

THE character and quantity of output must of necessity influence or govern the machinery equipment of any shop. Now, from this standpoint, let us run over briefly any general boiler shop. Is the output standardised, and is the work mainly duplication in smaller or larger quantities? Is it special, each case almost individual, or does it fall in the much larger class of jobbing, that is, part repair and part manufacturing? Each class may be further subdivided, but in final analyses certain fundamental features will be found common to all, with a wide range of special methods, apparatus and uses applicable to each class.

It should be borne in mind, also, that a discussion of the general subject will depend upon whether it is to cover an existing plant or the planning of a new installation. However, a logical treatment is to employ the natural subdivisions of production, or the methods and machinery of producing and storing compressed air; transmission, or the piping and means for conveying air to the points of application, separators or devices for cleaning and drying the air, and the final application or use of air through the medium of the standard tools and a large number of special appliances.

There are a variety of ways to compress air, each having some feature or features which may make it best for a certain set of conditions, and equally unsatisfactory under other conditions. Each installation requires careful individual consideration, and it is best not to attempt to make many sweeping general conditions which will apply equally in all cases so far as air compressing machinery is concerned.

Further, conditions change as a shop develops, and an equipment which in the beginning was adequate, and no doubt well selected to meet the then existing conditions, becomes inefficient and unsuited, due to gradual extension and additions not contemplated in the beginning. Besides, the wide range of uses to which compressed air lends itself is not at first fully appreciated, and experience may call for the installation of a device or machine at a remote place, or the use of a special appliance calling for a considerable volume of

* Paper read before the American Boiler Manufacturers' Association, March [illegible]

air, any one of which causes will disturb the balance of a once perfect plant.

General experience shows that for best all-round work the proper pressure at the point of application is from 90lbs. to 100lbs., and in some cases even slightly higher; however, 100lbs. at the tool will meet every requirement of 99 cases out of 100. To give 90lbs. to 100lbs. at the tool will call for a terminal or receiver pressure of from 100lbs. to 110lbs., depending on the piping or transmission system, to be discussed later. We now have the first production factor—pressure. Next comes the question of volume of air required, and this in turn necessitates a careful study of present and future requirements: What types of tool; the number of each to be operated; the probable number operated at the same time; the average time of operation of each; what special appliances will be installed; is air to be reheated, and what provision is to be made for growth? Fairly accurate tables are obtainable giving the air requirements for all standard tools and machines, and data are available from which the total volume of air needed can be readily worked out, or the manufacturer of compressor and tools will be very glad to assist in determining this second factor.

Having obtained the volume necessary, the third prime consideration is the power available for operating the compressor. Here again special conditions must govern, and it is not possible to lay down any hard and fast rule. If steam is at hand a steam-driven compressor of simple, duplex, or compound type, depending on the steam pressure and volume of air, generally recommends itself.

With low steam pressure from 75lbs. to 100lbs. and a required volume not exceeding 800ft., a single air cylinder finds frequent use. This type is not the most economical from the steam standpoint, but is compact, simple in construction, and has many desirable features. Above 800ft., and with the same low steam pressures, the duplex type with the advantage of four power impulses for each revolution is frequently employed. Either duplex or 2-stage air cylinders are used with this type. When the steam pressure is above 100lbs., compound cylinders should generally be employed, and especially if the steam pressure is much above 100lbs.

For the larger sizes, from 1,000 cub. ft. up, compound steam cylinders are almost essential and also 2-stage air cylinders. Larger units, of 2,000ft. and upward, should be of the Corliss type, their greater first cost being soon offset by the considerable saving effected by their low steam consumption. It is also well, when the volume of air to be supplied is large, to install two units, each having a capacity equal to light working demands or both together having a combined capacity equal to maximum demand and also some reserve for growth. It is always well to figure on a machine or equipment in excess of immediate demands and then operate the plant at less than full speed, with a resulting reserve capacity and increased life.

In many shops where shafting is running near the location selected for the compressor, and surplus power is available, a belt-driven machine forms the most satisfactory type. This should be arranged with tight and loose pulley if small, or a clutch, so that the compressor can be shut down, should occasion arise, without interrupting the operation of the entire plant. For belt-driven, except in the smaller sizes, the duplex—that is, two cylinders side by side, driven from one shaft having a pulley at the centre—is the most desirable form, as it gives four compressions per revolution, thus producing a more even belt load.

All belt-driven machines of whatever size or type should be securely anchored to a foundation to ensure correct alignment and proper resistance to belt pull. In every instance where electricity is available a belt compressor can be driven from a suitable motor. This arrangement is advantageous, in that it permits starting or stopping at will, without the intervention of idle pulleys, clutches or other power-absorbing devices.

Latterly motor-driven compressors are in considerable demand, either geared or, in the case of larger units, with motor mounted directly on the compressor shaft. For the smaller sizes an automatic starting controller and pressure regulator can be furnished if desired, and this will maintain practically a constant pressure, shutting down the motor when the desired limit is reached, or starting up where the pressure falls, due to an increased demand for air.

Still another method of driving in larger units is to mount the motor armature or rotor directly on the compressor shaft, an arrangement somewhat like a direct-driven generator outfit. The power is applied directly to the shaft, and all belts, gears, and other parts are unnecessary. This arrangement is, without doubt, the most simple and efficient type of power-driven compressor. However, it is not available except in sizes from 500ft. and above, because mechanical and electrical reasons will not permit the manufacture of slow speed motors at sufficiently low cost to compare with motors for belt or gear drive. At the same time the simplicity of this type and its high operating economy recommend its use wherever possible, even at a much higher first cost.

Remember that the power-generating plant, of which the air compressor is an important element, is really the heart of the establishment, and it is poor economy to skimp on that end, for a day's shutdown, due to failure of an essential part, may cost much more in money and prestige than the few extra hundreds called for in the beginning by the better equipment.

In piping up the compressor it is well, if possible, to take the inlet air from the shady side of the building or from outside the engine-room, where cool air can be obtained, as each 5° reduction in initial temperature will effect a saving of 1 per cent. in the operation of the compressor, or intake air 25° colder will increase the capacity of the compressor 5 per cent. It is also well to make the inlet of good size and as short and direct as possible, to reduce inlet friction to a minimum. Often, and always if in a dusty or sooty location, it is advisable to put a strainer on the exposed end of the inlet pipe or box. Such a strainer can be readily made by covering one side of a substantial box with wire netting and putting outside of this one or two layers of muslin, through which the air must be drawn. While a strainer is not essential under ordinary conditions, in many cases it is, and in nearly all cases strained air will help to avoid lubrication troubles and add to the life of valves, pistons, and glands.

The compressed air leaves the compressor at a fairly high temperature, averaging about 350°. As the amount of invisible moisture which can be held in air depends on its temperature, it is evident that all the moisture taken into the compressor is also discharged therefrom, to condense in the receiver or air mains later on. That this needs consideration is evident when it is recalled that a 500 cub. ft. compressor will draw in through the intake pipe $500 \times 60 \times 10 = 300,000$ cub. ft. of air per day of 10 hours, and on a damp or rainy day this may contain as much as a barrel of water for the day, although the average would be less. For this reason, especially in the larger installations, an efficient after cooler is most desirable, and it is actually essential if the transmission lines are long or exposed to the outdoors.

The after cooler is a device arranged to take advantage of the principle mentioned; that is, air will carry a varying amount of moisture, depending on its temperature, or at a given temperature air will hold only a certain amount of moisture, beyond which it becomes saturated and the excess moisture will be precipitated as dew or rain. Hence, if we can reduce the temperature of the air below that at which it will enter the transmission mains, moisture troubles will be very largely eliminated.

Of course, it must be remembered that when the air is actually used or expanded in the exhaust of the pump, engine, drill, or other air-driven device the rapid expansion causes a temperature reduction considerably below what can be obtained in the usual water-cooled after cooler, and there may be some precipitation from the compressed air at the point of application. Usually, however, the moisture noticed around air tools is on the outside and is really the accumulation from the surrounding air, like the moisture on the outside of a glass of ice water.

In principle the after cooler is simply a tank or receiver of suitable size and shape, to contain a nest of closely placed iron or brass tubes through which cooling water is circulated. The heated compressed air enters the tank and by means of baffle plates and tubes is forced to split up into thin sheets which wind in and about the cooling tube and give up to the water a proportion of the heat contained in the air, if such an expression will be permitted. The heat thus absorbed by the water is carried off and the chilling of the air reduces its saturation point to such an extent that most of the moisture

is precipitated and collects at the bottom of the tank portion of the after cooler. The air then passes out in a very much drier condition. While very desirable in larger installations, the after cooler is not necessary, and many installations have been operated for years without one.

From the compressor the air passes to the receiver, which performs a twofold function: First, as an equaliser of the pressure, to receive the rapid pulsations of the compressor's discharge, and, like a spring, or the gas bag on a gas engine, equalise or smooth out the pulsations, thus ensuring a steady flow of air to the transmission lines. Second, to contain a stored supply of compressed air, which helps the compressor over any sudden momentary increased demand for air.

There is an erroneous idea current with regard to the storage of air, for, without the use of an excessively large receiver it is not possible to store more than a few seconds' or a minute's supply. A receiver 48in. diam. and 12ft. long contains about 153 cub. ft.; when filled with air at 100lbs. pressure it will hold about 1,200 cub. ft. of free air. If the compressors supplying were shut down, the flow through a $1\frac{1}{2}$in. main would in a few seconds drop the pressure from 100lbs. to a pressure too low for working purposes. It is therefore evident that, except under peculiar conditions, the storage feature should be ignored and a compressor installed of sufficient capacity to easily take care of immediate and reasonable future requirements.

The receiver should always, if possible, be set up outside in a shady and cool place where the heated air from the compressor may have a chance to cool off and precipitate as much moisture as possible. To take care of this a suitable drain should be provided and used frequently to blow off any accumulated moisture or excess oil, if the operator has been careless enough to allow such a thing to happen.

Frequently it is a good plan to install additional receivers at junction points or elsewhere in the transmission system, to equalise the pressure and to take care of any sudden or excessive local demand. These auxiliary receivers also act as separators to remove from the air additional grit and moisture.

The transmission system or pipes conveying the air from the compressor to the various points of usage should receive most careful attention, both in location and in putting up. Lines should be made of ample proportion and figured with due regard to equivalent areas. They should be run as direct as possible, with few turns or angles, and it will pay in the end if bends or long turn fittings are used. Branches and outlets should be near enough to permit of sufficient tools being operated without the use of long hose lines, usually so that a 50ft. hose will over-reach another 50ft. hose. Each branch should have a tee and two outlets closed with good, solid globe or gate valves.

The practice of using nothing less than 1in. pipe for branches is to be recommended. Full-weight pipes, substantial fittings, first-grade valves, and care in supporting mains, drops, and branches are all essential, for it must be remembered that with air at 100lbs. pressure a $\frac{1}{16}$in. hole will leak the equivalent of a horse power for each 5 mins. Two or three such leaks, even in a large plant, would be a serious loss.

All piping should be carefully inspected, rapped to break loose inside scale, and then blown out. All joints should be made up with lead and screwed up tight, and every precaution taken to make the work permanently air tight. At suitable points drip tanks or separators should be inserted in the mains, these being provided with drip cocks. Drip cocks should also be placed at all low points. Further, it should be the duty of some one to see that all drips are blown off frequently and properly. Outlets should all be provided with an approved form of universal quick acting and locking hose coupling, and the same form should be used through and on all hose for interchangeability.

Only the best grades of hose should be used, wire wound for the longer or leader hose, and a short length of plain tubing for connecting with the leader. All hose should be cared for. It is expensive and deteriorates rapidly, and it has been shown that many troubles charged against the tool have been due entirely to the use of poor grades of hose, which have stripped or scaled inside and clogged the valve or working part of the air tool equipment. The hose should be regarded as part of the tool equipment, and each man to whom hose is issued should be held responsible for its return in good condition. In every case when getting ready the valve at the outlet should be opened an instant before connecting the hose. The hose should then be blown out, and then the hose connected to the tool.

We now come to the actual uses of compressed air. Aside from the line of standard power-driven machine tools for the boiler shop, such as shears, bending rolls, and punches, there are a large number of standard and special air tools fully as important. The principal ones are: Chipping, caulking, and bending hammers, long-stroke riveters, drills, reamers, tappers, flue expanders, flue cutters, yoke riveters, compression riveters, holders-on, jam riveters, rippers, rivet busters, pneumatic hoists, cranes, pneumatic jacks, scaling tools, staybolt rippers, telltale hole drillers, air forges, painting machines, grinders. Besides these, there are many other special appliances devised to meet peculiar conditions existing in each case. Limited time necessitates merely mentioning the names of most of these, and only a short review of the most important of these can be given.

First in importance should be mentioned the chipping and riveting hammers. The chipping, caulking, and bending hammers in six or eight different sizes for every character and weight of work, from the thinnest to the heaviest plates, range in weight from 6lbs. to 16lbs., with strokes from 1in. to 5in., and these striking at from 840 to 3,200 per minute, with air at 100lbs. pressure, acting on a $1\frac{1}{16}$in. diam. piston. It would seem that no argument is necessary to prove the advantage of these wonderful labour-saving tools over the old hand methods in the hands of even ordinary unskilled help.

Pneumatic chipping is unquestionably many times more powerful and efficient than hand chipping. Further, on account of their being no necessity to "swing a hammer," it is possible to work in out-of-the-way places and corners where hand chipping could only be done with the greatest difficulty. The varying sizes of these tools makes it possible to select a hammer to meet any peculiar set of conditions, and the spring throttle, which is always under the control of the operator, permits an instantaneous adjustment of the blow, from a very light tap to the full power of the hammer, thus enabling intricate chipping to be done quickly. Further, the chipping can be carried very much closer to the finished size than can possibly be done by hand.

When it is considered that an ordinary operator can take a $\frac{3}{8}$in. chip off a $\frac{1}{2}$in. plate at the rate of 8in. per minute, and this is compared with the time and work which would be required to cut the same chip by hand, some slight idea of the advantage of pneumatic chipping can be gained. It is a conservative statement to say that one man with a pneumatic chipping hammer can do from three to five times as much as he could do by hand.

For caulking, the pneumatic hammer is ideal; for, by selecting the proper weight of hammer or throttling the air pressure so as to limit the force of the blow, the metal can be condensed and caulked with an evenness impossible with hand methods, and the depth of the compacting of the metal can be regulated to suit conditions. In addition to the ordinary plate chipping and caulking, in most boiler shops there are usually iron or steel castings, all sorts of brackets and supports, stack bases, and other parts in and around the boiler or boiler settings, all of which need a certain amount of dressing. There are also many other special uses found for the chipping hammer, depending upon the particular shop and the type of boiler being handled.

The pneumatic riveting hammer of the long stroke type, weighing from 14lbs. to 21lbs., depending on the class of work for which it is intended, and having from 840 to 1,080 blows per minute, is a marvellous device, and even in the hands of an inefficient operator does so much more work and does it so much better than could be possibly done by hand that it is inconceivable that anyone would tolerate hand riveting of any sort. For any given case experience has pretty conclusively demonstrated that the work can be done in from one-fifth to one-third the time required to do it by hand work, with a proportionate reduction in cost and the very considerable advantage of having the work done better.

The reason for this is almost self-evident. It is not safe to heat a steel rivet beyond a certain point if its fibrous texture is to be retained and the full strength of the rivet made available. If the rivet is driven by hand it will be seen

that, no matter how rapidly the riveters strike, they cannot possibly upset and heat the rivet as quickly as it can be done by a machine which strikes a more powerful blow, probably 10 to 20 times faster than any riveter can possibly strike. On this account the rivet fills the hole and is headed before it is cooled to any great extent, and as it cools and is followed up by the riveter the plates are clamped together tighter than is the case with a hand-driven rivet. Besides, there is less likelihood of the rivet running over and heading up off the centre.

It is impossible to imagine any form of working machine simpler in construction than a riveting hammer, consisting as it does of the barrel, valve box and valve, handle and trigger, and while we sometimes hear complaint as to the cost of repairs, such cost is trifling compared with the results obtained. In fact, we do not believe it an exaggeration to say that any good shop has its capacity doubled or tripled by the introduction of pneumatic chippers, riveters, and drills. It is not necessary to occupy space with tabulated results, but statistics are available to show that it is a fact that pneumatic hammers double, triple, and often quadruple the working capacity of a man or gang, and in addition do the work better than it can be done by hand.

Along with pneumatic hammers come, of course, pneumatic holders-on for backing up the rivets; jam riveters for working in restricted places or in flues and other positions where the ordinary riveter cannot be operated; rippers for cutting up tanks, boilers, and other platework; rivet busters for flogging off the heads of rivets and staybolts, for purposes of repair or absolute dismantling of boilers and tanks, and other special devices of kindred sort, many of which are specially made, having been developed in some particular shop.

Pneumatic compression riveters, either portable or stationary, and yoke riveters of varying design, are largely used where the character of work demands this type. When properly mounted so as to be flexible they constitute a very important addition to any boiler shop equipment. In principle the compression riveter is much the same as the ordinary hydraulic riveter, except that the riveting plunger is advanced by means of a toggle or an arrangement of levers in turn moved by a piston moving in a compressed-air cylinder. Yoke riveters, on the contrary, are simply a heavy riveting hammer mounted on a suitable yoke frame, instead of being held by hand, the toe of the yoke constituting the holder-on. These also are largely used for certain classes of work.

Pneumatic drills are made in sizes ranging from the smallest midget type, weighing 6lbs. or 7lbs., to the powerful compound gear type having a capacity to drill up to 3in. or 4in. in metal and weighing up to 118lbs. In principle they consist of a multiple cylinder air-actuated engine, driving a crank shaft which is geared to the drill spindle or socket which takes the drill. On the smaller sizes the spindle speed is as high as 2,600 revs. per minute, whereas in the larger compound types the spindle speed is as low as 36 revs. per minute.

The power of these drills varies, of course, with the air pressure, but it is astonishing to see how rapidly they work and what enormous power they have. Their absolute flexibility lends them to all classes of work, and for general drilling, reaming, tapping, flue rolling or cutting out flues from old boilers there is nothing which compares with them. Through their use it has been possible to introduce methods of construction in boiler shops which have worked a revolution in the cost of boilers. More recently ball bearings have been substituted for the older types of sleeve bearings, and modifications in material made which have reduced the weight and increased the power and life of these drills to a great extent.

Scaling tools for removing the scale from the inside of boilers are nothing more than small, light pneumatic tools striking a fairly light blow but having a very high speed and they can accomplish an enormous amount of work in a most satisfactory manner.

Pneumatic hoists and pneumatic-geared cranes are largely used in boiler shops for convenience in handling the various parts entering into the construction of boilers in the different stages of their construction from machine to machine, and where air is available a considerable saving in labour can be effected through the use of these devices. The pneumatic cylinder hoist is a direct-lift type and can be furnished in capacities up to 20 tons and for any reasonable lift. Where this type cannot be used, the geared hoist is easily mounted on a hook and swung from a jib crane or may be arranged to travel on the under flanges of an I-beam trolley track. These can be obtained in standard sizes from one to 10 tons. They consist of suitable air motor and necessary gearing, together with a drum, all contained in a sturdy frame and suspended from hook or trolley wheels, as the case may be. They are a most desirable adjunct to any boiler shop, and with reasonable care have a long life and make a good showing in every way.

Pneumatic jacks also have a useful field, although not so great as some of the other devices mentioned. In principle they consist of a cylinder with a piston; a heavy piston rod projecting through the top head of the cylinder, the air being admitted to the bottom, the piston moves upward exactly as in the case of an hydraulic jack. These can be obtained in stock sizes from one to 20 tons and prove themselves a very useful tool, either for permanent installation in some fixed place as an adjunct to a permanent machine or mounted on wheels for ready movement.

Pneumatic forges for rivet heating or tool tempering are light and compact, hence readily transferable, and can be taken close up to where the work is being done, thus ensuring hot rivets without burning. They are simple in construction, durable, and very efficient, and eliminate any necessity for pumping or grinding a rivet forge.

Pneumatic grinders of several sorts can be obtained, and these are very desirable for finishing edges of plates, corners or for any other special grinding where it is desirable to take the tool to the work. They consist of a standard form of air motor, practically the same as that used in the pneumatic drills, with a suitable extension shaft for mounting on wheels which are made for either face grinding or edge grinding.

Pneumatic painting or paint sprayers may be used to considerable advantage in and around a boiler shop for painting boilers, tubes, &c., before shipment. In the hands of even an inexperienced operator they do rapid, economical, and satisfactory work.

This review of a most comprehensive subject is incomplete, as a paper much longer than the present one could be written on any one of the tools mentioned. However, it is hoped that interest has been aroused and that discussion will be provoked which will bring out special uses and devices that our various members may have found helpful in connection with their own practice.

The Manufacture of Petrol. — Mr. John Laing, F.I.C., read a paper to the members of the Edinburgh Association of Science and Arts on the 8th inst. on "The Manufacture of Petrol or Motor Spirit." Mr. Laing showed how the heaviest mineral oils could be converted into the lightest condensable products. By a simple ingenious arrangement of still the oil was kept distilling into itself until it arrived at the required density. The lecturer explained that some oils were more easily decomposed than others, and these required more heat forced into them in order to rupture their molecular bond. This was accomplished by distilling the oil under pressure, which had the effect of raising the boiling point, and thus necessitating a greater heat to vaporise the oil in the still. This extra heat forced the compound molecules apart and broke them down into lighter products. The more these got broken down the lighter became the products of distillation. Mr. Laing pointed out that some heavy oils would not part with their water of suspension except at a distilling heat, and in order to prevent this water returning to the still—now at a temperature higher than the distilling point of water—Mr. Laing interposes an oil-water trap connected with an ingeniously arranged superheater which retains the water and passes on the oil through a pipe bent in V form submerged in the hot oil in the still, where it gets heated and is redischarged into the still at or near its boiling point. The vapours as they leave the still under high pressure pass into a large vessel surrounded with cold water which acts as a condenser. Here the pressure being discharged over such a large area gets reduced to nil. What is condensed here flows out by an opening in the bottom to the receiver, while the uncondensed gases pass over by a pipe at the top to the finishing worm and are there condensed.

INDUSTRIAL AND TRADE NOTES.

Mersey Tides and Electricity.—The Wallasey Town Council have under consideration a scheme for utilising the tides of the River Mersey in order to generate electrical energy for the purpose of working the hydraulic lift at the Seacombe Ferry luggage stage, and also illuminating the promenade. The project involves the erection of a large water wheel in the space between the luggage stage and the shore to operate the generating plant.

New Clyde-built Destroyer.—The fast ocean-going torpedo-boat destroyer "Firedrake" was launched on the 9th inst. from Yarrow & Co.'s yard at Scotstoun. This vessel is the first of three special destroyers, 255ft. in length and 25ft. 7in. in beam, and having a contract speed of 30 knots. The propelling machinery consists of Parsons turbines driving two shafts, steam being supplied by three Yarrow water-tube boilers fitted for burning oil fuel only.

Marine Engineers' Wages.—Regarding the application for an advance in the wages of marine engineers, it was stated officially on Saturday last that a scale of wages had been practically agreed upon by the Emergency Committee of the Shipowners' Associations and the sub-committee of the engineers' societies to be recommended by the representatives on either side for acceptance by the District Committees in the various ports. It was further stated that the scale represented a considerable all-round improvement on the existing rates.

Sheffield Moulders' Strike Settled.—The Sheffield moulders' dispute was settled at a mass meeting on Saturday last. As a consequence, the 1,200 men who had been on strike seven weeks resumed work on Wednesday, pending a conference with the employers for a settlement of the points in dispute, and the formation of a demarcation board to decide what work belongs to moulders and what to coremakers. The main cause of the trouble was the moulders' complaint that work in their department had been given to coremakers who are paid less.

Proposed Royal Commission on Co-partnership.—In the House of Commons on Tuesday last, Lord Robert Cecil asked the Prime Minister whether he had received a memorial signed by 293 Members of that House, asking for the appointment of a Royal Commission on co-partnership, and if so, what decision the Government had come to on the point. Mr. Asquith said he had received the memorial referred to. The proposal should have the careful attention of the Government, which had for some time past had under consideration the question of industrial unrest and its causes.

Shipbuilding Order for Hebburn.—The Rederiaktiebolaget Lulea-Ofoten, which is a transport company subsidiary to the Trafik Aktiebolaget Grangesberg-Oxelosund, of Stockholm, has recently placed orders for two new steamers, to be delivered by the end of the current year. The vessels will be each 442ft. by 63ft. by 32ft. 6in., and the dead weight carrying capacity about 11,500 tons. They are to be built by Messrs. R. & W. Hawthorn, Leslie, and Co., Ltd., of Hebburn-on-Tyne, and they will be somewhat similar to, but larger than, the two ore-carrying steamships, the "Vollrath Tham" and the "Sir Ernest Cassel," built at Hebburn, under the designs and patents of Messrs. Johnson & Welin, of Gothenburg, for the same owners and during the past three years.

A New Process for Protecting Iron or Steel.—"Ironising" or "Ferrozincing," a new process introduced by Mr. Sherard Cowper Coles for protecting iron or steel from corrosion, has the advantage that it is more permanent than an ordinary zinc coating. The process consists of coating the iron or steel with pure iron by a special method which is quick and cheap. Pure iron is very inert to chemical action as compared with zinc, and is slightly electro-positive to the underlying iron or steel. A zinc, nickel, or brass coating applied to a pure iron surface forms a more durable coating than zinc applied to an iron or steel surface, as the electro-chemical action which is set up when once the zinc is penetrated is reduced. The process is cheaper than hot galvanising.

Iron Deposits in Australia.—The vigorous policy of railway construction now being pursued by the individual States of Australia, together with the large railway projects of the Federal Government, has led to an awakening of interest in the large and valuable iron ore deposits which exist in South Australia. At present the general manager of the Broken Hill Proprietary Company is in Europe collecting all information possible as to the manufacture of iron and steel and kindred industries. On his return the question of the establishment of ironworks in connection with the immense iron ore deposits at Iron Knob, in which the company is interested, will be thoroughly considered. The deposits of high grade iron ore at Iron Knob are estimated to total at least 21,000,000 tons.

State of the Skilled Labour Market.—The usual monthly memorandum prepared by the Labour Department of the Board of Trade states that employment in all industries in March was affected by the coal strike. In the tinplate, pig iron, and iron and steel trades the effects of the dispute were felt at an earlier date, and became increasingly marked with each successive week. Employment in connection with railways, shipping, and docks was also seriously reduced. Compared with a year ago most of the principal industries showed a decline due to the coal strike. In the 392 trade unions, with a net membership of 675,535, making returns 76,144 (or 11·3 per cent.) were returned as unemployed at the end of March. Returns from firms employing 422,707 workpeople in the week ended March 23rd, 1912, showed a decrease of 9·4 per cent. in the amount of wages paid.

Proposed Electrification of Berlin Suburban Railways.—The Prussian Landtag has under consideration a memorandum containing comprehensive proposals for electrifying and improving the Berlin city and suburban railways in order to render them capable of dealing with the increasing traffic. With this object in view it is proposed to set up two electric generating stations, one in a lignite district, probably near Bitterfeld, and the other near Berlin; the latter as a reserve station and to supplement the other during the heaviest periods of traffic. The total cost of the work, which will take about 4½ years to carry out, is put at about £6,167,500, of which about £2,500,000 are earmarked for permanent way and constructional work, &c., and the remainder for the provision and alteration of rolling stock. It will be necessary, *inter alia*, to provide 557 electric locomotives and 690 passenger coaches.

Central Ironmoulders and Amalgamation.—The ballot which has been taken of the members of the Central Ironmoulders' Association on the question of amalgamating with the six other ironmoulders' organisations in Scotland has resulted in an overwhelming majority of votes being cast against the proposed scheme. The Central Ironmoulders' Association, in which a large number of ironworkers in England are members, have been endeavouring for some time, along with four other ironmoulders' organisations in England, to obtain an advance in wages for workers employed in the light castings industry in England. The demand submitted was for an increase of 5 per cent. on the wages of pieceworkers and ½d. per hour to time workers. The employers have now conceded an advance of 2½ per cent. to the piece workers and 1s. per week to those engaged on the time principle, with certain additions to apprentice wages.

Shipyards and Travelling Time.—A matter which has been provocative of considerable friction in shipbuilding districts has been settled by an agreement between the Amalgamated Society of Engineers and the Steam Engine Makers' Society, with the Employers' Federation. The agreement provides, we understand, that workmen taken on by a firm at the premises of another firm shall work 53 hours per week and receive the district rate of wages, plus an allowance of 9d. per day, but shall not be entitled to travelling time. Workmen when sent to work away from the premises where they were taken on shall be paid the district rate of wages, plus an allowance of 6d. per day, and shall travel in their employers' time. The agreement is to apply to engine builders engining warships and merchant ships. The agreement is regarded as a concession to the men, as it has hitherto been the custom of some firms to pay men off when moving a vessel from one place to another, and then to re-engage them, which meant that they had to pay their own travelling expenses and travel in their own time.

Russian Manganese Industry.—A report by H.M. Consul at Batoum states that the manganese industry of the Trans-Caucasus experienced somewhat of a check in 1911, due to a great extent to the seamen's strike in the United Kingdom and the Italo-Turkish war, which seriously affected freights from Black Sea ports. Failing official returns, which are not likely to be published until late in the second half of the current year, the production of manganese in the Trans-Caucasus in 1911 is estimated at about 518,000 tons. An important feature in the trade of Batoum for the past year was, the report continues, the activity of business in manganese and the very large increase in the exports of this ore from the port, the totals being 43,119 tons for 1910 and 129,233 tons for 1911. The quantities of manganese ore shipped from Batoum to various countries in 1911 were as follows:—Belgium, 12,994 tons; United States, [illegible] tons; France, [illegible] tons; United Kingdom, 31,869 tons; Germany, [illegible] tons; Austria-Hungary, 1,256 tons; Netherlands, 27,999 tons.

The "Ideal" Portable Oxy-Acetylene Welding Plant.—Messrs. Chas. [illegible] & Co., Ltd., of St. Simon Street, Manchester, are introducing a compact and cheap form of oxy-acetylene welding plant which will meet the wants of general engineers, who can often find much useful work for apparatus of this kind, but for whom the

plants hitherto on the market have been too expensive. The "Ideal" apparatus is specially convenient for effecting numerous repairs, such as the fushion jointing and repair of pipes, the repair of cracks, blisters, and flaws in castings and forgings, and cast iron, or as a substitute for brazing and soldering in nearly all instances for copper, brass, aluminium, and the like. Since being introduced a few years ago for application to metal working, the oxy-acetylene welding process has made great strides. Its universal adoption has, however, been prevented by the high price of most of the plants, which have been elaborate in design and more or less fixed. By placing on the market a portable plant at a low cost, Messrs. Churchill have now placed it within the reach of all engineers. For mills and factories a portable plant of this description is invaluable. Piping and all classes of breakdowns can be repaired on the spot, and in most cases without even stripping down. New teeth can be welded into gear wheels in a few minutes and made as good as new.

Canadian Pig Iron in 1911.—According to the American Iron and Steel Association, the production of pig iron in Canada during 1911 was 824,345 tons, as compared with 740,210 tons in 1910. Of this total, basic pig iron accounted for 413,303 tons, as against 365,090 tons in 1910, and Bessemer pig iron 186,274 tons, as against 221,494 tons in 1910; the remainder was chiefly foundry pig iron. On December 31st, 1911, Canada had 18 completed furnaces, of which 12 were in blast and six were idle. Of the furnaces in blast, one was operating on charcoal. Of the 18 furnaces in existence, 14 usually use coke for fuel and four use charcoal. In 1911 the Canadian furnaces consumed 1,565,877 tons of iron ore, &c., and 41,427 tons of mill cinder, scale, turnings, &c., in the manufacture of pig iron, ferro-silicon, &c. They also consumed 567,462 tons of limestone for fluxing purposes. The average consumption of iron ore, mill cinder, scale, &c., in 1911 per ton of pig iron made was 1·94 tons. The Dominion Iron and Steel Company, Ltd., is adding two blastfurnaces to its works, at Sydney, Nova Scotia, to be known as Nos. 7 and 8. Each stack is to be 85ft. by 20ft., and will have an annual capacity of about 80,000 tons of basic pig iron. Each furnace will be equipped with four hot blast stoves, each 85ft. by 21ft. The Steel Company of Canada is about to add two 60 ton open-hearth furnaces to its steel plant at Hamilton. It will also add a blooming mill, a billet mill, and a rod mill.

Demand for Oil Engines in Russia.— A report by the British Vice-Consul at Baku (Mr. A. E. R. McDonell) on the trade of that district in 1911 states that a great demand exists for internal-combustion engines working with crude oil as fuel. Most of the oil producers of Baku are now dismantling their boiler installations and are erecting motor electric plants for power purposes. Keen competition between electric and oil motor power is the result. Oil motors are holding their own at present, but it is difficult to say what the ultimate issue is likely to be. The best internal-combustion engines at present sold in the Baku market are undoubtedly those of British make. Their only disadvantage is in price, which is comparatively high. Foreign competitors, by having the heavier and coarser parts manufactured in Russia (payment of freight and duty on which are consequently avoided), and by importing only the more intricate and flexible parts, are able to furnish this class of machinery to the Baku market at lower prices than British manufacturers. It would be advisable, in Mr. McDonell's opinion, for British manufacturers intending to do business with Baku in motors of the description referred to, to make several practical trials and tests with crude oil actually received from the Baku fields. Internal combustion engines and motors would, says the Vice-Consul, also sell well in Trans-Caspia and the agricultural districts of the Caucasus, where they are much used for driving cotton machinery, mills, and irrigation plant. Excellent motors are now made entirely in Russia. They are, of course, cheaper than the foreign-made article, and have met with certain success in the Baku market.

Railway Accidents in 1911.—The Board of Trade have just issued a summary of accidents and casualties reported as having occurred on the railways in the United Kingdom during the past year. The number of persons killed and injured was as follows: Passengers, from accidents to trains, rolling stock, permanent way, &c., 14 killed, 468 injured; by accidents from other causes, 92 killed, 2,257 injured; from accidents to trains, five servants of the company were killed and 115 injured; and by accidents from other causes 385 were killed and 5,196 injured. There were 84 persons killed and 38 injured in passing over railways at level crossings; 462 persons, classified as trespassers (including suicides), were killed and 124 injured; and 28 persons on business at stations and others not coming under the above classifications were killed and 139 injured. The total number of persons killed was 1,070, and the number injured 8,345. The total for 1910 was 1,062 killed and 8,342 injured. In addition to the above the railway companies have reported to the Board of Trade the following accidents which occurred during the year upon their premises, but in which the movement of vehicles used exclusively upon railways was not concerned, namely six passengers, 56 servants of the companies or contractors, and 27 other persons killed, and 767 passengers, 22,537 servants, and 609 other persons injured, making a total in this class of accident of 89 persons killed and 23,913 injured, as against two passengers, 37 servants and 20 other persons killed and 759 passengers, 20,419 servants and 590 other persons injured in 1910, a total of 59 persons killed and 21,768 injured.

Mineral Production of Germany in 1911. — The "Deutscher Reichsanzeiger" (Berlin) publishes a provisional statement of the mineral and metal production of Germany and Luxemburg in 1911. These are given, along with the figures for the preceding year, in the following table:

	1910.		1911	
	Quantity.	Value.	Quantity	Value.
Minerals—	Metric tons.	1,000 marks.	Metric tons.	1,000 marks
Coal	152,827,777	1,526,604	160,747,580	1,572,769
Lignite	69,547,299	178,618	73,760,867	183,357
Petroleum ...	145,168	10,146	142,992	10,045
Iron ore ...	28,709,700	106,809	29,879,361	114,531
Zinc ore	718,316	45,185	699,970	49,324
Lead ore ...	148,497	14,064	140,154	14,132
Copper ore ...	925,957	23,406	868,600	21,531
Manganese ore	80,560	981	87,297	1,048
Products of reduction works—				
Pig iron	14,793,604	802,851	15,280,527*	850,511
Zinc	221,396	99,399	235,776	114,359
Lead, pigs, bars, &c.	159,851	42,042	161,287	44,152
Copper, refined.	34,926	42,389	37,452	44,014
Tin	11,394	31,272	12,412	39,496
Products from pig iron—				
Castings, second fusion	2,651,612	474,363	2,722,028	495,561*
Wrought iron and steel—				
Crude blooms, mill bars and cement steel for sale...	26,039	2,873	21,556	2,479
Finished wrought-iron products...	436,265	65,500	316,842	46,889*
Cast iron and steel—				
Ingots for sale ...	708,778	59,680	740,732	64,256
Slabs, billets, &c., for sale	2,262,963	198,749	2,601,606	231,856
Finished cast-iron products	9,721,025	1,373,676	10,703,535*	1,510,016

* Returns incomplete. Metric ton = 2,204·6lbs.; Mark = 11·8d.

METAL QUOTATIONS.

TUESDAY, APRIL 16TH.

Aluminium ingot	67/	per cwt.
,, wire, according to sizes, &c. ......from	102/-	,,
,, sheets ,, ,, ... ,,	120/-	,,
Antimony .... £27 -/- to	£27/10/-	per ton
Brass, rolled	8½d.	per lb.
,, tubes (brazed)	10¼d.	,,
,, ,, (solid drawn)	9d.	,,
,, ,, wire	8⅝d.	,,
Copper, Standard	£70/10/	per ton.
Iron, Cleveland	54/1½	,,
,, Scotch	60/1½	,,
Lead, English	£16/13/9	,,
,, Foreign (soft)	£16/6/3	,,
Mica (in original cases), small	6d. to 2/	per lb.
,, ,, ,, medium	2/6 to 4/-	,,
,, ,, ,, large	4/6 to 8/6	,,
Quicksilver	£8/12/6	per bottle
Silver	26$\frac{11}{16}$d.	per oz.
Spelter	£25/15/	per ton.
Tin, block	£197/10/-	,,
Tin plates	14/3	,,
Zinc sheets (Silesian)	£29/	,,
,, (Stettin; Vieille Montagne)	£28/15/-	,,

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1910.

Direct acting pumps. Shore. 26302.
Process for the manufacture of alloys. Weiss. 29904.

1911.

Rock drilling engines. Leyner. 1933.
Internal combustion engines. Downie. 6119.
Nut lock. McGavock. 7031.
Screw propellers. Hamilton. 7044.
Operation of centrifugal pumps. Akt. Ges. Brown, Boverie, et Cie. 7065.
Spinning machine for corrugating metal tubes. Pankhurst. 7150.
Machinery for operating liquid pressure engines or auxiliary hydraulic motors. Internationale Rotations Maschinen Ges. 7287.
Fuel supports for gas producers. Koller. 7330.
Hydraulic briquetting machinery. Denison & Korte. 7365.
Carburetters of liquid fuel furnaces. Kirby Banks Screw Company, and Edwards. 7451.
Reciprocating pumps. Callender's Cable and Construction Company, and Anderson. 7590.
Process and device for the production of alloys by the employment of metal, fusible at high temperatures only. Titan Ges. and Meissner. 7663.
Composition or flux for brazing cast iron. Herring. 7730.
Carbide cartridges and acetylene generators. Wakefield and Carbic, Ltd. 7776.
Bolts and nuts. Mackenzie Kennedy. 7781.
Metallic alloys. Duke. 7863.
Treatment of moulds for making metal castings. Poulson. 8180.
Mechanical stokers. Wood. 8239.
Method of automatically obtaining varying quantities of steam for heating purposes from steam engines. Hartung. 8312.
Gas firing of furnaces. Forster. 8316.
Annealing or heat treatment of metals and alloys. Hughes. 8362.
Inverted tooth or silent driving chains. Renold, and Hans Renold Ltd. 8736 and 8737.
Brake mechanism for tramcars. Spencer & Dawson. 8740.
Steam superheaters for locomotive and marine boilers. Luard and Robinson. 9165.
Detachable joints for driving chains. Renold, and Hans Renold Ltd. 9326.
Carburetters for internal combustion engines. Thompson. 9504.
Piston pumps. Bellot & Bellot. 9543.
Rotary pumps, blowers, and motors. Austin. 9689.
Apparatus for separating oil and steam from the water of condensation. Clarkson. 9883.
Converters for the manufacture of steel. Soc. Anon. des Forges et Fonderies de Montataire. 10666.
Combination single and double-action reversible one-cylinder pump. Boonzaier. 11068.
Treatment of producer gases. Vickers, Ltd., and Imrie. 11940.
Vice. Parks & Selson Engineering Company. 12224.
Pressure gauges. Schaffer & Budenberg, Ltd. 12944.
Carburetting or vaporising apparatus. Terry. 13130.
Feed mechanism for reciprocating machine tools. Shanks. 13173.
Welding and cutting burners. Hendler. 13399.
Equilibrium float valve for use in steam traps, constant water feed boilers, high and low, water alarm, regulating feed to water tanks. Hough. 13463.
Method of treating manganese steel. Kohlhaas. 13478
Moulding machines for foundry use. Martin. 13955.
Liquid fuel burners. Pearson, Cox, and Pearson & Cox, Ltd. 14341.
Metallic alloy. Duke. 15740.
Regulator cocks for steam heating systems. Tcherniakotsky. 16499.
Chucks for use in grinding or similarly working upon toothed gear wheels. David Brown & Sons (Huddersfield), Ltd., and Bostock. 16976.
Automatic timing apparatus particularly applicable to the regulation of the stoking of boiler furnaces. Evershed & Vignoles, Ltd., Needham, and Kilroy. 17144
Fluid pressure engines and pumps having rotating cylinders. Redrup. 17154.
Steam collectors for superheaters. Cole & Hoffmann. 17990
Rotary engines. Stercq. 18388
Apparatus for suspending the action of spring pawls in wheel gear. Trinks. 18961.
Means for supplying air to boiler furnaces. Muir-Vincent Smoke Consumer and Fuel Economiser Company. 20118.
Steam boiler superheaters. Vaughan. 21824.
Safety gear for lifts. Foster. 21899.
Compression relieving devices for internal-combustion engines. Guest. 22896.
Nut lock. Berckenkamp & Schwarz. 23812.
Automatic railway signalling apparatus. De Braam. 24128 and 24237.
Apparatus for breaking pig iron. Johnson. 26418.
Variable speed friction gearing. Kitchen & Storey. 26459.
Process for the recovery of tin from ores. Richards. 26614.
Variable-speed gearing. Moore. 26871.
Interrupting devices for internal combustion engines. Robert Bosch. 26929.
Joints and couplings for pipes and tubes. Garner. 27636.
Two-stroke cycle internal-combustion engines. Geb. Sulzer. 28698.

1912.

Valveless suction and force pump. Eeles. 2398.

ELECTRICAL, 1911.

Electromagnetic ore separators. Steinert & Stein. 1619.
Self regulating dynamos. Midgley & Vandervell. 2158.
Suspension of electric conductors. Allgemeine Elektricitäts Ges. 4623.
Electric motor controllers. Edwards & Stait. 6996.
Devices for suspending, lowering, and hoisting electric lamps. Johnson & Phillips, Ltd., and Brockie. 7092.
Electric meters. Hill. 7522.
Telephone exchange systems. Clement. 7611.
Dynamos for generating high frequency electric currents. Ballsillie. 7749.
Controlling electric motors. Holmes & Holmes. 7785.
Continuous electric switch. Johnson. 7872
Type printing electric telegraphs. Belin. 9556.
Electric lifts. Marryat. 10848.
Electric signal systems for railways. British Thomson Houston Company. 12579.
Magneto-electric machines for ignition purposes. Electric and Ordnance Accessories Company, Garner, and Collins. 13246.
Intercommunication telephone systems. Roose & Finlay. 13601.
Telephone exchange systems. Aitken and British Insulated and Helsby Cables, Ltd. 15503.
Telephones. Gwozdz. 18235.
Common battery telephone systems. Aktiebolaget L. M. Ericsson and Co. 21924.
Appliance for obtaining static electricity from either positive or negative pole of the secondary of an induction coil. Blake. 22660.
Electrically heated thermal accumulator. Rittershaussen. 27843.

1912.

Switching apparatus for telephone exchange systems. Clement. 3497.

Institute of Metals.—At a meeting of the Birmingham section of the Institute of Metals, held on Tuesday last, Mr. W. H. A. Robertson read a paper on "Cold Rolling Mills." He described the differences between the cold rolling processes in various countries and those in England, and showed illustrations of the latest types of German and English mills.

World's Largest Telescope.—For some time past opticians have been engaged in making the glass mirror for a reflecting telescope, having the largest aperture ever attempted. The mirror is to be 100in. diam., 13in. in thickness, and $4\frac{1}{2}$ tons in weight. This gigantic telescope is intended for the Solar Observatory, Mount Wilson, California. The enormous difficulties which are encountered in the successful casting of such a large disc of optical glass free from defect and blemish have delayed its mounting, and it has more than once had to be recast and begun afresh. For more than half a century the record in size for a telescope has been held by Lord Rosse's reflecting telescope, mounted in Ireland, and having a mirror 72in. diam., but this was made of polished metal, instead of the now usual method of glass with a coating of silver. At the Mount Wilson Observatory there is already in use a reflecting telescope with a diameter of 60in., but the mirror of this telescope, being of silvered glass, and such mirrors being superior to those made of metal, this instrument has given better results than Lord Rosse's reflector.

The Mechanical Engineer

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Superheating in Locomotives.

THE application of superheating to locomotives has passed through its experimental stage with comparative rapidity. It is only a few years since experiments in this direction were first instituted in this country, though they had been preceded for some time on the Continent, and it was not until Mr. Hughes, the chief mechanical engineer of the L. & Y. Railway, presented his paper* to the Institution of Mechanical Engineers in March, 1910, that reliable data as regards British practice were available. Mr. Hughes' investigations were made to some extent with the object of determining the relative advantages and disadvantages of compounding and superheating. Although compounding has been in operation on several lines for a considerable period and economies in certain classes of service demonstrated, the concensus of opinion has been far from universal as regards its merits or the extent to which its adoption was desirable. The object of both compounding and superheating in the main is ultimately the same, viz., economy of fuel in working, but economy is a term much more difficult to express with locomotives than it is with stationary engines where pounds of coal or pounds of steam per indicated horse-power per hour carry a meaning which permits of fairly universal application. With locomotives the case is different—weight of fuel per train mile, per ton mile, per indicated horse-power per hour, or per unit of time merely bear different interpretations as regards advantage, according to the nature of the service. Speaking generally, it may be stated that compounding on the whole has made very little headway and the general experience and tendency of modern practice would seem to show that even where compounding has been adopted it will eventually be supplanted by superheating. Both methods seek to secure economy by increasing the range of expansion, but whereas in compounding two or more cylinders are necessary for expan-

* See "The Mechanical Engineer," March [illegible] pp. 332, 335, and 380.

sion, with superheating the end is sought in one cylinder. It is true superheating and compounding might be combined as in stationary practice, but the complication entailed is generally conceded to be too inconvenient for locomotive practice and the end is therefore sought by one or the other system. Hence in a superheater locomotive the higher rate of expansion means a larger cylinder and an earlier cut-off. Two main systems, "high superheat" and "low superheat," are in use. In the former the superheating is effected mainly by live heat (*i.e.*, from gases that are in contact with boiler heating surface), and carried to 250°-280° Fah. above the temperature of the saturated steam, while in the latter, the superheat, derived mainly from the waste heat in the smokebox, is seldom more than 100° Fah. over saturation point. The wide range of load in locomotives affects to some extent the economy of superheating, inasmuch as it springs from the prevention of initial condensation, and as this latter increases with the number of expansions it follows that a superheat necessary to prevent initial condensation with an early cut-off would be higher than was necessary if the cut-off were later and thus lead to loss of heat in the exhaust. On the other hand, the practical difficulties which arise with varying rates of cut-offs in compounds are avoided. Mr. Hughes in summarising his experiments arrived at the conclusion that on the whole superheating is more advantageous with passenger than with goods engines, whereas the reverse is the case with compounds, whose economies as compared with single engines are more pronounced when the load is variable and intermittent, as it is when engaged in shunting, light running, or ballasting service, or when detentions are frequent. As regards actual coal economy, Mr. Hughes did not find that any special advantage could be placed to the credit of either, but speaking broadly his conclusion was that while compounding was advantageous in slow-speed goods traffic, superheating was more suitable for passenger service with constant loads, and it is mainly in connection with such service that superheating is now being applied on the main lines and about which there appears to be a general agreement amongst all locomotive engineers as to economy, though the precise measure of this, as we have explained, is difficult to express in figures permitting of universal application. The economies range from 10 to 20 per cent. of coal and from 20 to 30 per cent. of water. The latter item is important and often counts for more on railways than in stationary practice. Already there are about 1,000 superheated locomotives in service or under construction on British railways. In probably about 40 per cent. of these the Schmidt type is being used and is the one which has received widest acceptance both here and on the Continent, where superheating, it should be stated to the credit of German engineers, was first initiated and where it is becoming almost universally adopted for all classes of service. There are many designs of locomotive superheaters, and patent rights can only apply to particular arrangements. The Great Central Railway are adopting a design of the chief mechanical engineer of the company, although they have a number of engines equipped with the Schmidt type, while the Great Western are using the Swindon type, the patents of which have been acquired by the Schmidt Company. The London and South-Western are experimenting with a superheater of the Trevethick type in which the temperature is only a little in excess of that of saturated steam, while a superheater of a similar type is also being tried on the North British Railway along with the Schmidt arrangement. It is too early as yet to permit of comparisons between various designs and, having regard to their common principle, it is probable opinions will always differ as to their individual merits owing to personal interests involved. There is no doubt, however, that locomotive superheating has come to stay, and will to some extent give this type of motor a further lease of life in any struggle that the future may bring between it and rival methods of traction.

INGLIS CONTROLLER FOR WINDING ENGINES.

AT the annual meeting of the Mining Institute of Scotland recently held at Glasgow, Mr. James Black read a paper on "Overwinding Prevention and Controlling Gear for Colliery Winding Engines, with a Description of the 'Inglis' Controller." An ideal controller should, he observed, be capable of performing the following operations: (1) The prevention of an overwind or an underwind; and (2) to control the speed of the cages throughout the entire wind. Most controllers in use were very reliable as regards the prevention of overwinding, but the same could not be said of them as regards underwinding, which presented a more difficult problem. In the raising of coal there was a practical limit beyond which it was not desirable to reduce the cage speed when nearing the completion of the wind, from which it appeared that a controller arranged to permit of coal winding could not prevent an underwind. In the Inglis controller dangerous overwinding was prevented, during the time when men were being raised or lowered, by the engineman making a simple adjustment on the controller, and the author considered that some such alteration would be essential in all controllers designed to prevent underwinding when men were being lowered into the mine. A controller which prevented overwinding would also prevent underwinding, provided that the passage of the cage was unobstructed for some distance below the lowest hanging-on point in the shaft. This might seem an easy way out of the difficulty, but it was not, as keeping a pit open for some distance below the hanging-on point presented several difficulties, which were well known. Accidents resulting from the use of controllers were likely to occur, unless great care was taken when fitting and adjusting the brake which was brought into operation by the controlling gear. When a winding engine was running at a high speed, the large mass comprising the moving parts contained a great amount of kinetic energy, which, if arrested quickly by the brake, caused a considerable strain on the machinery. The practice of using a brake wheel in conjunction with a controller was not to be recommended, as a terrific strain was thrown upon the keys which secured the wheel to the drum shaft. The most efficient and safest method was to have a brake rim fitted on each drum. There was a tendency at the present time to overload the brake lever with the object of stopping the engine as quickly as possible after the controlling gear came into operation. This was a mistake, and only served the purpose of subjecting the machinery to a much greater strain than need be.

The controller had been tested exhaustively by the engineers and officials at the Holytown Colliery, Lanarkshire. The following tests, among others, had been successfully carried out: (1) The engine was started with the larger drum unwinding, and full steam was admitted. When the engine reached 70 revs. per minute at the eighth revolution, the governor acted and brought the engine to a stop in three revolutions. (2) The engine was allowed to run at its predetermined speed of 60 revs. per minute without any checking, when the governor catch came into contact with the higher stepped part of the rack and brought the engine to a stop in 2¼ revolutions. (3) The engine was started in the wrong direction with full steam on, and it was almost instantly brought to a standstill. The height of the cage above the pit head plates was found to be 3ft. 1in. This height could, of course, be increased by an adjustment of the set pin. (4) Several tests were made in order to ascertain the efficiency of the controller in preventing dangerous underwinding. It was found that whenever the speed of the rope exceeded 350ft. per minute at the beginning of the last revolution of the wind, the controller acted instantly and stopped the engine.

A DISASTROUS LOCOMOTIVE BOILER EXPLOSION.

THE accompanying photo views, for which we are indebted to our American contemporary "Power," show the effects of what is probably the most disastrous explosion of a locomotive boiler on record. The explosion occurred to passenger engine No. 704, of the Southern Pacific Railroad, while standing in the yard at the railroad shop at San Antonio, Texas, on Monday morning, March 18th, and resulted in 28 employés being killed and more than 40 others injured. Part of the roundhouse collapsed, several small buildings were demolished, and the engines in the roundhouse were badly damaged. It is estimated that the monetary loss will reach the sum of £40,000. According to our contemporary, the probable cause of the explosion was excessive steam pressure. This belief is substantiated by the testimony of employés, who stated at the Interstate Commerce Commission investigation that a workman had screwed down the safety valve just previous to the explosion, and that the oil burners had been extinguished and then re-lighted shortly before the accident. Referring to the illustrations, Fig. 1 shows the wrecked engine and roundhouse. All that is left of the boiler shell is the crumpled and torn sheets, shown beyond the tubes. The only part of the boiler which remains is the extension front, shown in the foreground, and the mass of tubes, some of which are still intact in the front tube sheet. Fig. 2 shows the engine frame after the wreckage had been cleared away from around it, and gives a view of the boiler ready for the Government inspector. The rear driving wheel was blown clear of the shafting, but was prevented from further flight by the side-rod connection. The force of the explosion tore the steel boiler plates into shreds, which, from the condition of the riveted joints, which are uninjured, indicates that the internal pressure must have been excessive. Figs. 3 and 4 illustrate several parts of the exploded locomotive, and afford a good idea as to the extent of the damage to the locomotive. It would appear that the explosion was more severe at the firebox end of the boiler, as the front end was carried only a short distance, while the firebox end was thrown almost at right angles to the original position of the engine. That the boiler tubes and front extension were not thrown a greater distance is doubtless due to the giving way of the boiler shell in its entirety at practically the same moment. The photographs indicate that the initial rupture occurred in the firebox, and was probably due to the failure of the staybolts, which were in many instances broken in two in the centre.

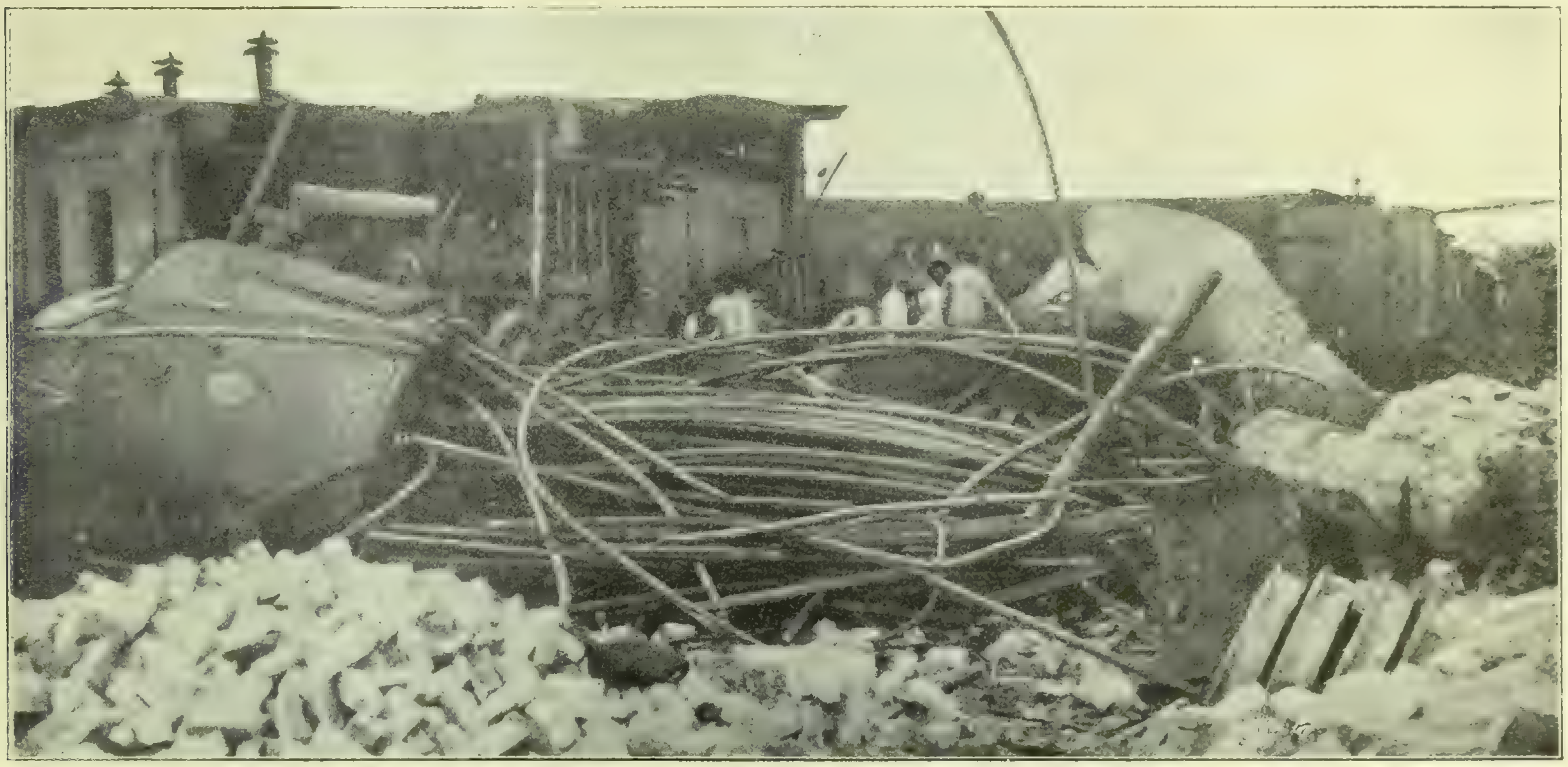


FIG. 1.—A DISASTROUS LOCOMOTIVE BOILER EXPLOSION.

STEEL RIVETS.*

BY D. J. CHAMPION.

RIVETS are the most important articles you use. On their trustworthiness, life and property depend, and for this reason too much importance cannot be attached to guarding the quality and looking after the workmanship in order to ensure, as nearly as possible, perfection along these lines. Improvements in the quality of rivets have kept pace with the improvements in the manufacture of steel, and excel them to some extent. Twenty years ago, steel rivets were practically unknown, and the conservative boilermaker would throw his hands up in horror even at the mere mention of them. So great was the antipathy against them that one of the leading manufacturers who was then successfully producing steel rivets was afraid to call them by their proper name, "steel rivets," and sought to appease the prejudice against them by using the misnomer, "semi-steel."

The word "steel" was formerly used to indicate hardness and brittleness; that is, it conveyed the idea of an unyielding metal, principally intended for razors, swords, chisels, ploughshares, gun barrels, or other articles of like hardness that required a very good strong, stiff material that would wear well. With the advent of basic open-hearth steel, however, a metal was placed on the market that was a surprise even to the most sceptical. The metallurgist and the steel maker worked hand in hand to make this metal thoroughly reliable, and the result to-day is that good, soft basic open-hearth steel cannot be surpassed for the manufacture of good rivets or other articles requiring the maximum of strength and toughness.

The great desideratum long sought for, viz., low sulphur and low phosphorus, was attainable for the first time by the use of this process of steel manufacture. So great have been the improvements in the manufacture of this steel, and so responsive under intelligent management have been the furnaces and rolling mills for the manufacture of it that it is put on the market to-day as a very reliable product at a reasonable price.

For the enlightenment of those who still lean toward iron in preference to this steel, let it be said that this steel is over 99 per cent. pure iron, and much more reliable for the production of rivets than the best Norway iron. This is not meant to convey the idea that good iron, either Norway or best charcoal bloom, has not its uses for certain purposes, for instance, where the action of the contents of a vessel has a tendency to oxidise the metal to such an extent that more is expected

* Abstract of paper read before the American Boiler Manufacturers Association, March 13th, 1912.

of the rivets than of the plates into which they are driven. But what I contend is that for all other purposes where rivets are used mild steel is superior to iron.

Those who will recall their troubles of years past when they used charcoal-hammered iron for boiler plate and the best iron for rivets, can now appreciate the truthfulness of my assertions in regard to the improvements made in the manufacture of steel. Steel to-day in the shape of boiler plate, bars, shapes, or rivets, is ideal, compared with the product put before the public 20 years ago. Failures in the use of it are now very rare. The steel maker knows how to make it, the workman understands better how to handle it, and there is no question but that their work will come up on final test to their highest expectations. In line with the progress of the age in which we live, more and more is expected of every piece of power machinery manufactured, and if it were not for the improvements made in the manufacture of steel it would be a physical impossibility to accomplish what we are accomplishing to-day.

Fig. 2. A Disastrous Locomotive Boiler Explosion. (See page 507.)

A structure is no stronger than its weakest member, and this applies to the rivets in a structure in an emphasized sense. Did you ever stop to consider that rivets, of all the articles you use, are often tested to the death, and even then are expected to stand up and fill their place in the structure just as well as the plates into which they are driven, though these plates have not been heated or hammered or treated one-quarter as harshly as the rivets that hold them together? In other words, to use a homely expression, good rivets are expected to be "fool proof," and if not "fool proof" they are often condemned. Would any of you tolerate your flange turner to hammer on a plate when it is blue? Yet very frequently you allow your rivet drivers to hammer on rivets until they are "black and blue," and condemn them if unfortunately the heads come off. Rivet making is an art, and a few of us have shown a disposition to acquire that art and work faithfully to gain our ambitions along these lines. Suffice it to say that if "eternal vigilance be the price of success," then the rivet field offers ample opportunities to the painstaking and ambitious.

Too much importance must not be placed on the very interesting but misleading test of nicking and bending. It is a test intended for iron, not steel. Good iron is fibrous in its structure and will stand the test admirably, whereas steel may be of a granular structure and consequently should not be expected to stand this test like iron. If you should be in doubt about the superiority of one steel rivet over another, and you are inclined to test out the rivet by nicking and bending, I would suggest that you subject the two rivets to a heat suitable for driving, and then allow them to cool until both are entirely cold. Then nick and bend, and you will find that the good rivet will show a good, clean fracture, free from crystallisation, but it will not bend and show a coarsely fibrous fracture like iron.

The nicking and bending test should never be used on a steel rivet to show fibre, for the structure of a good steel rivet may be finely granular instead of fibrous. Fine fibrous structure is, of course, noticeable in a steel bar of small diameter after coming from the rolls. At this stage the bar, under the nicking and bending test, would bend flat on itself without breaking and show a finely fibrous structure. But we should not expect to get this result after the double heating which must be given the bar in order to make the rivet. The United States Government realises this fact, and does not require rivets for its use to stand the nicking and bending test. If made at all, it is only to show the appearance of the fracture.

Under the caption of "experiences," I am led to reproduce here a few suggestions which I consider of sufficient merit to have them copyrighted. They are as follows:—

(1) Hold some reliable maker responsible for the quality and workmanship of the rivets you drive.

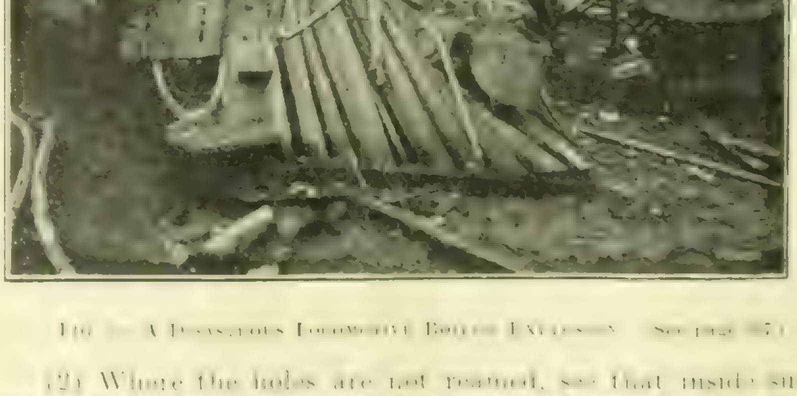


Fig. 3. A Disastrous Locomotive Boiler Explosion. (See page 507.)

(2) Where the holes are not reamed, see that inside surfaces of the holes are parallel to each other without undue overlapping.

(3) Heat your rivets intelligently, grading the degree of heat to conform to the work you are doing, allowing hand-driven rivets to come to an almost white heat; pneumatic-

driven rivets to come to a bright cherry red; and hydraulic-driven rivets to a dull cherry red; bearing in mind at all times the amount of pressure your machine is capable of putting on the rivets at the point of upset, and regulating the heat accordingly—the lower the heat, the greater the pressure—relaxing the pressure when the rivet is cold, or nearly so. Such rivets will fill the holes and avoid undue shrinking and, possibly, caulking. When high-pressure work is being riveted, ream the holes $\frac{1}{32}$in. full only, as tighter work can then be done.

(4) Never continue hammering (on either end of the rivet) until it is blue.

(5) Never try to fill a hole with a rivet smaller than the regular diameter required for such hole, which in all good work is $\frac{1}{32}$in. larger, bearing in mind that steel expanded by compression (as in the case of a rivet shank expanded to fill the hole that is more than $\frac{1}{16}$in. larger) is materially weakened in all its qualities of strength. Therefore, the closer the fit, the tighter and stronger the joint.

(6) Never use heavy pneumatic tools on small rivets. In other words, never use a tool out of proportion to the size of the rivet.

(7) Never drive a cold-made rivet cold without first annealing.

(8) Never introduce a high-pressure blast into your rivet-heating furnace unless you break the flame by a fire wall, and even then a graduating valve should be used, reducing the pressure so as not to be over 15lbs., bearing in mind that only sufficient rivets be placed in the fire as can be conveniently handled by the driver without allowing them to soak too long, or becoming scaled.

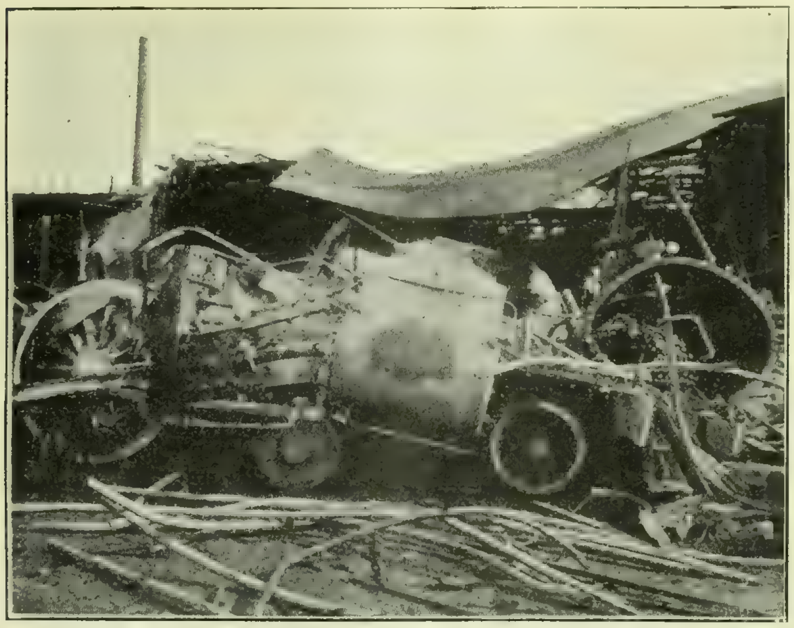


FIG. 4.—A DISASTROUS LOCOMOTIVE BOILER EXPLOSION. (See page 507.)

(9) Never allow your rivets to soak in the fire, either during the noon hour or over night. If a cessation of work is contemplated, draw them out of the fire, but avoid replacing them in the fire. If they have had too much heat previous—use new ones.

(10) Never pass up to the driver a rivet showing that the metal therein started to melt. Such a rivet will cause trouble ultimately, as it is liable to remain loose in the hole, or lose its head if caulking has to be done.

If you follow out these suggestions faithfully, you will never have trouble with good steel rivets.

Belgium Blastfurnaces.—The number of blastfurnaces in activity in Belgium at the commencement of April was 45, while five furnaces were out of blast at the same date. The number of furnaces in blast at the commencement of April, 1911, was 41, while six furnaces were out of blast. The production of pig in Belgium in March was 188,320 tons, as compared with 171,510 tons in March, 1911. The aggregate output for the three months ending March 31st, this year, was 555,650 tons, as compared with 505,500 tons. The total of 555,650 tons was made up as follows: Puddling pig, 8,950 tons; casting pig, 23,600 tons; and steel pig, 523,100 tons.

THE DIESEL OIL ENGINE, GEARED TURBINE, AND SUCTION GAS ENGINE.*

RELATIVE POSSIBILITIES AS COMPARED WITH THE RECIPROCATING ENGINE FOR MARINE PROPULSION.

SUCTION GAS ENGINE.

BY A. C. HOLZAPFEL.

(Concluded from page 462).

I WISH to congratulate your committee on the happy conception of the idea to compare power installations of equal capacity for a vessel of given size, as it is in this way only that the practical advantages of each system can be brought home to the general public. The vessel for which this installation is required is assumed to have the following dimensions:—

	Feet.	Inches.
Length overall	412	0
Length between perpendiculars	400	0
Breadth extreme	52	0
Depth moulded	29	0
Draught	26	1
Deadweight	8,465 tons.	
Displacement	11,560 tons.	
Speed at sea	$10\frac{1}{2}$ knots.	
Indicated horse-power	2,600.	

If fitted with reciprocating engines and steam boilers, this vessel will have an engine room about 48ft. long; and to obtain the usual reduction in registered tonnage for engine spaces, I propose to maintain the same length of engine room. I also propose to give the vessel twin-screw engines, on account of the greater security, and to have everything connected with her power installation as nearly as possible in duplicate. I propose to start the main engines by electricity, and to use no compressed air. I also propose to have all auxiliary machinery, such as steering gear, winches, tar extractors, pumps, and fans electrically driven.

Producer Plant.—I propose to have four producers about 5ft. 6in. square by 15ft. high. These would each be capable of giving sufficient gas for 750 h.p., so that the total gas plant would be suitable for 3,000 h.p. These four producers I propose to place in a recess 15ft. by 15ft. amidships, abaft the fore engine room bulkhead. They would rest either on the tank tops or on a platform a few feet above the keel. The recess would be completely shut off from the engine room and other parts of the vessel by gas-tight bulkheads, but would be entered from engine room by a gas-tight door. It would reach right to the upper bridge deck, but just on the level of the producer tops there would be a platform from which the coals would be filled into the hoppers. At the sides there would be a grating allowing of ample ventilation, and there would be another grating level with the upper bridge deck. The bunker coals would be in 'tween deck side, bunkers reaching to the sides of the recess, and there would also be a spare bunker in the lower hold at the front of the fore engine room bulkhead, from which the coal could be raised to the coaling platform by an electric hoist. Of course, the gas plant is intended to use bituminous coal for fuel, and each producer would, therefore, be fitted with four openings at the top for stoking. These would be closed by the usual perforated cannon-ball arrangement; but to prevent leakage of gas, a screw-down cap would be fitted over each cannon ball and would be closed when the openings were not in use. All the pipes leading from the producers to the coolers would be in the middle of the recess, so as to be easily accessible. The cooling towers would be placed on a platform just above the water level and would be four in number, about 7ft. diam. and 20ft. high. By placing the coolers or scrubbers above the water level, the exhaust water can flow overboard on either side by gravitation. They would be filled either with earthenware tubes or earthenware balls of special design. The top portion of each cooler would be a water tank about 3ft. deep. From the coolers, the gas would pass to two centrifugal tar extractors electrically driven, each taking about 25 h.p. So far as I am aware, perfect gas is being obtained from

* A discussion introduced April 1st, 1912, by E. L. Orde, the Hon. Sir Charles A. Parsons, K.C.B., F.R.S., R. J. Walker, and A. C. Holzapfel, before the North-east Coast Institution of Engineers and Shipbuilders

bituminous coal by means of these tar extractors which have now been fitted in many hundreds of installations. From the tar extractors the gas would pass under slight pressure induced by the fans of the tar extractors to two dry scrubbers, and thence to the engines. The water vapour for the gas would be obtained by a Holzapfel patent duplicate vaporiser fitted to the exhaust. This vaporiser consists of two cylinders into which sea-water is pumped under slight pressure and through which the exhaust gases pass, through tubes about 2in. diam. There is a constant drip of brine from these cylinders equal to about half the water pumped in. A small quantity of kerosene is also pumped in, and while preventing or reducing incrustation, it helps, after vaporising, to enrich the gas in the producers. The exhaust can be so arranged as to pass through either or both of these cylinders, and they are both fitted with hand holes and manholes for removal of incrustation, the idea being to clean one if necessary while the other one is in use. They also act as efficient silencers without reducing the power of the engine.

Gas Engines.—For prime movers I propose to have two 6-crank gas engines, each of about 1,400 b.h.p. Owing to the somewhat elastic platform on board ship, I consider six cylinders most essential, as otherwise vibration is too considerable. While there would be no difficulty in getting 1,400 h.p. into six or less cylinders, I propose in this case to employ two tandem engines each of 12 cylinders, the cylinders being small enough to make piston cooling unnecessary. The cylinders of these engines would be about 20in. diam. and the stroke 18in. At 300 revs. per minute, this would give a piston speed of 900ft. per minute.

The diameter of the upper row of cylinders can be increased and that of the lower row reduced in order to permit of the withdrawal of the piston through the upper cylinder. Diameters of 22in. have been successfully used without piston cooling. In front of each engine I would place a dynamo of about 90 h.p., and in front of the dynamo again an oil or paraffin vertical engine about 100 h.p. These latter would be used in port to generate the necessary electric power for eight winches and for lighting and ventilation. Either or both the dynamos would be driven by the main engines while at sea, but as the power required for the steering gear and tar extractors, fans, pumps, and lighting would probably be under 80 h.p., only one dynamo would be in gear while the vessel is at sea and the other one would remain as a stand-by. I propose to start the main engines by means of the dynamo and oil engines. This would be quite easy as it will be seen later on that there would be no load on the engines when they are started.

As regards ignition, either high and low tension Bosch magneto, or else low-tension Bosch magneto and Lodge accumulator ignition would be used. It is desirable to have two ignitions and separate sparking plugs to each cylinder.

Transmission Gear.—The gas engines not being reversible, I propose to fit to each engine a Fottinger transformer, so adjusted as to reduce the revolutions from 300 to 100 on the propeller shaft. Sufficient has been written and said about the Fottinger transformer to make a description of this superfluous. My own experience with the transformer on board the "Holzapfel I." is a perfectly satisfactory one, and its rapidity of action is remarkable, while practically no attention to it is required by those in charge.

One of the advantages of the transformer to which I should here call attention is, that when the lever of the transformer is placed at neutral, the prime mover, or gas engine, will run without load. It is therefore possible to start each gas engine with the 100 h.p. oil engine at the fore end of the dynamo. A further advantage is that when the transformer stands at neutral, the propeller shaft can revolve freely, enabling, for instance, an auxiliary sailing vessel or yacht to sail without any drag from the propeller. The fact that the propeller runs loose when the transformer stands at neutral, will also make the transformer eminently suitable for war vessels, which frequently have to run at cruising speed. For such vessels the power necessary for cruising speed can, for example, be delivered to one propeller in the middle, while the side turbines, which may be made more powerful than the middle one, are at rest, and the side propellers by means of the transformer can freely revolve while the middle propeller alone is working. I consider the transformer would absorb about 12 per cent. of the total power delivered by the gas engine, and assuming that at sea the gas engines produce 2,800 h.p. less 100 h.p. absorbed by one dynamo, and deducting 12 per cent. from the remaining 2,700 h.p., the transformer would deliver about 2,376 b.h.p. to the propeller shafts, which are fully equal to the 2,600 i.h.p. stipulated by your committee. The cost of this power would be at the rate of nine-tenths of a pound of bituminous coal per brake horse-power per hour, a rate freely guaranteed by gas-engine builders. This is exactly 26½ tons per 24 hours continuous running on the 2,800 b.h.p. of the prime movers, and includes steering gear, lighting, pumps, and ventilation.

In regard to the quality of coal used, the Bower Gas Corporation claim that any quality of coal can be used in their producers, but on my part, I always discriminate in favour of a dry coal with not too strong a tendency towards caking. A coal as free as possible from slag should always be selected. As regards size, small and nuts are preferable and make a good mixture. Coal suitable for this purpose can generally be bought on the Tyne at an average price of 8s. or 9s. per ton, and in the Welsh ports at 1s. or 2s. more.

Space Occupied.—The length of 48ft. would be more than sufficient for the continuous length of the transformer, gas engine, dynamo, and oil engine. The latter would reach slightly beyond the recess containing the producers. There would be no lower bunkers in the engine space, but a 'tween deck bunker of considerable size would be fitted level with the top of the producers or about 20ft. 6in. above the top of the keel, giving a bunker of about 9ft. 3in. deep and about 18ft. wide on either side, practically the full length of the engine room. This would give about 180 tons of bunker space in each 'tween deck bunker. I take it that accommodation for engineers would be on a bridge deck above the 29ft. 9in. moulded depth of the vessel. The engine room would be exceedingly roomy and airy with this arrangement, and would also have a large amount of top light available.

Weight of Installation.—I estimate the weight of the gas plant, including cooling water in the tanks of the cooling towers and fuel in the producers, at about 220 tons; that of the two gas engines at 120 tons; two transformers, including water, at 60 tons; two oil engines and dynamos at 25 tons; pumps, electrical motors, gas pipes, coolers, &c., complete, at a further 50 tons; which makes a total of 475 tons.

As regards the cost, the two gas engines would cost about £7,500; two transformers, £4,000; gas plant complete, about £2,000; oil engines, dynamos, steering gear, electric winches, and windlass, about £3,200; total, about £16,700. These figures are based on estimates obtained by me some little time ago. It will be realised, first, that as regards fuel consumption, the gas engine is by far the most economical motive power for ships; secondly, that by its use in conjunction with electrical auxiliary machinery, great economies in fuel consumption would also be effected; thirdly, that although the cost of such an installation at the present time is about equal to, or somewhat in excess of, a steam installation of equal power, there is no doubt that when this class of work has been standardised and produced under stress of competition it can and will be supplied at considerably lower prices than the present steam-power installations.

Lastly, I would submit to this Institution that while oil has to be imported from abroad, and while oil strata cannot be measured, there is consequently no guarantee of a continuity of supply. Also, while the production of oil is under the control of a few powerful financial groups, one or two of which have in the past manifested strong monopolistic tendencies, we have, on the other hand, an unlimited supply of suitable coal in strata which have been carefully calculated by our geologists and which is produced under conditions of free competition.

Before concluding, I think it would interest the meeting if I referred to some of the improvements in gas-engined vessels which have suggested themselves to me from my experience with the "Holzapfel I." These relate almost exclusively to the gas plant.

Producers generally are lined with firebrick. Clinker readily forms on the firebricks, and has to be removed by stoking tools, when the bricks are apt to be broken or loosened. A different lining should be adopted, and I have suggested

steatite as a substitute, as clinker is not likely to adhere on a steatite surface. Experiments so far made have not been successful, probably owing to the quality of the steatite. I still consider that blocks of pure steatite will prove to be the best lining.

When the gas engines are suddenly stopped, gas is apt to develop in the producers. At such times a safety blow-off is opened. This is generally fixed low down on the gas-pipe leading from the producers to scrubbers, where it can be shut off by water entering the pipe. It should be fitted at the top of the gas pipe, where there is no danger of water shutting off the gas. The handles for opening the valves of this blow-off should be so arranged as to be near the throttle valve of the engines, in order that the engineer may open them the moment he has stopped the engine.

The pipes leading from producers to scrubbers should be so arranged that water cannot possibly enter into them while the ship is pitching and rolling about at sea, *i.e.*, they should slant downwards just before entering the scrubbers.

Scrubbers are generally filled with furnace coke. This is not suitable for a sea-going vessel and should be substituted by earthenware balls or tubes of good strength and of a design to give a maximum of cooling surfaces.

All the troubles and delays of the "Holzapfel I." were due to the inadequate appreciation of these facts in the beginning. All the faults have now been remedied and a useful but expensive lesson has been learnt.

I would finally submit that the gas engine and gas plant in their present form are capable of vast improvements, and are well deserving of the devotion of that brain energy and ingenuity which British marine engineers have in the past so successfully devoted to steam power.

SOME BRASS ALLOYS.

BY J. R. ANDERSON.

IN the last five years brass foundries have sprung up all over the country by the hundreds, owing to the greatly increased demand for brass castings of all kinds. Especially is the demand for plumbers' supplies and automobile factories very great. This being so, the writer gives some of the many useful compositions of brass now in use. The first thing I wish to call attention to is the melting of brass or copper, as therein is to be found a greater part of the trouble caused by bad brass castings, with pin holes, shrink holes, and spongy or hard spots. In any kind of furnace, air or blast or oil, the furnace should be well cleaned before starting the fire. It is good practice to let the fire get well started before putting in the crucible. If melting either copper or scrap, always fill the pot when placed in the furnace, then keep it full. If desirable to use flux, there is nothing better so far discovered than a handful of common salt, thrown into the crucible just as the copper or brass, as the case may be, commences to melt.

It is all-important, it matters not what kind of brass you are making, to attend to the melting closely. The melter should see to it that as soon as the stock commences to go down the crucible is kept full, and it is a great help to have rings to fit the top of the crucible, so as to put on more stock at a time. When the stock is melted hot enough, care must be taken that the metal does not burn. Particularly is this so when melting old brass, and the metal, either copper or brass, must be hot enough, because if cold metal is poured, pinholes or spongy places will show up in machining. In melting copper, the writer always had the best success when putting in the tin before taking the crucible from the furnace. After taking out the crucible, add the other compositions in the quantities desired.

A good brass for ordinary bearings or bushings is made with 70lbs. copper, 70lbs. old brass, and 10lbs. of tin.

Another good bearing metal is the following: Copper 90lbs., old brass 45lbs., tin 15lbs., zinc 5lbs., lead 5lbs.

A good phosphor bronze is made with copper 100lbs., tin 10lbs., zinc 5lbs., lead 4lbs.

Any of these will stand the test if properly mixed and melted.

For rings and pipe fittings an alloy of lake copper 75lbs., zinc 17lbs., tin 4lbs., lead 3lbs., is recommended.

A good brass for stove burners and other things in the same class is copper 80lbs., zinc 15lbs., lead 3lbs., tin 3lbs., phosphor-copper 4ozs.

A good straight yellow brass is copper 75lbs., zinc 25lbs., and tin 2lbs.

A mixture that will braze is copper 90lbs., zinc 18lbs., and lead 3lbs.

A white alloy for very small castings for typewriters and like machines is copper 60lbs., nickel 20lbs., zinc 20lbs., aluminium 3lbs.

A special red brass for sprinkler heads and other small castings: Copper 90lbs., zinc 10lbs., tin 3lbs., lead 2lbs.

To make a good trolley wheel: Copper 90lbs., tin 6lbs., zinc 5lbs.

A good brass that will resist acid much better than others is lake copper 70lbs., phosphor-copper 3lbs., tin 2lbs., antimony 4lbs., and lead 10lbs.

For bearings and to resist acid: Copper 70lbs., manganese copper 1lb., tin 5lbs., lead 20lbs.

Always melt the copper, then add the other parts in the order given.

Gold-coloured brass may be made with the following: Copper 90lbs., tin 7lbs., zinc 4lbs., lead 3lbs.

To match yellow brass tubing, use the following: Copper 75lbs., zinc 30lbs., tin 1lb., lead 2lbs.

The making of bronze castings gives more trouble than other kinds of brass, on account of eating into the sand when cast and shrinking. The best remedy the writer has ever tried for these troubles is heavy risers or heads and skin-drying the moulds. This brings us back to the melting of all brasses, and I would again lay great stress on the melting. It is so easy to fail in the melting by just a little neglect. A melter sometimes is too persistent by trying to hurry the metal, and is continually punching at the stock and coke, with the furnace open. The furnace should be kept closed except when absolutely necessary to open it.

The writer said bronze castings required a heavy riser to prevent shrinking. All brass castings do. The pouring gate should be high on all brass castings, so as to get a good pressure on any casting that is very heavy. In making very light or thin brass castings, the use of stick phosphorus is almost indispensable. The amount to be used depends entirely on how the metal is to begin with, and the nature of the casting to be poured. The writer is not a great believer in fluxes of any kind for any metal. Give me the genuine article every time properly melted and mixed; but we all must admit that fluxes do help us sometimes—or, at least, we think so.

Six years ago he thought he could not make a sound casting of iron without fluorspar, but he has learned better. He has not used a pound in five years, and has made just as good or better castings than ever before, on an average. Still he does not condemn fluxing in some cases. For copper and brass, common salt seems to be almost universally used, and seems to do good. Plaster of paris is also used in many cases, especially for melting scrap brass of all kinds when pouring into ingots. Aluminium is used for a flux for brass sometimes, and to good advantage. It makes the metal more fluid and runs better, and in most cases adds to the strength of the metal.

Anti-friction or babbitt metal: Common babbitt metal can be made with 80lbs. of lead, antimony 20lbs., tin 5lbs., and bismuth 1lb.

A good babbitt metal that will stand the test is made with copper 15lbs., tin 30lbs., antimony 45lbs., and lead 10lbs.

Any of these compositions, if properly melted, will give good results. There are, of course, many more good compositions, some costing more and some less. Most brassmoulders and most brassfounders have their own ways of mixing, but they vary but little. To make any kind of brass, have the right formula for what you want, the right kind of sand, a good moulder who knows his business, and a melter who knows his and will do it, and brassfoundry troubles, so far as making castings are concerned, will be reduced to a minimum.—"Southern Machinery."

FEED MECHANISM FOR PLANING MACHINES.

We illustrate herewith an arrangement of automatic feed mechanism for reciprocating machine tools, the invention of Thomas Shanks & Co., Union Iron Works, Johnstone. The arrangement is more particularly applicable to planing

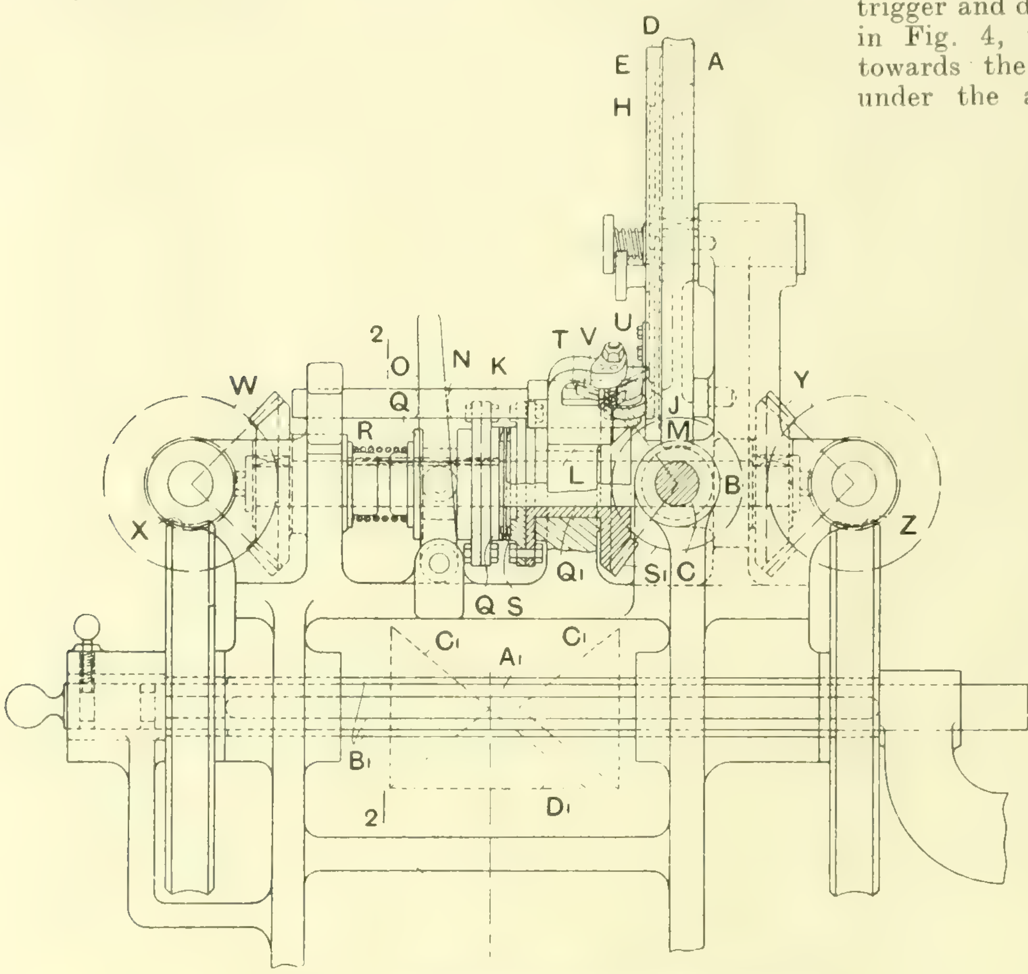


FIG. 1.—FEED MECHANISM FOR PLANING MACHINES.

machines, wherein the requisite feeding movement is transmitted to the tool from the main drive just before the driving belt is shifted off the driving pulley or just before reversal of direction of travel of the tool so that the full power of the driving belt or motor will be available for imparting the feeding movement.

In the accompanying illustrations Fig. 1 is an elevation, partly in section, and Fig. 2 is a section on the line 2-2, showing the arrangement applied to a planing machine. Figs. 3 to 8 show details. Referring to Figs. 1 and 2, there is fitted on the face of a worm wheel A (which meshes with a worm B on the first motion shaft C connected to the main driving pulleys or motors) a disc D circularly adjustable relatively to the worm wheel A and adapted to be locked in any desired position. Part of the face E of the disc D is cut away as at F, so as to afford an arcuate depression terminating at one end in a cam part G. Circularly adjustable on the disc D is a second disc H provided with graduations and being fitted with a trip device or trigger extractor J. It will be understood that the worm wheel A and therewith the two discs D and H will make a fraction of a rotation in each direction, *i.e.*, will continue to oscillate so long as the machine is running. The disc D is adjusted relatively to the worm wheel A in such a position that the cam part G will just come opposite a plunger K as the driving belt is about to be shifted. The plunger K is slidably fitted in a bracket L adjacent the periphery of the worm wheel A, the end of the plunger being fitted with a roller M adapted to enter the arcuate depression in the cam disc D and to ride up the cam part G. Operatively engaged with the plunger K (as for instance by passing through a slot N therein) is a lever O constituting an element of a rocking frame P which embraces a spring actuated clutch member Q slidably mounted on a feed controlling shaft Q^1, the spring R normally tending to force the clutch member Q into engagement with the other member S of the clutch, which member S is freely mounted relatively to the shaft Q^1 and is adapted to be driven by means of bevel gearing S^1, from the first motion shaft C.

The plunger K is normally held in such position that the clutch member Q is disengaged by the action of a spring-pressed trigger device which engages the plunger as at T. This trigger device is made in two yieldingly connected parts U and V, the part U projecting into the path of the trip device J formed on the disc H, as indicated in Fig. 3, so that on the oscillation of the worm wheel A during the return stroke of the machine the trip device J will contact with the trigger and disengage the same from the plunger K, as shown in Fig. 4, thereby permitting movement of the plunger towards the cam disc D, as shown in Figs. 4 and 5, under the action of the spring R actuating the clutch

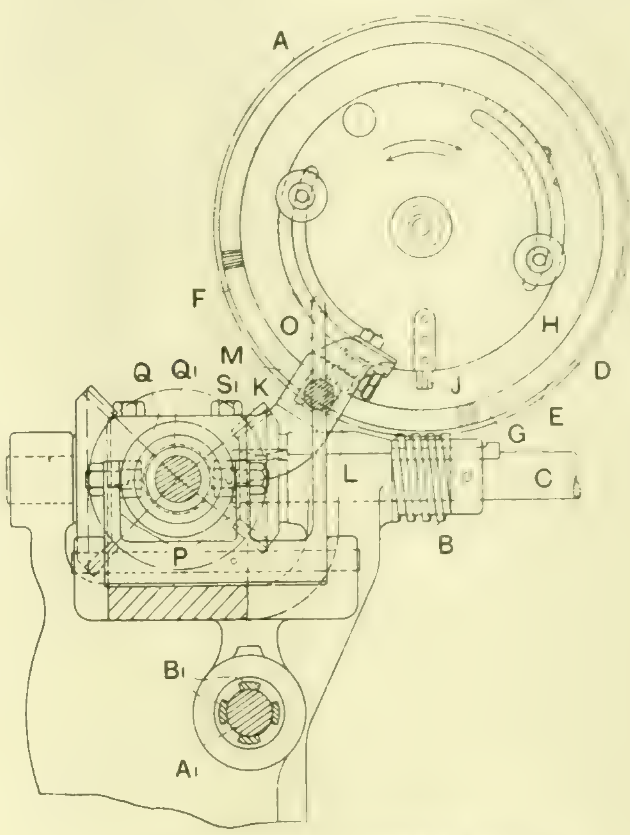


FIG. 2.—SECTION ON LINE 2-2 OF FIG. 1.

member Q, which spring R also causes the lever O to rock and the clutch faces on the clutch members Q and S to be brought into engagement and thus to effect transmission of movement to the feed shaft through

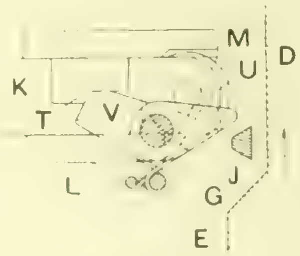


FIG. 3.

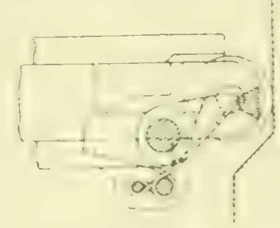


FIG. 4.

FIG. 5.

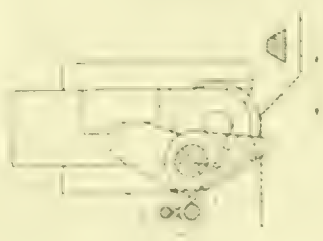


FIG. 6.

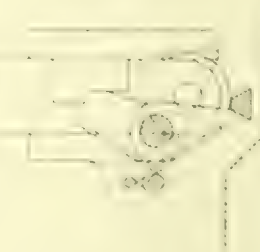


FIG. 7.

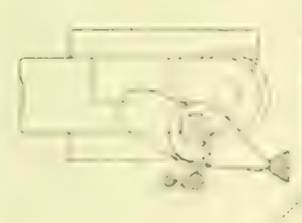


FIG. 8.

FEED MECHANISM FOR PLANING MACHINES.

suitable gearing. As the worm wheel A continues its movement, the roller M at the end of the plunger K rides up the cam part G on the disc D whereby the plunger K is caused to return to initial position, as shown in Fig. 6, and by rocking

the lever O to disengage the clutch members Q and S, the trigger device being again brought into operative engagement with the plunger K. Just at this moment the driving belt is shifted off the driving pulley and the worm wheel A makes its oscillating movement in the opposite direction, and the cutting stroke of the tool now commences. As the trigger is made in two yieldingly connected parts U and V, the part U in the path of the trip device J slips past the latter on the return movement of the worm wheel A, as shown in Figs. 7 and 8. The adjustment of the disc H on the disc D determines the range of feed.

As shown, movement may be transmitted from the feed-controlling shaft Q_1 to the feed shaft through the intermediary of bevel gearing W and worm gearing X, or through bevel gearing Y and worm gearing Z, the teeth of the worm wheels being of different pitch so as to permit of further variation of movement of the feed shaft. The worm wheels are adapted to be made fast—one at a time—to an axially movable shaft A_1 provided with feather keys B_1 and carrying bevel gears C_1 one or other of which is adapted to mesh with a bevel gear D_1 connected to the feed shaft.

EXPERIMENTS WITH MANGANESE BRONZE.

By C. Vickers.

Manganese bronze, as the term is generally understood, applies to an alloy of copper and zinc modified and improved by small percentages of manganese, iron, phosphorus, and tin, and fluxed with aluminium or silicon. Its composition is similar to that of Delta metal, Airch metal, Tobin bronze, and Muntz metal, which are all alloys of copper with high percentages of zinc and contain small quantities of iron, tin, and sometimes manganese. Manganese bronze is subject to considerable variation in composition, and may be either soft and ductile, or hard and strong. In the former case the tensile strength is low and the ductility high, while in the latter case these qualities are reversed. It is an alloy very difficult to make to obtain the highest tensile strength uniformly, as the percentage of zinc is the determining factor and, as is well known, this metal is very volatile. Consequently, the tensile strength of the alloy will fall considerably each time it is melted if provision is not made to restore it again to pitch, by additions of zinc to compensate for what has been lost. To adjust the zinc content to its normal proportions involves considerable difficulty, and, as it is better to err on the side of too little zinc than too much, the remelted metal usually shows some falling off in tensile strength as compared with the new alloy.

Consequently, when castings of the highest quality are desired it is always advisable to use new metals, as gates and risers, remelted and mixed with new metal, are liable to cause a considerable drop in the ultimate strength of the castings. It is not always possible to obtain the same results in tensile strength and elongation in castings made from different heats of manganese bronze, even when the greatest care is exercised to have the proportions of the component parts of the alloy the same, and the melting conditions uniform. Wide variations in the strength of the castings will often be noted, which no doubt are due to slight differences in the working of the furnaces. These are unobservable even to the trained eye, but permit of greater oxidation of the metal in one heat than in another, lowering both tensile strength and elongation. In other heats more zinc will be volatilised, which also causes a variation in physical properties by increasing the elongation at the expense of the tensile strength. As an example of these variations, tests of eight heavy castings are given in the following table: —

	Tensile Strength, Pounds per square inch.	Elongation in 2 inches, per cent.
1	70,700	25
2	71,250	26
3	70,600	24·5
4	72,750	29
5	71,500	34·5
6	71,650	32·5
7	77,150	28·5
8	74,900	32·5

The castings were all made from separate heats, with due regard to conditions that would lead to uniformity of results. They were all moulded and gated in the same manner and cast, as nearly as could be judged, at the same temperature. All the fractures were classed as crystalline. It will be noted that fairly uniform tensile test results were obtained from the first six castings, although there was a variation of 10 per cent. in the elongation. The seventh casting, however, was much stronger and the elongation was also high for an alloy of that tensile strength. Between the seventh and third alloys there is a difference of 6,550lbs. in tensile strength, and 4 per cent. in elongation, while the eighth alloy fell off in tensile strength, and, as would be expected, gained in elongation. This was, no doubt, due to a greater loss of zinc, which resulted in a gain of 4 per cent. in elongation and a loss of 2,250lbs. in tensile strength. The poor showing of the third alloy was, in all probability, due to the absorption of oxides, as both tensile strength and elongation were reduced. While the elongation of alloy No. 6 is the same as that of No. 8, the tensile strength is 3,250lbs. less, a variation difficult to explain without analyses of the two alloys. This might have been caused by accidental impurities in the metals, or by a slight difference in the temperature at which this alloy was poured. Numerous other causes could be advanced and these would emphasize, further, the importance of careful attention to details when making this alloy, if fairly uniform results are desired.

Many different formulæ for making manganese bronze are used, but when the highest physical results obtainable are desired, the alloy must contain the maximum quantity of zinc with the minimum amount of lead. The latter impurity is so potent in reducing the strength of the alloy that ordinary commercial brands of zinc cannot be used, as they always contain lead. Therefore only the purest and best brands should be used. The more zinc contained in the alloy the harder it will be and the higher its tensile strength. An alloy of copper 52 per cent., zinc 46 per cent., tin 1 per cent., and iron 1 per cent., when first melted is very hard and brittle, showing that the zinc is too high, and in order to make a strong alloy of this formula it seems to be necessary to boil out some of the zinc, or to increase the copper. Experiments made to determine the length of time required to boil out sufficient zinc to produce a dense, tough metal from this mixture showed that it cannot be done in less than an hour when using remelted ingots.

An investigation was made of the effects produced on an alloy of the composition given by various deoxidising elements. When working this alloy, the copper was melted under charcoal and the iron was added in the form of tin plate. The zinc was added after the tin plate. The mixture was well stirred and poured into ingots. This mixture gave a very hard metal with a brilliant golden fracture and small crystals. It was low in ductility and could be easily broken. Some of this metal was then remelted and 0·5 per cent. of aluminium added. The metal was poured into ingots which were afterwards broken so that the fracture could be examined. The addition of this small amount of aluminium, it was found, made the metal more fluid, produced the characteristic manganese bronze appearance, changed the colour of the fracture to a deeper gold, but did not materially strengthen the alloy. The addition of 3 per cent. of 50 per cent. ferro-silicon produced great changes in the structure of the original alloy, the metal being hard and stiff and the fracture slate-coloured. The metal was both hard and strong. The addition of 3 per cent. of 10 per cent. phosphor-copper produced a great change in the structure of this alloy. The fracture of the ingot showed long, golden fibres arranged at right angles to the cooled surface of the ingot and extending axially from the centre to the circumference. The metal, however, was not greatly strengthened, owing to the fibres running crosswise instead of lengthwise of the ingot. Magnesium, in the proportion of 0·25 per cent., gave the alloy a white, steel-like fracture. The alloy was hard, but not tough. Manganese, in the form of 16 per cent. manganese-copper, when added in the proportion of 3 per cent., produced no change in the appearance of the fracture of the original ingot, although the manganese was visible externally on the ingot.

When combinations of these various elements were tried in the manganese bronze formula given, it was discovered that phosphorus and silicon should not be used together in this alloy; that phosphorus and magnesium should not be used together, but that aluminium and phosphorus can be used together to great advantage, producing a good alloy having a very close, drab-coloured fracture.—"The Foundry."

STRENGTH OF STEEL TUBES, PIPES, AND CYLINDERS UNDER INTERNAL FLUID PRESSURE.*

BY REID T. STEWART.

PART I.—A COMPARISON OF THE THEORETICAL FORMULÆ.

IN order to arrive at some definite conclusion as to what formula or formulæ should be used for calculating the strength of tubes, pipes, and cylinders subjected to internal fluid pressure, the different published formulæ have been investigated and compared. These are five in number, namely, the common formula, and those by Barlow, Lamé, Clavarino, and Birnie.

These formulæ have been put into the simplest form for application to tubes, pipes, and cylinders, and are reduced to a common notation for the sake of making an easy comparison. The notation used is as follows:—

D_1 = outside diameter in inches.
D_2 = inside diameter in inches.
t = thickness of wall in inches.
p = internal gauge pressure, or difference between internal and external fluid pressures, in pounds per square inch.
f = fibre stress in the wall in pounds per square inch.

The formulæ here given are for the usual conditions of practice, namely, where the external pressure is atmospheric and the internal pressure is expressed as gauge pressure. They are also applicable to cases where the external pressure is not excessive by taking p as the difference between the internal and external pressures. In all that follows it is assumed that the length of the tube or pipe relative to its diameter is sufficiently great to eliminate the influence of end support tending to prevent rupture.

Nature of Stress in Tube Wall. — An internal fluid pressure may give rise (*a*) to a circumferential stress within the wall of a tube or pipe, or (*b*) to both a circumferential and a longitudinal stress acting jointly. In either case the tube

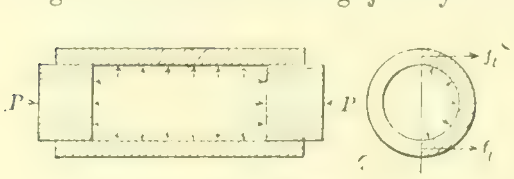


FIG. 1.—TUBE WITH FRICTIONLESS PLUNGERS.

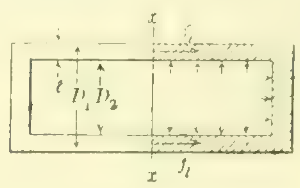


FIG. 2.—TUBE WITH BOTH ENDS CLOSED.

wall is under radial compressive stress as indicated by the arrows, Figs. 1 and 2. Fig. 1 illustrates a tube with frictionless plungers fitted into its ends, the plungers being kept in place by the external forces PP, which exactly balance the internal fluid pressure, tending to force them outward. In this case the tube wall is subjected only to the internal forces shown as acting at right angles to its inner surface. It is obvious that these forces can give rise to radial and circumferential stresses only in the tube wall. The value of the circumferential stress f_t in pound per square inch is

$$f_t = p\frac{D_2}{D_1 - D_2} = \frac{pD_2}{2t} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Fig. 2 illustrates the ordinary case of a tube or pipe with both ends closed. In this case the tube wall, as in Fig. 1, is subjected to the circumferential stress, f_t, along with the radial stress, and at the same time is subjected to the longitudinal stress f_1. The longitudinal stress is caused by the internal fluid pressure tending to force the attached heads outward and expressed in pounds per square inch is

$$f_1 = p\frac{D_2^2}{4(D_2 + t)t} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

When the thickness of wall t is relatively small with respect to the diameter, the longitudinal stress becomes approximately

$$f_1 = \frac{pD_2}{4t} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

or one half the corresponding circumferential stress.

Common Formula. — This is the formula generally found in books on mechanics. It is based on the condition that the tube wall is subjected to circumferential stress only, Fig. 1, and assumes (*a*) that the material of the tube wall is devoid of elasticity, and (*b*) that the stress is the same on all the circumferential fibres from the innermost to the outermost. These assumptions are only approximately true for tubes of comparatively thin walls, and are greatly in error for tubes having very thick walls. Using the notation as given above, the formula is

$$\frac{p}{f} = 2\frac{t}{D_2}\,;\ p = 2f\frac{t}{D_2}\,;\ t = \tfrac{1}{2}D_2\frac{p}{f}\,;\ f = \tfrac{1}{2}D_2\frac{p}{t} \quad . \quad (4)$$

Referring to the charts, Figs. 3 and 4, it will be seen that the common formula gives quite close results for comparatively thin walls when used for the conditions shown in

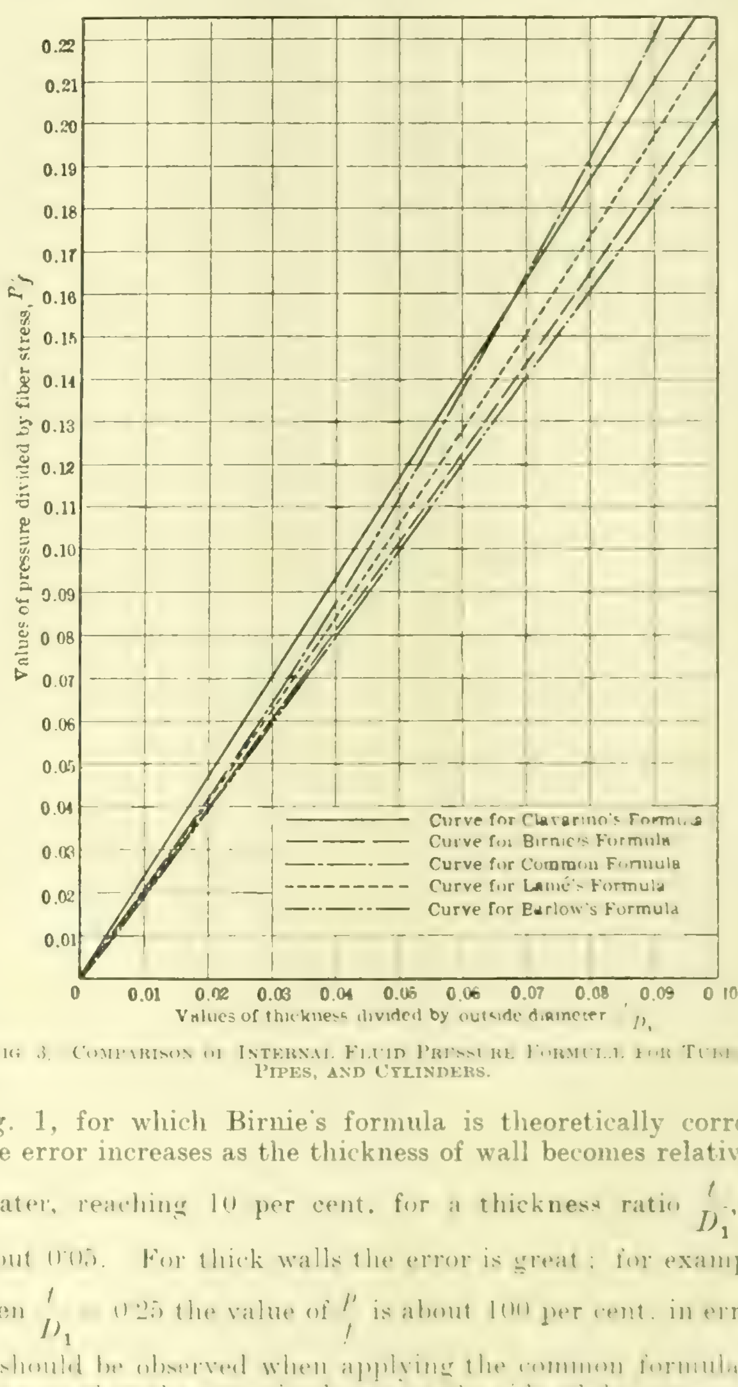


FIG. 3. COMPARISON OF INTERNAL FLUID PRESSURE FORMULÆ FOR TUBES, PIPES, AND CYLINDERS.

Fig. 1, for which Birnie's formula is theoretically correct. The error increases as the thickness of wall becomes relatively greater, reaching 10 per cent. for a thickness ratio $\frac{t}{D_1}$, or about 0·05. For thick walls the error is great; for example, when $\frac{t}{D_1}$ = 0·25 the value of $\frac{p}{f}$ is about 100 per cent. in error. It should be observed when applying the common formula to this case that the error is always on the side of danger.

For the conditions shown in Fig. 2, that is, when the tube is subjected to the stresses due to an internal fluid pressure acting jointly on the tube wall and its closed ends, for which Clavarino's formula is theoretically correct, the curves show for a thickness ratio $\frac{t}{D_1}$ less than 0·07 that the common formula errs on the side of safety, the greatest error being about 12 per cent.; while for thickness ratios greater than 0·07 the error is on the side of danger, reaching 10 per cent for a thickness ratio of 0·1 and about 100 per cent. for a ratio of 0·25.

Barlow's Formula. — This formula assumes (*a*) that because of the elasticity of the material, the different circumferential fibres will have their diameters increased in such a manner as to keep the area of cross-section constant; and (*b*) that the length of the tube is unaltered by the internal fluid pressure. As neither of these assumptions is theoretically correct, this formula can give only approximately

* Paper read before the American Society of Mechanical Engineers.

correct results. Using the notation given above, this formula is

$$\frac{p}{f} = 2\frac{t}{D_1};\ p = 2f\frac{t}{D_1};\ t = \tfrac{1}{2} D_1 \frac{p}{f};\ f = \tfrac{1}{2} D_1 \frac{p}{t}. \quad (5)$$

It should be observed that while Barlow's formula is similar in form to the common formula, it gives results that are quite different when applied to tubes, pipes, and cylinders having walls of considerable thickness. This is due to the fact that Barlow's formula is expressed in terms of the outside diameter D_1, whereas the common formula is expressed in terms of the inside diameter D_2. Referring to Figs. 3 and 4, it will be seen that Barlow's formula gives quite close results when used for the condition shown in

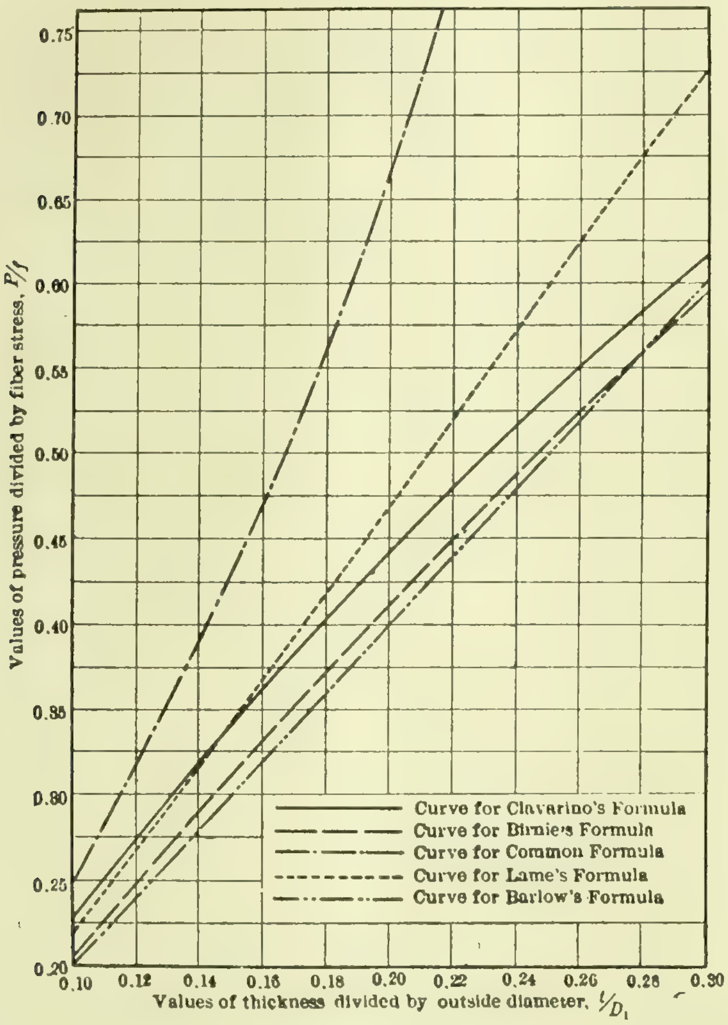


FIG. 4.—COMPARISON OF INTERNAL FLUID PRESSURE FORMULÆ FOR TUBES, PIPES, AND CYLINDERS.

Fig. 1, for which Birnie's formula is theoretically correct. The curves show for the entire practical range of thickness ratios that the error in values of $\frac{p}{f}$, for this case, does not exceed 3 per cent., the error throughout the whole practical range being on the side of safety. This then is the best of the simple theoretical formulæ for application to the cases illustrated in Fig. 1.

For the conditions shown in Fig. 2, namely, when the tube is subjected to the stresses due to an internal fluid pressure acting jointly on the tube wall and its closed ends, for which Clavarino's formula is theoretically correct, the curves show that Barlow's formula gives values of $\frac{p}{f}$ whose errors range from 15 per cent. for tubes, pipes, and cylinders having thin walls, to 10 per cent. for those having thick walls, the error being on the side of safety for all practical thickness ratios.

Lame's Formula.—This formula is meant to apply to the conditions shown in Fig. 2. Each material particle of the tube wall is supposed to be subjected to the radial compression, the circumferential and longitudinal tensions due to an internal fluid pressure acting jointly on the tube wall and its closed ends; and the material of the tube wall is supposed to be elastic under these actions. Lamé's formula, however, ignores the coefficient of lateral contraction, known as Poisson's ratio, and consequently is not theoretically correct. Using the notation as given above, this formula is

$$\frac{p}{f} = \frac{D_1^2 - D_2^2}{D_1^2 + D_2^2};\ p = \frac{D_1^2 - D_2^2}{D_1^2 + D_2^2} f;\ D_2 = D_1\sqrt{\frac{f-p}{f+p}};$$

$$D_1 = D_2\sqrt{\frac{f+p}{f-p}} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Referring to Figs. 3 and 4, it will be seen that Lamé's formula, which is meant to apply to the conditions for which Clavarino's formula is theoretically correct, gives for thickness ratios, $\frac{t}{D_1}$, less than 0·15, an error on the side of safety, the error having a maximum value of about 14 per cent. when $\frac{t}{D_1}$ equals 0·01. For thickness ratios greater than 0·15 the error is on the side of danger, reaching 10 per cent. for a ratio of about 0·23.

Clavarino's Formula.—In this formula, as in Lamé's formula, each material particle of the tube wall is supposed to be subjected to the radial compression and the circumferential and longitudinal tensions due to an internal fluid pressure acting jointly on the tube wall and its closed ends; and the material is supposed to be elastic under these actions. Unlike Lamé's formula, however, this formula expresses the true stresses in the tube wall as based upon the coefficient of lateral contraction, known as Poisson's ratio, and is consequently theoretically correct for the conditions shown in Fig. 2, providing the stress on the most strained fibre does not exceed the elastic limit of the material. Using the notation given above and assuming the value of the coefficient of lateral contraction for tube steel to be 0·3, this formula is

$$\frac{p}{f} = \frac{10(D_1^2 - D_2^2)}{13D_1^2 + 4D_2^2};\ p = \frac{10(D_1^2 - D_2^2)}{13D_1^2 + 4D_2^2} f;\ D_1 = D_2\sqrt{\frac{10f + 4p}{10f - 13p}};$$

$$D_2 = D_1\sqrt{\frac{10f - 13p}{10f + 4p}} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

This theoretically correct formula for the conditions shown in Fig. 2 has the disadvantage that it is difficult to apply directly in making calculations. In order to remove this difficulty Table I. has been prepared, by means of which any desired calculation can be as readily made by Clavarino's formula as by any of the simpler formulæ. The entries of this table are the values in Clavarino's formula of the factor

$$\frac{10(D_1^2 - D_2^2)}{13D_1^2 + 4D_2^2} = K$$

It will be observed that these factors are tabulated for thickness ratios, $\frac{t}{D_1}$ from 0·01 to 0·3, advancing by thousandths. Thus for a wall thickness t of 0·25in. and an outside diameter D_1 of 10in., the thickness ratio, $\frac{t}{D_1}$, would be 0·25 divided by 10, or 0·025. The required factor corresponding to this thickness ratio is 0·0587 and is found in the column headed 0·005 opposite 0·02 in column 1. Similarly for an outside diameter of 4in. and a wall thickness of 0·5in., the thickness ratio would be 0·125 and the corresponding internal pressure factor is 0·2869. If we designate the value of any tabular factor by K, then it is obvious that Clavarino's formula may be written

$$\frac{p}{f} = K;\ p = Kf;\ f = \frac{p}{K} \quad . \quad . \quad . \quad . \quad (8)$$

Table I. is well adapted to the ready solution of problems involving the strength and safety of a tube, pipe, or cylinder which is subjected to the stresses due to an internal fluid pressure acting jointly on its wall and closed ends, as illustrated in Fig. 2.

Problem 1. Required the safe working pressure, p (Fig 2), when the outside diameter, D_1 = 4in.; thickness of wall, t = 0·5in.; and the working fibre stress of the steel, f = 10,000lbs. Solution: (*a*) the thickness ratio, $\frac{t}{D_1}$ = 0·125; (*b*) the corresponding tabular factor, K, is found from Table 1 to be 0·2869; and (*c*) the required safe working fluid pressure, $p = Kf$, equation (8), or 0·2869 × 10,000, or 2,869lbs. per square inch.

Problem 2. Required the fibre stress, f, in the wall of a cylinder, Fig. 2, when the outside diameter, $D_1 = 5{\cdot}5$in., the thickness of wall, $t = 0{\cdot}25$in.: and the working fluid pressure, $p = 1{,}500$lbs. per square inch. Solution: (*a*) the thickness ratio, $\frac{t}{D_1} = 0{\cdot}045$: (*b*) the corresponding factor, K, is found from Table 1 to be 0·1054; and (*c*) the required fibre stress, $f = \frac{p}{K}$, equation (8), or $1{,}500 \div 0{\cdot}1054$ or 14,200lbs. per square inch.

TABLE 1.—*Internal Fluid Pressure Factors K.*

For conditions shown in Fig. 2.

CALCULATED BY CLAVARINO'S FORMULA, ASSUMING FOR STEEL A COEFFICIENT OF LATERAL CONTRACTION (POISSON'S RATIO) = 0.3.

RULE: DIVIDE THICKNESS OF TUBE OR PIPE BY ITS OUTSIDE DIAMETER, BOTH BEING EXPRESSED IN INCHES, THEN MULTIPLY THE TABULAR VALUE CORRESPONDING TO THIS QUOTIENT BY THE WORKING FIBER STRESS IN LB. PER SQ. IN. THE RESULT WILL BE THE SAFE INTERNAL PRESSURE IN LB. PER SQ. IN.

$\frac{t}{D_1}$	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.01	0.0235	0.0259	0.0282	0.0306	0.0329	0.0352	0.0376	0.0399	0.0423	0.0446
0.02	0.0470	0.0493	0.0517	0.0540	0.0564	0.0587	0.0610	0.0634	0.0657	0.0681
0.03	0.0704	0.0727	0.0751	0.0774	0.0797	0.0821	0.0844	0.0867	0.0891	0.0914
0.04	0.0937	0.0961	0.0984	0.1007	0.1031	0.1054	0.1077	0.1100	0.1123	0.1147
0.05	0.1170	0.1193	0.1216	0.1239	0.1263	0.1286	0.1309	0.1332	0.1355	0.1378
0.06	0.1401	0.1424	0.1448	0.1471	0.1494	0.1517	0.1540	0.1563	0.1586	0.1609
0.07	0.1632	0.1655	0.1678	0.1700	0.1723	0.1746	0.1769	0.1792	0.1815	0.1838
0.08	0.1861	0.1883	0.1906	0.1929	0.1952	0.1974	0.1997	0.2020	0.2043	0.2065
0.09	0.2088	0.2111	0.2133	0.2156	0.2178	0.2201	0.2223	0.2246	0.2269	0.2291
0.10	0.2314	0.2336	0.2358	0.2381	0.2403	0.2425	0.2448	0.2470	0.2493	0.2515
0.11	0.2537	0.2559	0.2582	0.2604	0.2626	0.2648	0.2670	0.2692	0.2715	0.2737
0.12	0.2759	0.2781	0.2803	0.2825	0.2847	0.2869	0.2890	0.2912	0.2934	0.2956
0.13	0.2978	0.3000	0.3022	0.3043	0.3065	0.3087	0.3108	0.3130	0.3152	0.3173
0.14	0.3195	0.3216	0.3238	0.3259	0.3281	0.3302	0.3323	0.3345	0.3366	0.3388
0.15	0.3409	0.3430	0.3151	0.3472	0.3494	0.3515	0.3536	0.3557	0.3578	0.3599
0.16	0.3620	0.3641	0.3662	0.3683	0.3704	0.3724	0.3745	0.3766	0.3787	0.3808
0.17	0.3828	0.3849	0.3869	0.3890	0.3910	0.3931	0.3951	0.3972	0.3992	0.4013
0.18	0.4033	0.4053	0.4073	0.4094	0.4114	0.4134	0.4154	0.4174	0.4194	0.4214
0.19	0.4234	0.4254	0.4274	0.4294	0.4314	0.4333	0.4353	0.4373	0.4393	0.4412
0.20	0.4432	0.4452	0.4471	0.4490	0.4510	0.4529	0.4548	0.4568	0.4587	0.4606
0.21	0.4626	0.4645	0.4664	0.4683	0.4702	0.4721	0.4740	0.4758	0.4777	0.4796
0.22	0.4815	0.4834	0.4852	0.4871	0.4889	0.4908	0.4926	0.4945	0.4964	0.4982
0.23	0.5001	0.5019	0.5037	0.5055	0.5073	0.5091	0.5109	0.5127	0.5145	0.5163
0.24	0.5181	0.5199	0.5216	0.5234	0.5252	0.5269	0.5287	0.5304	0.5322	0.5340
0.25	0.5357	0.5374	0.5391	0.5408	0.5426	0.5443	0.5460	0.5477	0.5494	0.5511
0.26	0.5528	0.5545	0.5561	0.5578	0.5594	0.5611	0.5628	0.5644	0.5661	0.5677
0.27	0.5694	0.5710	0.5726	0.5742	0.5758	0.5774	0.5790	0.5806	0.5822	0.5838
0.28	0.5851	0.5870	0.5885	0.5901	0.5916	0.5932	0.5947	0.5963	0.5978	0.5991
0.29	0.6009	0.6024	0.6039	0.6054	0.6069	0.6084	0.6099	0.6114	0.6129	0.6143
0.30	0.6158	0.6173	0.6187	0.6201	0.6216	0.6230	0.6244	0.6259	0.6273	0.6287

Problem 3. Required the thickness of wall, t (Fig. 2), when the outside diameter, $D_1 = 8$in.; the working fibre stress of the steel, $f = 15{,}000$lbs. per square inch; and the working fluid pressure, $p = 2{,}000$lbs. per square inch. Solution; (*a*) the factor, $K = \frac{p}{f}$, equation (8), or $2{,}000 \div 15{,}000$, or 0·133; (*b*) the value of the thickness ratio, $\frac{t}{D_1}$, corresponding to this value of K is found from Table 1 to be 0·057; and (*c*) the required thickness will result from multiplying this thickness ratio, $\frac{t}{D_1}$, by the outside diameter, D_1, or $0{\cdot}057 \times 8 = 0{\cdot}456$in.

Note.—When the inside diameter, D_2, the internal pressure, p, and the working fibre stress, f, are given and it is required to find the thickness of wall, t, proceed by finding first the value of the outside diameter, D_1, by means of equation (7); after which the required thickness may be had by taking one-half the difference of the outside and inside diameters or

$$t = \frac{D_1 - D_2}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Birnie's Formula.—This formula is based upon the conditions illustrated in Fig. 1. In its derivation precisely the same assumptions are made as for Clavarino's formula, with the single exception that the longitudinal stress f_1, due to the internal fluid pressure acting upon attached heads, is assumed not to exist. Birnie's formula consequently is theoretically correct for tubes, pipes, and cylinders that are subjected to an internal fluid pressure in such manner as not to give rise to longitudinal stress in the wall; provided the stress on the most strained fibre does not exceed the elastic limit of the material. Using the same notation as before and assuming the value of the coefficient of lateral contraction for steel to be 0·3, this formula is

$$\frac{p}{f} = \frac{10(D_1^2 - D_2^2)}{13D_1^2 + 7D_2^2}; \quad p = \frac{10(D_1^2 - D_2^2)}{13D_1^2 + 7D_2^2}f; \quad D_1 = D_2\sqrt{\frac{10f + 7p}{10f - 13p}};$$

$$D_2 = D_1\sqrt{\frac{10f - 13p}{10f + 7p}} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

Birnie's formula, like Clavarino's formula, has the disadvantage of being difficult to apply directly in making calculations. In order to remove this difficulty Table II. has been prepared, the entries being the values in Birnie's formula of the factor

$$\frac{10(D_1^2 - D_2^2)}{13D_1^2 + 7D_2^2} = K$$

TABLE 2.—*Internal Fluid Pressure Factors K.*

For conditions shown in Fig. 1.

CALCULATED BY BIRNIE'S FORMULA, ASSUMING FOR STEEL A COEFFICIENT OF LATERAL CONTRACTION (POISSON'S RATIO) = 0.3.

RULE: DIVIDE THICKNESS OF TUBE OR PIPE BY ITS OUTSIDE DIAMETER, BOTH BEING EXPRESSED IN INCHES, THEN MULTIPLY THE TABULAR VALUE CORRESPONDING TO THIS QUOTIENT BY THE WORKING FIBER STRESS IN LB PER SQ. IN. THE RESULT WILL BE THE SAFE INTERNAL PRESSURE IN LB PER SQ. IN.

$\frac{t}{D_1}$	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.01	0.0201	0.0221	0.0241	0.0261	0.0282	0.0302	0.0322	0.0342	0.0363	0.0383
0.02	0.0403	0.0423	0.0444	0.0464	0.0485	0.0505	0.0525	0.0546	0.0566	0.0586
0.03	0.0607	0.0627	0.0648	0.0668	0.0689	0.0709	0.0730	0.0750	0.0771	0.0791
0.04	0.0812	0.0832	0.0853	0.0873	0.0894	0.0915	0.0935	0.0956	0.0976	0.0997
0.05	0.1018	0.1038	0.1059	0.1080	0.1100	0.1121	0.1142	0.1163	0.1183	0.1204
0.06	0.1225	0.1245	0.1266	0.1287	0.1308	0.1329	0.1349	0.1370	0.1391	0.1412
0.07	0.1433	0.1453	0.1474	0.1495	0.1516	0.1537	0.1558	0.1579	0.1599	0.1620
0.08	0.1641	0.1662	0.1683	0.1704	0.1725	0.1746	0.1767	0.1787	0.1808	0.1829
0.09	0.1850	0.1871	0.1892	0.1913	0.1934	0.1955	0.1976	0.1997	0.2018	0.2039
0.10	0.2059	0.2080	0.2101	0.2122	0.2143	0.2164	0.2185	0.2206	0.2227	0.2248
0.11	0.2269	0.2290	0.2311	0.2332	0.2353	0.2374	0.2395	0.2416	0.2437	0.2457
0.12	0.2478	0.2499	0.2520	0.2541	0.2562	0.2583	0.2604	0.2625	0.2646	0.2667
0.13	0.2688	0.2708	0.2729	0.2750	0.2771	0.2792	0.2813	0.2834	0.2854	0.2875
0.14	0.2896	0.2917	0.2938	0.2959	0.2979	0.3000	0.3021	0.3042	0.3062	0.3083
0.15	0.3104	0.3125	0.3145	0.3166	0.3187	0.3208	0.3228	0.3249	0.3270	0.3290
0.16	0.3311	0.3332	0.3352	0.3373	0.3393	0.3414	0.3434	0.3455	0.3476	0.3496
0.17	0.3517	0.3537	0.3558	0.3578	0.3598	0.3619	0.3639	0.3660	0.3680	0.3700
0.18	0.3721	0.3741	0.3761	0.3782	0.3802	0.3822	0.3842	0.3863	0.3883	0.3903
0.19	0.3923	0.3943	0.3963	0.3983	0.4003	0.4024	0.4044	0.4064	0.4084	0.4104
0.20	0.4124	0.4144	0.4163	0.4183	0.4203	0.4223	0.4243	0.4262	0.4282	0.4302
0.21	0.4322	0.4341	0.4361	0.4380	0.4400	0.4419	0.4439	0.4459	0.4478	0.4498
0.22	0.4517	0.4536	0.4556	0.4575	0.4594	0.4613	0.4633	0.4652	0.4671	0.4690
0.23	0.4710	0.4729	0.4748	0.4767	0.4785	0.4804	0.4823	0.4842	0.4861	0.4880
0.24	0.4899	0.4918	0.4936	0.4955	0.4973	0.4992	0.5010	0.5029	0.5048	0.5066
0.25	0.5085	0.5103	0.5121	0.5139	0.5157	0.5176	0.5194	0.5212	0.5230	0.5248
0.26	0.5266	0.5284	0.5302	0.5320	0.5338	0.5355	0.5373	0.5391	0.5409	0.5427
0.27	0.5444	0.5462	0.5479	0.5496	0.5514	0.5531	0.5548	0.5566	0.5583	0.5600
0.28	0.5617	0.5634	0.5651	0.5668	0.5685	0.5702	0.5718	0.5735	0.5752	0.5769
0.29	0.5786	0.5802	0.5818	0.5835	0.5851	0.5867	0.5884	0.5900	0.5916	0.5933
0.30	0.5949	0.5965	0.5981	0.5996	0.6012	0.6028	0.6044	0.6059	0.6075	0.6091

This table is used in a manner precisely similar to the table of factors for Clavarino's formula.

PART II.—RESULTS OF TESTS ON COMMERCIAL TUBES AND PIPES, AND THE APPLICABILITY OF THE THEORETICAL FORMULÆ.

In Part I. there appears a full statement of the basis of each of the five theoretical formulæ for the strength of tubes, pipes, and cylinders, when subjected to internal fluid pressures, together with a comparison of results obtained by their use. One or the other of these formulæ, taken apparently at random, has often been used without sufficient understanding of their application to practical conditions. It is the purpose of what follows to illustrate the proper application of these formulæ, making use of the results of hydrostatic tests recently made on commercial pipes at one of the mills of the National Tube Company.

Yield Point Tests on Commercial Pipe.—Tests were made under Clavarino's condition, Fig. 2, on 19 specimens of 10in. and 79 specimens of 12in. lap-welded steel pipes, all of which were made up into cylinders with heads welded to the pipe. The hydrostatic pressure was raised until the yield point of the material was reached. The unit stresses on the most strained fibres were then calculated by means of Clavarino's formula, the pipes having been measured by micrometer before welding in the head, to determine the least thickness of wall.

The average results of the yield points of the most strained fibres of the material constituting these pipes, when compared with the average yield point of tensile test specimens cut from about 400 similar pipes, may be summarised as follows:—

Outside diameter of pipe, inches	10·00	12·00
Least thickness of wall, inches	0·172	0·164
Hydrostatic pressure at yield point, lbs. per square inch	1,435	1,195
Yield point by Clavarino's formula, lbs. per square inch	35,600	37,100
Yield point average of tensile tests, lbs. per square inch	37,000	37,000
Apparent error in yield point by Clavarino's formula, per cent....	−3·8	+0·3

This summary of the average results of 474 tests is a very satisfactory confirmation of the accuracy of Clavarino's formula when applied to commercial steel pipes for the conditions under which the formula theoretically applies.

TABLE 3A.—*Bursting Tests of Commercial Tubes and Pipes.*

Size	No. of Pieces Burst	Nominal External Diameter, In.	Average Thickness of Walls, In.	Bursting Pressure Pounds per Square Inch			Head Condition*	No. Burst by Failure of Material not at Weld	Average Fiber Stress by Barlow's Formula	Class of Material
				Minimum	Maximum	Average				
				Steel, Butt-Welded						
⅛	10	0.405	0.066	11840	17320	14266	C	[illegible]	44011	Standard pipe
¼	10	0.540	0.085	8830	14680	12206	C	1	38645	Standard pipe
⅜	10	0.675	0.088	5850	13030	10330	C	1	39272	Standard pipe
½	10	0.840	0.101	11380	16310	14038	C	0	58163	Standard pipe
¾	10	1.050	0.109	7150	9150	8020	C	0	38657	Standard pipe
1	10	1.315	0.131	4500	8800	6990	C	0	35085	Standard pipe
1¼	10	1.660	1.139	4400	7300	5808	C	0	34603	Standard pipe
1¼	15	1.660	0.140	5500	11900	7700	C	1	45215	Redrawn
1½	10	1.900	0.143	8000	6100	4960	C	0	33031	Standard pipe
2	11	2.375	0.149	3830	6060	4951	C	0	40485	Standard pipe
2½	10	2.875	0.198	4310	5740	5134	C	0	37351	Standard pipe
3	10	3.500	0.204	4650	6370	5398	C	0	46234	Standard pipe
1¼	10	1.660	0.180	7910	14280	10514	C	0	48922	Extra strong
2	10	2.375	0.213	7250	8940	8238	C	0	45935	Extra strong
2	10	2.375	0.220	6160	8920	7661	C	0	41347	Extra strong
2	10	2.375	0.445	8500	18314	14992	C	0	40023	X-X strong
							General average		41686	
				Steel Lap-Welded						
2	10	2.375	0.155	4890	7940	6645	C	1	50962	Standard pipe
2	10	2.375	0.182	4860	10060	7361	C	0	47889	Standard pipe
3	10	3.500	0.210	3830	8200	6368	C	7	53560	Standard pipe
4	10	4.500	0.232	4810	5680	5249	C	1	51462	Standard pipe
5	10	5.563	0.258	3410	5260	4538	C	1	48882	Standard pipe
6	5	6.625	0.275	2450	5210	4088	C	0	49286	Standard pipe
6	5	6.625	0.275	3170	4760	3666	B	0	44106	Standard pipe
10	5	10.750	0.349	3560	4730	4290	C	1	66080	Standard pipe
10	5	10.750	0.347	2770	3940	3396	B	2	52692	Standard pipe
2	10	2.375	0.218	2500	9870	7909	C	0	43254	Extra strong
2	10	2.000	0.108	5100	6560	6062	C	7	55607	Boiler tubes
3	10	3.000	0.112	3220	4860	3967	C	1	52957	Boiler tubes
4	5	4.000	0.135	3640	4070	3810	C	2	56978	Boiler tubes
4	5	4.000	0.136	3720	4040	3914	B	1	57440	Boiler tubes
							General average		52225	

* C = Clavarino conditions, Fig. 2. B = Birnie conditions, Fig. 1.

Other tests show that when the heads are attached to the pipe, as in Fig. 2, it lengthens upon application of an internal fluid pressure and that when the heads are held independently, as in Fig. 1, it shortens in accord respectively with the assumptions which constitute the basis of Clavarino's and Birnie's formulæ regarding change of length under internal fluid pressure.

Applicability of Clavarino's and Birnie's Formulæ.—The above summary of results of tests on pipes shows that Clavarino's formula is applicable to commercial wrought-steel pipe for the conditions shown in Fig. 2, when the yield point of the most strained fibre is not exceeded and the least thickness of wall is accurately known. Tests made at the Watertown Arsenal in 1892, 1893, 1894, 1897, and 1902 on sections of steel guns, show that Birnie's formula for the condition shown in Fig. 1, when applied up to the elastic limit of the most strained fibre, gives results which agree with the results of direct tests that are within the ordinary range of experimental error. These Watertown Arsenal tests were all made on tubes, the material and dimensions of which were uniform to a degree obtainable only by boring and turning from forgings of the choicest portion of selected ingots.

It is apparent that any variation below the nominal or average value in strength of material, thickness of wall and efficiency of joint in welded pipe, or above the nominal in diameter, will give results which err on the side of danger when making use of either Clavarino's or Birnie's formulæ. These formulæ then should be restricted in their use to certain classes of seamless tubes and cylinders and to critical examinations of ordinary tubes, pipes, and cylinders, when exact results are desired and sufficiently accurate data are available.

For all ordinary calculations of strength of commercial tubes, pipes, and cylinders, Barlow's simple approximate formula, equation (5), is preferable.

Bursting Tests of Commercial Tubes and Pipes.—Tables 3A, 3B, and 4 show the average results of several hundred tests of commercial tubes and pipes, all of which were burst by hydrostatic pressure at one of the mills of the National Tube Company. Of these 95 per cent. was made by this company, while 86 per cent. of the wrought iron pipe tested was obtained by purchase in the open market. The average ultimate tensile strength of pipe steel is 57,000lbs. per square inch, whether taken in the direction of rolling or transversely thereto, while that of the seamless steel tested is 60,000lbs. per square inch. No tensile tests were made of the material of the wrought-iron pipes.

TABLE 4.—*Strength of Welds of Commercial Tubes and Pipes, selected from preceding Table of Bursting Tests.*

Size	No. Pieces Bursting in Weld[1]	Average Fiber Stress by Barlow's Formula	Class of Material
	Steel, Butt-Welded		
⅛	9	43938	Standard pipe
¼	9	37777	Standard pipe
⅜	9	38954	Standard pipe
½	10	58163	Standard pipe
¾	10	38657	Standard pipe
1	10	35085	Standard pipe
1¼	10	34603	Standard pipe
1¼	14	45643	Redrawn
1½	10	33031	Standard pipe
2	11	40485	Standard pipe
2½	10	37351	Standard pipe
3	10	46234	Standard pipe
1¼	10	48922	Extra strong
2	10	45935	Extra strong
2	10	41347	Extra Strong
2	10	40023	X X Strong
	General average	41634	
	Steel, Lap-Welded		
2	9	50052	Standard pipe
2	10	47889	Standard pipe
3	3	54510	Standard pipe
4	9	51019	Standard pipe
5	9	48852	Standard pipe
6	10	47026	Standard pipe
10	7	59537	Standard pipe
2	10	43254	Extra Strong
2	3	56933	Boiler tubes
3	9	51980	Boiler tubes
4	7	57521	Boiler tubes
	General average	51688	
	Iron, Butt-Welded		
1¼	7	31136	Standard pipe
1¼	9	30680	Standard pipe
2	8	27323	Standard pipe
1¼	9	27073	Extra strong
	General average	29053	
	Iron, Lap-Welded		
2	9	24581	Standard pipe
2	2	34340	Extra strong
	General average	29461	

1.—These only are included in averages.

An examination of these tables will lead to the following general conclusions: (*a*) In commercial welded pipe the variations in thickness of wall, perfection of weld, &c., give rise to variations in bursting strength of sufficient magnitude to render unnecessary any consideration of Birnie's or Clavarino's condition of head support as shown in Figs. 1 and 2 respectively. (*b*) The relative strengths of steel pipes and tubes, when using Barlow's formula and basing the calculations on average diameter, thickness of wall, and ultimate

tensile strength of material, are as follows: For butt-welded steel pipe, 73 per cent.; for lap-welded steel pipe, 92 per cent.; and for seamless steel tubes, approximately 100 per cent. In steel pipe, then, the strength of the butt-weld is about 80 per cent. of that of the lap-weld. (*c*) The relative

TABLE 3B.—*Bursting Tests of Commercial Tubes and Pipes.*

Size	No. of Pieces Burst	Nominal External Diameter, In.	Average Thickness of Walls, In.	Bursting Pressure Pounds per Square Inch: Minimum	Maximum	Average	Head Condition*	No. Burst by Failure of Material not at Weld	Average Fiber Stress by Barlow's Formula	Class of Material
Steel, Seamless										
2	10	2 000	0 098	5120	6590	6052	*C*	10	61530	Boiler tubes
3	10	3 000	0 112	3940	4730	4272	*C*	10	57075	Boiler tubes
4	6	4 000	0 134	4160	4410	4318	*C*	6	64450	Boiler tubes
4	4	4 000	0 134	4250	4410	4328	*B*	4	64488	Boiler tubes
						General average			61886	
Iron, Butt-Welded										
1¼	10	1 660	0 136	2880	6290	5283	*C*	3	32126	Standard pipe
1¼	10	1 660	0 136	3640	5680	4891	*C*	1	29817	Standard pipe
2	10	2 375	0 156	2930	4250	3687	*C*	2	28051	Standard pipe
1¼	10	1 660	0 188	2770	7330	5895	*C*	1	26678	Extra strong
						General average			29168	
Iron, Lap-Welded										
2	10	2 375	0 152	2400	3940	3213	*C*	1	25122	Standard pipe
2	10	2 375	0 207	5530	7120	6349	*C*	8	36461	Extra strong
						General average			30792	

* *C* = Clavarino conditions, Fig. 2 *B* = Birnie conditions, Fig. 1

strengths of wrought-iron and steel pipe, from Table III., are as follows: Butt-welded wrought-iron pipe is 70 per cent. as strong as similar butt-welded steel pipe; and lap-welded wrought-iron pipe is 57 per cent. as strong as similar lap-welded steel pipe.

Applicability of Barlow's Formulæ.—Of the five formulæ considered in Part I., that by Barlow is the best suited for all ordinary calculations pertaining to the bursting strength of commercial tubes, pipes, and cylinders. The theoretical

$$\frac{p}{f} = 2\frac{t}{D_1};\quad p = 2f\frac{t}{D_1};\quad t = \tfrac{1}{2}D_1\frac{p}{f};\quad f = \tfrac{1}{2}D\frac{p}{t}$$

where

D_1 = outside diameter, in.

t = average thickness of wall, in.

p = internal fluid pressure, pounds per square inch.

n = safety factor as based on ultimate strength

f = working or safe fibre stress, pounds per square inch.

$= \frac{40{,}000}{n}$ for butt-welded steel pipe.

$= \frac{50{,}000}{n}$ for lap-welded steel pipe.

$= \frac{60{,}000}{n}$ for seamless steel tubes.

$= \frac{28{,}000}{n}$ for wrought-iron pipe.

These average values of f are based on the accompanying tables of bursting tests of commercial tubes and pipes. They are intended for substitution in Barlow's formula in case more exact data for the working fibre stress are not at hand.

GAS ENGINE CONNECTING ROD BOLTS.

AMONGST those whose duty it is to record and analyse the causes of engine breakdowns it is well known that one prolific source of failure in gas-engine practice is fracture of the bolts in connecting rod ends. The principal complaint against this detail is insufficient strength, but this defect may be aggravated when the shank of the bolt is still further weakened by unnecessary cutting away of the metal, as is shown in a gas-engine breakdown recorded in the March issue of "Vulcan," and which is illustrated in the accompanying photo view. It appears, from the account in our contemporary, that a hole had been drilled into the shank of the connecting rod bolt for the reception of a "keep" to prevent the bolt rotating when it was tightened up, and

A CONNECTING ROD BOLT FAILURE AND ITS EFFECTS: VIEWS OF FRACTURED BOLT SHOWING HOLE DRILLED INTO SHANK FOR KEEP.

error on the side of safety resulting from its use will generally not exceed the actual combined error on the side of danger when using either Birnie's or Clavarino's formula, due to the ordinary range of variation in the thickness of wall, strength of the material, &c., when applied to the ordinary commercial product. This is true, at least up to the yield point of the material, for any ratio of thickness of wall to outside diameter less than three-tenths. In this respect Barlow's formula is very superior to the common approximate formula which gives errors that are absurdly large on the side of danger for very thick walls (Fig. 4).

For all ordinary calculations, then, pertaining to the bursting strength of commercial tubes, pipes, and cylinders use Barlow's formula* (equation [5]).

* For certain classes of seamless tubes and cylinders and for critical examination of welded pipe, where the least thickness of wall, yield point of material, &c., are known with accuracy and close results are desired, see Clavarino's formula and Birnie's equations (7) and (10).

instead of drilling a small hole into the head of the bolt parallel to the axis and driving in a small pin, a hole was drilled into the shank of the bolt at right angles close to the head. This materially reduced the sectional area on a section which was naturally weak owing to change of section. It was this defect which, unfortunately, led to the complete breakdown of the engine.

NOTES ON POWER STATION WORKING.

BY J. W. JACKSON.

IN the course of a paper on power station working read before the Newcastle section of the Institution of Electrical Engineers, Mr. J. W. Jackson stated that a few years ago one of our leading consulting engineers remarked that the difficulties to be dealt with in the future would be on the mechanical rather than on the electrical side. In view of the fact that

there was a serious amount of electrical difficulty and breakdown at that time, many engineers considered that the statement was not at all likely to be confirmed, and yet to-day we find that the mechanical side of a station requires exactly the same close attention that it always did, while the electrical side very much more nearly took care of itself. The immediate future should intensify this difference still further when it was remembered that switchboards were being built of the iron-clad type. The present-day design of high-class oil switch appeared to be not far from perfection. The protection gear for the cables was also working out in much the same way. A few years ago a breakdown on a big system would seriously affect a good deal of that system, and often the whole of it. To-day we found balanced protective relay gear of a high discriminating value, so much so that when cables broke down it was seldom that any other portion of the system was affected than that fed by the particular cable. Even this difficulty was reduced where anything approaching a ring main was in service. Further, because the relay gear had become so discriminating the present-day oil switches were made to operate at such a high rate of speed that the shock to the generating station became comparatively small. This point was borne out by the evidence of the breakdown of the cable. Faults on cables were often difficult to locate because the rupture on the broken-down portion was such a small one that it often sealed itself up again, whereas in the past there was little chance of a cable again becoming insulated.

On the mechanical side a real advance had, he observed, been made in steam turbo-alternator design and operation, and there were distinct possibilities of further improvement. Short turbines had many advantages over long ones, some important ones being that they were cheaper to build, safer at fine clearances, they were no less efficient if run at suitable speed, and they could deal with highly-superheated steam. The difficulties of the pure reaction type were due to increased length with size, coupled with fine clearances, both of which were necessary to give the maximum possible efficiency. This made unwieldy machines above a certain capacity. Above a certain sized alternator the speed must be reduced, thus necessitating a turbine still bigger and longer. The solution of this point had been found in splitting the machines, making two turbines instead of one, one high pressure and one low pressure. This was where the "impulse-compounded" and the "impulse-reaction" types came in, because they shortened down the machine to a reasonable length and allowed of it being built inside one casing. It would appear from present practice that the turbines to meet general commercial purposes most successfully must be of the mixed type, namely, of the reaction and impulse types combined, the favourite design at present being known as the "disc" and "drum."

Dealing next with condensers, he said that several different types had been put on the market in recent years. These different types had become necessary owing to the demand of the turbine for superior vacuum. It had now been found possible to design a condenser so that the section of its effective body was of the shape of an isosceles triangle. One very successful condenser of this type was on the triangular principle, but was arranged in the usual circular body so that the triangle was cut up into three portions. This might have some slight disadvantage owing to the change in direction of the steam in going from one section to the other. The particular advantage which this condenser offered was that with a first cost little more than for a simple condenser, it allowed of the condensed water being withdrawn at a temperature within a few degrees of the exhaust steam entering. Condensers were working showing a difference between the two temperatures of only 3° Fah., while producing a vacuum of about 1·25in. to 1in. mercury of absolute pressure. With the simple type of condenser the same vacuum could be obtained, but the condensed water was of a temperature from 20° to 30° lower than that of the exhaust steam entering.

The centrifugal pump was being applied to work that a few years ago would have seemed impossible, and it seemed certain that for nearly all purposes it would, in the author's opinion, displace the ram pump. The efficiency of the modern centrifugal pump was very high, the maintenance charges were low, and the reliability was considerable. The main reason for this was that the centrifugal pump took its water in a manner that was almost entirely free from shock. Centrifugal pumps were now being applied to a very much more difficult class of work, namely, that of extracting the condensed water from condensers operating under high vacuum. A very short time ago this would have been considered quite impossible. A still later development of the centrifugal pump was the rotary air pump. Owing to its special design of impeller and casing, it could build up a vacuum and give better all-round results than the old-fashioned plunger pump. This rotary type of air pump could be made of generous capacity for its work and yet occupy a small space. Centrifugal pumps had also for some years been used for pumping the feed water into boilers, and for this work it was, he considered, difficult to imagine a better type.

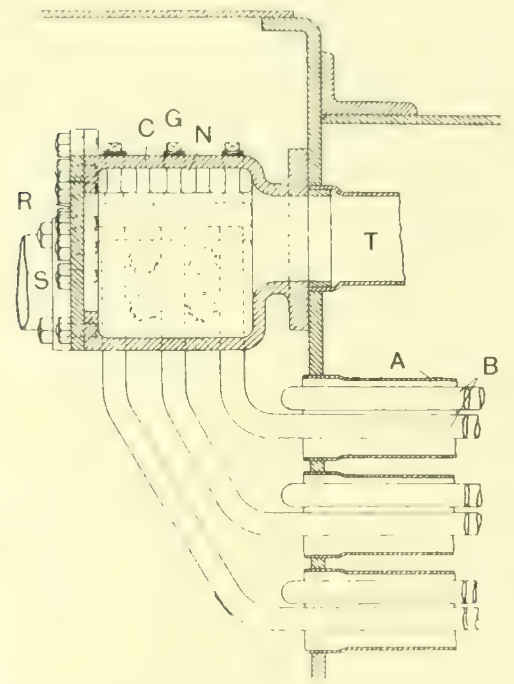
Referring to the steam generating portion of a power station, he remarked that although alterations had been made in the design of boilers in recent years, no great increase in economy had been effected. Calculations readily showed the reason for this, and did not hold out much hope of further improvement over what had already been obtained. It was true that further proposals had been made to work a boiler with high speed of gases, by means of which the flue temperature was reduced below 212° Fah., thus utilising the latent heat of the steam in the gases. One of the greatest troubles with boiler operation to-day was the same as it was 50 years ago, namely, that of admitting just the right quantity of air to the fuel to allow of complete combustion taking place. For general all-round work a boiler with straight tubes undoubtedly gave the least trouble, and the boiler with straight tubes that were nearly vertical must surely be the best for all-round purposes. With the best of boiler arrangements and feed-water filters, a considerable amount of mud was found in the water as a result of the completion of the water-softening taking place in the boiler. With straight vertical tubes this mud had a chance of slipping into the bottom drum, which should be of fairly large capacity. The other great advantage with a vertical tube was that it did not offer a surface that soot could readily cling to. The gas path among the tubes could be so arranged that the gas temperature was reduced to an equally low value with any type of boiler. This type of boiler called for a number of drums into which the tubes were expanded directly, and this arrangement had much fewer joints to make and keep tight than most of the various horizontal tube boilers. This made inspection a comparatively simple job. A straight-tube boiler had a considerable advantage over a bent-tube boiler of almost any make. For replacement a comparatively small stock of tubes was needed, and further, all straight-tube boilers usually had tubes of the same diameter and length, whereas with bent-tube boilers an almost equal number of each type of tube need to be kept in stock, some boilers having as many as 20 different types of tubes.

An important advance in boiler work had been made with economisers, and with an economiser of ample size it was now possible to obtain overall boiler and economiser efficiencies as high as 85 per cent. Close attention to economisers was well repaid in prolonging the life of the metal, as well as in keeping the economiser casing airtight. By looking after air leaks on a boiler and economiser combined in regular commercial service it was possible to reduce heat losses going up the chimney to about 10 per cent., whereas a neglect of precautions would allow these losses to rise to as much as 30 per cent.

New stoker gear was continually being put on the market with improvements made to meet varying conditions. There appeared to be very few stokers on the market that would burn any class of coal under varying conditions with equal efficiency. Some coals burnt quite readily without furnace arches at all; others required short arches with air admitted between the coal and the arch, and others, again, required specially long arches and would not bear any extra air over the fuel bed. Therefore each coal required a set of conditions which would be settled by its particular requirements. Furnace linings had always given a considerable amount of trouble, and it was still a very difficult matter to find the firebrick that would withstand satisfactorily the high temperatures desired for high-efficiency working. Many manufacturers of first-class firebricks would not guarantee their firebricks to withstand a working temperature of 3,200° Fah., and very few bricks indeed would withstand a temperature of 3,500° Fah.

SUPERHEATER FOR LOCOMOTIVE AND MARINE BOILERS.

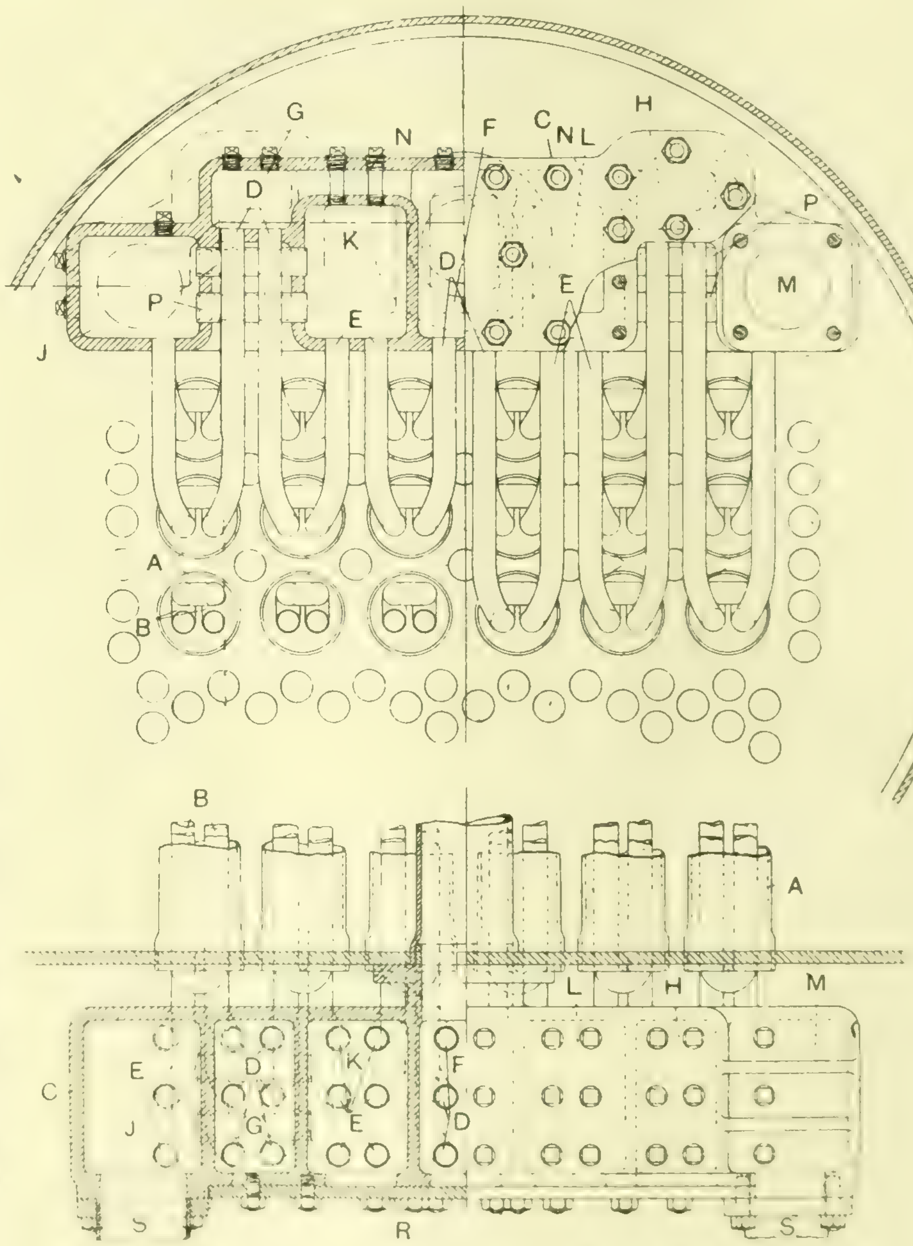
The accompanying illustrations show a design of superheater for locomotive, marine, and other similar boilers, the joint invention of Mr. E. S. Luard and Mr. John G. Robinson, Boothdale, Fairfield, Manchester. The steam superheating pipes B, four of which form an element and extend into each of the enlarged smoke tubes A, are provided with return bends at their ends. The ends of the superheater pipes B, which project into the smokebox, are bent upwardly to the header C. D and E indicate, respectively, the saturated steam inlet end and the superheated steam outlet end of each superheater element. The header C is formed with saturated steam compartments F, G, and H, and with superheated steam compartments or chambers J, K, L, and M, these



several compartments being arranged side by side and transversely of the header so that the saturated and superheated steam compartments alternate in the header. The two end or outer saturated steam compartments G and H of the header are formed in the upper part of the header and at a higher level than the remaining steam compartments of the header, these compartments G and H being connected to the central saturated steam compartment F and also to each other by means of passages N formed in the upper part of the header and extending across the tops of the superheated steam compartments K and L.

The superheated steam compartments J and K and the superheated steam compartments L and M are connected by short transverse tubes P. In the top of the header C there are provided a number of holes which are opposite to the holes in the bottom tube plate of the header, so that the tube expanding mandril can be introduced into the header through the top holes. Screwed plugs are provided for closing the holes in the top of the header. R is the removable cover of the header which when placed on the front of the header closes the open front ends of all the steam compartments in the header with the exception of the end superheated steam compartments J M, to which latter compartments are connected the main steam pipes S to the cylinder valve chests of the engine. Saturated steam from the steam dome or source of supply passes to the superheater header C through the pipe T. Screwed plugs are inserted in screwed holes in the end walls of the header and in alignment with the outer ends of the small cross tubes P, through which holes a tube expanding mandril may be introduced for the purpose of expanding the outer ends of the cross tubes in the header.

With the superheater in action saturated steam enters the central saturated steam compartment F of the header through the pipe T, and also enters the saturated steam compartments G and H through the passages N in the header. The saturated steam then passes through each of the superheater pipe ends D into and circulates through the horizontal portions of each superheater element or pipe B, the highly superheated steam leaving the elements and passing into the superheated steam compartments J, K and L, M of the header through the superheated steam outlet ends E of the superheater pipes, the superheated steam passing out of the header through the end compartments J, M into the main steam pipes to the valve chests of the engine. Owing to the provision of the short cross tubes P, any reduction in temperature of the superheated steam in the superheated steam compartments of the header—due to the walls of compartments being contiguous to or forming also the walls of the



Superheater for Locomotive and Marine Boilers.

saturated steam compartments—is compensated or more than compensated by the hot gases issuing from the smoke or fire tubes of the boiler acting upon the small cross tubes, thus rendering the superheater highly efficient. The provision of the removable cover R on the header provides for easy access to the steam compartments of the header, and not only enables the interior of the header to be readily inspected, but also enables the superheater pipe ends to be easily and quickly secured in the header, and also enables the pipes to be easily and quickly withdrawn from the header whenever it becomes necessary to do so. By disconnecting the steam pipe flanges and steam pipes S from the header, access is obtained to the end superheated steam compartments J and M. A damper box with damper (which may be of the louvre plate or other suitable kind) is mounted in the smokebox, so as to enclose the bent ends D, E of the superheater elements or pipes B.

AUXILIARY MACHINERY FOR INTERNAL-COMBUSTION ENGINED VESSELS.*

BY W. R. CUMMINS.

THE past year has seen several important developments in marine oil engines of considerable power. All the larger and more important work has been designed by our competitors on the other side of the German Ocean. British firms appear to be sitting on the fence waiting to see how these experiments will turn out. It is to be hoped they will not sit there too long, and that when they do get down on the other side they will profit by the experience of their rivals and be able to go one better.

The auxiliary machinery on board a modern vessel is of such varied character and has to fulfil so many different conditions that the problem of applying a suitable motive power is of some difficulty. It is of course desirable, if not necessary, that the same motive power should be used throughout the ship. In the case of steam, with its great flexibility, very few difficulties are met in adapting it to drive the various types of machinery, or perhaps it would be more correct to say that any difficulties which arose in the past have been overcome long since.

It will be useful at this stage to give a list of all the auxiliary machinery required for, say, a moderate-sized liner, carrying passengers. (1) Starting engine; (2) jacket water circulation pump; (3) oil service pumps where oil fuel is used; (4) gas cooling pumps where producer gas is used; (5) gas scrubbing pumps or gear (if necessary); (6) producer water pump; (7) bilge pumps; (8) ballast pumps; (9) sanitary pumps; (10) fire pumps; (11) hydraulic pumps for water-tight doors; (12) fresh water pumps; (13) electric light dynamos; (14) steering engine; (15) deck winches and hoists; (16) windlass; (17) ventilating fans; (18) refrigerating engine; (19) siren and whistle; (20) fresh-water distiller.

In addition to the above, a certain amount of heat is required for heating and cooking purposes, and also a certain amount of power for small labour-saving machinery. We will first consider, as seems most natural, the starting engine, and it will be taken for granted that the main engines will be coupled direct to the propeller shafting without the intervention of clutches of any kind, mechanical, electric, or hydraulic. Recent practice appears to favour this direct coupling for engines of any but the smallest size. Some type of clutch is useful for motor boats and other small craft to allow of hand starting.

There are two methods of applying a starting force to the crank shaft, the first being to utilise the power cylinders themselves, air or gas under pressure being distributed by the ordinary or special valves. In the second method the starting engine may be coupled to the engine shafting, mechanically, hydraulically, or electrically during the manœuvring periods. The first system is most in favour at the present time.

A great many complicated contrivances have been designed to make the 4-stroke engine to reverse and to start in either direction, but as the 4-stroke engine for marine purposes is dying a natural death, there is no need to go further into these schemes. In the case of 2-stroke engines the problem is simplified, as the outlet of the starting air from the cylinder takes place through the exhaust ports, and only the air inlet has to be provided for.

It is usual to work the air inlet valves from a cam shaft, with one set of cams arranged for ahead and another set for astern gear, the cam shaft being moved longitudinally to bring either set of cams to operate the valve spindles. This arrangement involves lifting the valve spindles or lowering the cam shaft before it is moved longitudinally. The arrangement adopted by the M.A.N. in their Diesel engines is preferable in that they use two starting valves to each cylinder, one for ahead and the other for astern. The cam shaft has two sets of cams, either of which is made to operate the valves by the insertion of a finger-piece between the cam and the valve spindle. This system involves two starting valves in the cylinder head in addition to the inlet valve, thus adding to the risk of leakage, and it must always be remembered that leaky valves in a Diesel engine mean disablement.

There are, generally speaking, many disadvantages in using the power cylinder as a starting cylinder, as while it is employed in starting it cannot undertake its normal functions. In addition to this, in 2-stroke engines the exhaust ports open at about 85 per cent. of the stroke, so that the last 15 per cent. of the stroke is not available for starting. In the system patented by the writer the bottom end of the power cylinder is closed and used as a scavenging and cushioning cylinder. The starting air is admitted to this bottom end of the cylinder, thus leaving the top end of the cylinder free to take up its normal functions immediately the engines are started up.

The second system of starting has not been used up to the present. So far as the writer is aware, it is a development of the system as used for starting up the engines of motor-cars and motor-boats, with the difference that engine or other power is used instead of hand power. The starting motor would be geared by chain or spur gearing to a friction clutch on the main engine shaft, this clutch being in gear only when manœuvring. The starting motor would be reversing and able to start from any position. It might be worked: (1) pneumatically; (2) hydraulically; (3) electrically.

Passing on to the various pumps as given in the list of auxiliaries, with the exception of the hydraulic pumps for the water-tight doors and the fire pumps, all deliver at a comparatively small head. For this duty electrically driven, direct

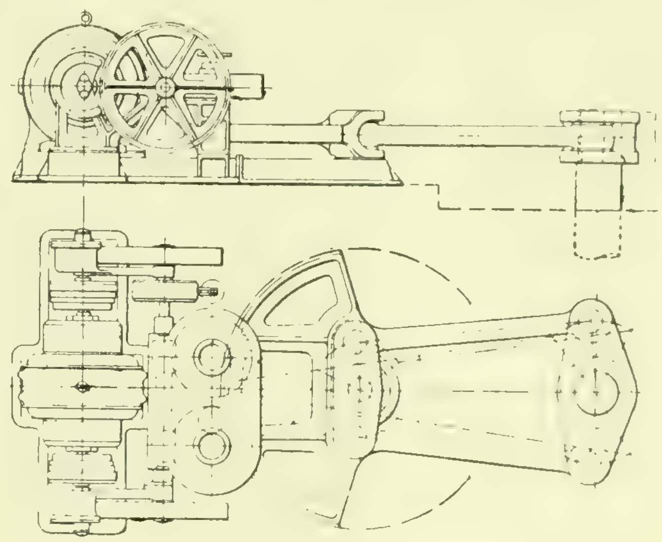


FIG. 1.

coupled, single stage centrifugal pumps will be far and away the most efficient combination. Centrifugal pumps have been greatly improved of late years as regards their hydraulic efficiency. Their extreme simplicity, freedom from breakdown and small upkeep cost make them ideal pumps for the various water-lifting and circulating duties required on board. It may be mentioned here that the electric motor and the centrifugal pump suit each other as regards speed, and that no damage can be done to the motor or the pump even if the discharge valve be closed when the pump is going full bore, and, further, no escape valves are required. Another point in favour of the electrical drive is that the amount of current taken by the motor adjusts itself to the duty being done by the pump.

The hydraulic pumps for the water-tight doors might quite easily be driven by electric motor and gearing, or on the other hand would work just as well with compressed air as with steam. The fire pumps could be of the centrifugal multi-stage type, driven direct by electric motor. These multi-stage pumps have been developed in recent years by continental makers and are highly efficient.

Coming to the ventilating fans, of which a large number are required in the passenger accommodation, besides those in the machinery space, the electric drive is also in this case the most economical and suitable in every respect.

So far it has been easy going, and we now come to the steering engine, which presents a knotty problem. The present-day steam steering engine, the result of many years' experience, is a very reliable piece of machinery, and deals successfully with the heavy and variable stresses which come on the gear in a seaway. They are, however, not economical machines, and the friction of the usual slow pitch worm added to that of the thrust collars gives a low mechanical efficiency.

* Paper read before the Institute of Marine Engineers, January 15th, 1912.

This, combined with the leak past the control valve, makes them rather extravagant in steam consumption. An easy solution of the problem would be to use compressed air in place of steam, thus utilising the present standard engines.

It is a sign of the times that many engineering firms who make a speciality of ship's auxiliary machinery are now devoting their attention to electrical and hydraulic driving. Through the courtesy of Mr. B. P. Haigh, the writer is enabled to describe an electrical steering engine of Mr. Haigh's design (Figs. 1 and 2). The experimental gear was made by Messrs. Brown Bros. & Co.

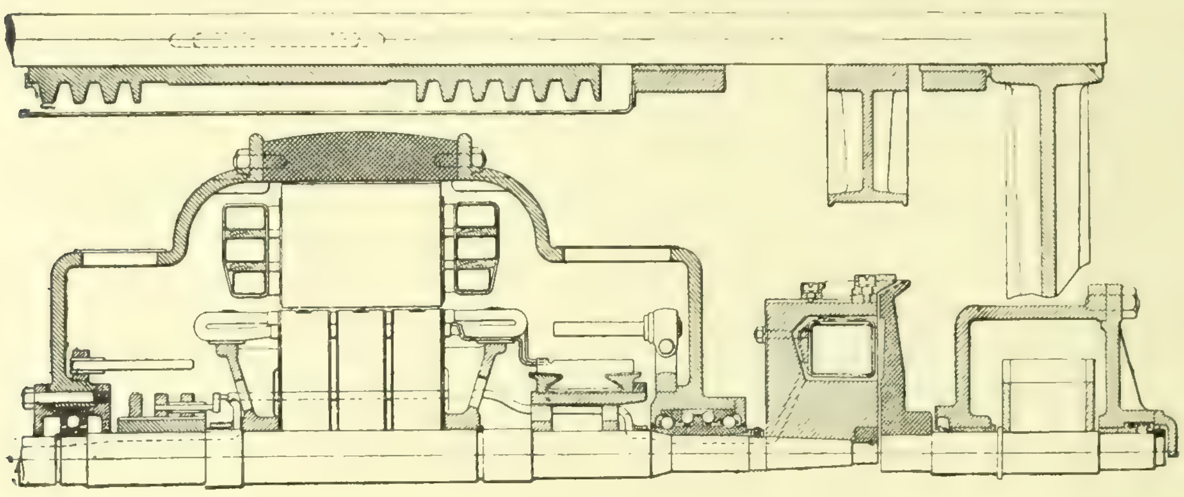


FIG. 2.

The motor runs continuously in one direction only, and there is a magnetic clutch at each end of the armature spindle, the engagement of one clutch giving port helm and the engagement of the other starboard helm. The motion of either clutch is transmitted through suitable gear to a worm shaft having two worms engaging wheels so arranged that the worm thrusts balance one another. The worm wheel shafts carry pinions which engage with a quadrant rack connected to the rudder head in the usual manner by two connecting rods.

One of the chief points to be guarded against in electrical drives is that of overloading the motor. If the steam engine of a steam steering gear were to get out of control and put the rudder up against the stops, or if a heavy sea struck the rudder, the engine would just pull up, no damage would be done, and the engine would start up again when the excessive load was removed. In the case of a motor, if it were pulled up dead it would burn out if no overload cut out were provided. In Mr. Haigh's gear any ordinary excess load would be eased by the slipping of the clutch, and any extraordinary excess current is arranged to break the circuit of the magnetic clutch, the circuit being again completed when the excessive load is removed.

Messrs. Clarke, Chapman, & Co., of Gateshead, manufacture another type of electric steering gear of which the writer is enabled by their courtesy to give the following particulars. The motor is of the reversing type, and runs in one direction for port helm and in the other for starboard helm. The steering wheel works the control gear starting the motor, and the usual "hunting" gear stops the motor when the helm has answered the movement of the steering wheel. On this gear an overload cut out will be required to deal with excessive rudder resistance, which will entail the stoppage of the motor until the cut out is put in again.

Messrs. Brown Bros. & Co. are now perfecting a combined electric and hydraulic steering gear. The electric motor runs continuously and operates two crank shafts, which in their turn work ram pumps which discharge into hydraulic cylinders controlling the position of the tiller. The novelty of the gear consists in the arrangement by which the two crank shafts, although always coupled together, may be put into different phase with one another. By this means the ram pumps worked by the crank shaft may work one against the other, each pump on its suction stroke taking its neighbour's discharge, in which case no pumping action takes place. The phase of the crank shafts may also be arranged that the ram pumps assist each other, each contributing its full output, in which case the pumping action is at its maximum. Any intermediate output can be obtained by altering the phase of the crank shafts.

Another combined electric and hydraulic gear is that invented by Dr. Hele-Shaw and Mr. Leigh Martineau. Through the courtesy of Messrs. John Hastie & Co., of Greenock, I am able to illustrate this gear (Fig. 3). It will be seen that the novelty in this gear consists in the variable output of the rotary pump which is effected by the movement of the pump case. Not only is the pump output varied by this movement, but the pump suction and discharge are also reversed so that the pump can be connected directly to the two hydraulic cylinders controlling the tiller without any immediate mechanism.

The windlass presents somewhat similar difficulties as regards driving as the steering gear. It must have brute force, but does not require delicate control like the steering gear. Compressed air would be a satisfactory way of working it, as it would have all the flexibility and reliability of steam. Messrs. Clarke, Chapman, and Co. also make an electrical windlass, in which a worm drive is employed, which will to a great extent protect the motor from undue loads, but in addition to this the usual overload cut out is fitted.

The cargo winches and cranes may be worked by compressed air or electrically. As an alternative the cargo could be worked by hydraulic power. Hydraulically-driven cargo hoists have many advantages, the chief being their noiselessness and small upkeep cost.

There is, of course, no difficulty about the electric light dynamo. It would be coupled direct to a high-speed oil or gas engine, as the case might be. The pumps and ventilating fans would all be driven by this same dynamo. The refrigerating engine could be driven electrically or by compressed air, but in the case of a vessel carrying frozen cargoes, a separate plant would be required, the compressors being direct coupled to oil or gas engines.

The siren and whistle could be worked by compressed air, which would be cleaner and more convenient than steam, as there would be no trouble from condensation. The fresh water distiller presents no difficulties, as there is plenty of

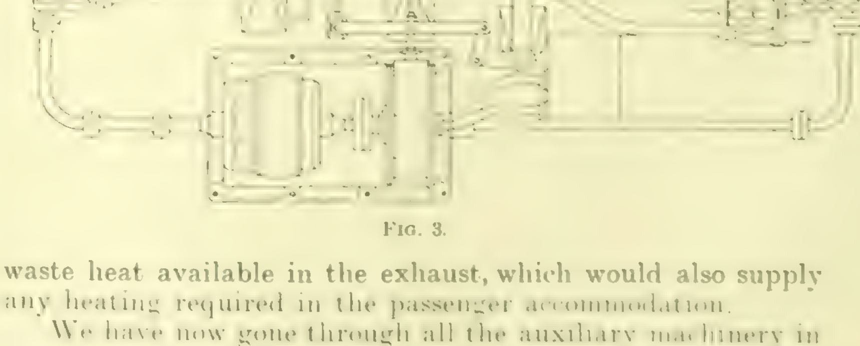


FIG. 3.

waste heat available in the exhaust, which would also supply any heating required in the passenger accommodation.

We have now gone through all the auxiliary machinery in detail, and it will have been seen that either of the three systems of power transmission, *i.e.*, electricity, compressed air, or water under pressure, could be used to operate the auxiliary machinery, and we can now consider each system on its merits, taking into account the factors of (1) Reliability, (2) efficiency as a power transmission system, (3) flexibility, (4) adaptability for power storage.

At the same time it is important to keep in view the desirability of having one system only if at all possible. As electric light is one of the necessities of the case electricity will be dealt with first. As regards reliability, the present-day electrical machinery as manufactured by responsible firms

is quite reliable and suitable for use on board ship. As a power transmission system electricity is very efficient, good motors and dynamos having efficiencies up to 90 per cent. and over. The line losses for the comparatively short leads on board ship are trifling. One of the great advantages of electric transmission is the fact that the motor takes just as much current from the line as is required from the work to be done, so that good efficiencies are obtained at low loads. No precautions are necessary to provide against frost, and the

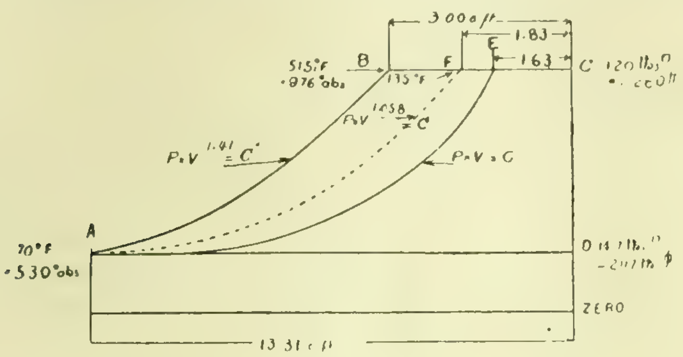


FIG. 4.

wiring can be led through places where pipework would not be permissible. We can say, therefore, that an electrical transmission system would have an over-all efficiency of about 75 per cent. at full load, reckoning from the brake horsepower of the auxiliary driving engine to the brake horsepower of the driven motor.

Two systems could be used for the electrical starting of the main engines. In the first, a reversing motor could be geared by chain or spur gearing to a friction clutch on the main shafting. The starting switch of the motor would be operated along with the clutch gear, and so arranged that the motor would get a flying start before the friction clutch came into gear. On the second system, the armature of the starting motor would be mounted direct on the shaft, and no friction clutch would be required. The winding of the motor would be arranged to give a large starting torque, and the commutator brushes would be raised clear when manœuvring was completed. The disadvantages of this system would be the large size and expense of a motor to give the necessary starting torque.

Direct current would probably be the most satisfactory for the purpose, but perhaps some of our electrical expert members could say whether the more robust alternating motor could be applied. This system would permit of all the auxiliary work being done electrically. The only practical method of storage would be by accumulators, which are expensive and unsatisfactory for ship use.

Coming next to the compressed air system, there would be a gas or oil driven air compressor delivering to a storage receiver for use when manœuvring. The compressed air would be used for starting the main engines by admission direct to the power cylinders or by means of a compressed air reversing motor coupled by gearing or chain to a clutch on the main shaft. The winches and windlass would also be worked by compressed air, but the steering gear, pumps, fans, and all other small machinery by current from a gas or oil driven dynamo. This arrangement would lend itself to economical working, as the compressed air portion would only be in use when in port and manœuvring, and the electric portion would have a practically constant load. The compressed air would be quite as reliable as steam, and perfectly suitable for the rough work of the winches and windlass.

As regards efficiency as a power transmission system, the usual methods of working compressed air do not give economical results for two reasons, viz.: (1) The air is not compressed isothermally, the consequence being that a great deal more power is required for the adiabatic, or nearly adiabatic compression; and (2) the compressed air cannot be used expansively as the moisture contained in it freezes, and the cylinders and valves get cut up, and the passages choked by the ice thus formed. If the air after being adiabatically compressed could be used at once before it lost any of its heat, then expansive working could be used in the motor without the formation of ice, but in practice this is difficult to attain, as the compressor cylinder must be jacketed for practical reasons, and a sufficient lagging of the piping to prevent any appreciable loss of heat would be very expensive. Two methods are used to diminish the power required for the compression process. In the first, water is injected into the air before compression, and in the second, the compression is effected in stages, and the air is cooled when passing from the low pressure to the high pressure stage. In both cases the cylinders are provided with water jackets, which have of course considerable cooling effect. The heating of the cold compressed air before being used in the cylinders of the motor is also practised, an example of which is afforded by torpedo work, where petrol is used to give the necessary heat. A marked increase of economy has been attained by this process.

In a gas or oil driven compressor there is a certain amount of heat available in the exhaust which can be transferred to the compressed air. The writer's suggestion is to use water injection in the water-jacketed cylinders of the compressor in order to get as nearly isothermal compression as possible, and then pass the compressed air through a coil heated by the exhaust gases. As the compressed air pressure need not be more than about 100lbs. per square inch, it is proposed to use single stage compression for the sake of simplicity. To get an idea of the overall efficiency to be expected, it will be convenient to take a numerical example.

A B C D (Fig. 4) represents the theoretical diagram for adiabatic compression, vertical ordinates representing pressures in pounds per square foot, and horizontal ordinates representing volumes in cubic feet. Then for adiabatic compression of air the equation to the curve A B is $P \times V^{1.41} = C$. A E C D is the theoretical diagram for isothermal compression, and the equation to the curve A E is $P \times V = C$. The volume of 1lb. air at 70° Fah. is $\frac{12 \cdot 38 \times 530}{493} = 13 \cdot 31$ cub. ft. The temperature at B on the end of adiabatic compression would be $530 \left(\frac{120}{14 \cdot 7}\right)^{\cdot 29} = 976°$ abs. and the volume B C would be

$$\frac{13 \cdot 31}{\left(\frac{120}{14 \cdot 7}\right)^{\cdot 71}} = 3 \cdot 00 \text{ cub. ft.}$$

With isothermal compression the temperature at E will be 530° abs. and the volume E C will be

$$\frac{13 \cdot 31 \times 14 \cdot 7}{120} = 1 \cdot 63 \text{ cub. ft.}$$

The work done in compressing the air adiabatically from atmospheric pressure to 120lbs. absolute will be

$$P_1 V_1 + \frac{P_1 V_1 - P_2 V_2}{\cdot 41} - P_2 V_2 = 81{,}370 \text{ft.-lbs.},$$

equivalent to 105·4 B.T.U.

The work done, if the air were compressed isothermally, would be

$$P_1 V_1 \left(1 + \log. E \frac{V_2}{V_1}\right) - P_2 V_2 = 58{,}846 \text{ft.-lbs.},$$

equivalent to 76·2 B.T.U.

The adiabatic compression, it will be seen, has raised the

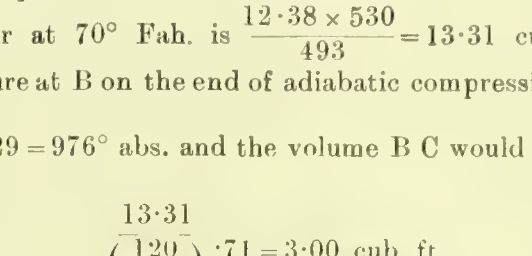


FIG. 5.

temperature of the air 115° Fah., entailing extra work to the tune of 1·38 times that of isothermal compression.

The most convenient method of applying the injection water for cooling the air during compression will be to let it first circulate through the jacket and then be passed on to an atomiser of the scent-spray type fixed in the air inlet pipe.

It will be assumed that each pound of air will be able to carry in suspension ·15lb. of water.

Perfectly isothermal compression is, of course, impracticable, and it will be assumed that the temperature after compression will be 135° Fah.

The extra amount of heat in each pound of air over and above what it would contain if isothermally compressed will be (135 – 70) × ·237 = 15·4 B.T.U.

The heat developed by adiabatic compression is 105·4 – 76·2 = 29·2 B.T.U.

29·2 – 15·4 = 13·8 B.T.U. to be taken up by the water.

·15lb. of water raised from, say, 50° to 135° will take up 12·75 B.T.U., and the balance will be taken up by extra flow through the jacket.

We have, therefore, at the end of compression 1lb. of air and ·15lb. water at 135° Fah.

The volume of the air at 135° will be

$$\frac{1 \cdot 63 \times 596}{530} = 1 \cdot 83 \text{ cub. ft.}$$

We can determine the curve joining A and F roughly from the value of P and V at A and at F, from which we get

$$P \times V^{1 \cdot 058} = C.$$

Work done in compressing:—

$$- P_1V_1 + \frac{P_1V_1 - P_2V_2}{\cdot 058} - P_2V_2 = 62{,}557 \text{ft.-lbs.,}$$

equivalent to 81·03 B.T.U., which is only 1·06 times the work of isothermal compression.

	Ft.-lbs.		B.T.U.
Adiabatic compression	= 81,343	...	105·40
With jacket and ·15lb. injected	= 62,557	...	81·03
Isothermal	= 58,846	...	76·20

We can now proceed to calculate what heat is available from the exhaust, and how much of it can be utilised for heating the air before it is put to do work.

In modern gas and oil engines of the total heat of combustion of the gas or oil as delivered to the engine, about 35 per cent. is turned into work, 20 per cent. is carried away by the jacket water, and about 35 per cent. by the exhaust, so we can assume that the amount of heat going away in the exhaust is equal to the amount of heat turned into work.

In our case the work done on 1lb. air is 62,577ft.-lbs., equivalent to 81·03 B.T.U. With an overall efficiency of 85 per cent., the work done in the power cylinder will be 95·3 B.T.U.

The temperature of the compressed air is 135° Fah., and that of the exhaust will be, say, 500° Fah.

Assuming that the exhaust temperature as it leaves the heater will be 235° Fah., we shall have $95 \cdot 3 \times \frac{500 - 235}{500} = 50$ B.T.U. available.

1lb. air raised from 135° to say 250° takes					30·2 B.T.U.
·15lb. water	,,	,,	,,	,,	17·2 B.T.U.
Total	...	...	...		47·4

The balance will allow for radiation losses.

We can now proceed with the expansion diagram. J, K, L, M, N (Fig. 5) will represent the work obtained from the air.

The volume J K will be

$$\frac{1 \cdot 83 \times 696}{596} = 2 \cdot 13 \text{ cub. ft.}$$

We will fix the temperature at end of expansion at L as 50° Fah. to prevent any chance of freezing.

This will fix the ratio of expansion

$$V_2 = V_1 \left(\frac{T_1}{T_2}\right)^{2 \cdot 45} \text{ from which } V_2 = 4 \cdot 51$$

$$\text{and } P_2 = P_1 \left(\frac{V_1}{V_2}\right)^{1 \cdot 41} \text{ from which } P_2 = 50 \cdot 8 \text{lbs.}$$

The work done as per the diagram J K L M N is 35,968ft.-lbs., equivalent to 46·5 B.T.U.

We have thus expended in the power cylinder 95·3 B.T.U. and obtained in the motor cylinder 46·5 B.T.U., an efficiency of about 48 per cent. This efficiency would be improved if more heat were available for heating the air, which would be the case if other auxiliaries (such as the electric dynamo) were being run. As regards storage the compressed air system has many advantages, and suitable reservoirs are cheap to manufacture, and are not very bulky. When working the winches and windlass a large storage of power would not be necessary, as the auxiliary engine would run continuously when cargo was being dealt with. The engine would also be kept running when manœuvring, so that the receiver capacity need only be sufficient for an emergency manœuvre.

There remains the purely hydraulic system to consider, but as this is so very inefficient at low loads, it does not appear to offer any advantages. It is, however, not a flexible system, and there is the trouble of leading heavy pressure flow and return pipes in exposed positions on deck. There would also be difficulties in designing a suitable reversing engine to do the manœuvring, and the storage accumulator would be bulky and inconvenient.

DETERMINING SIZE OF SPIRAL SPRINGS.

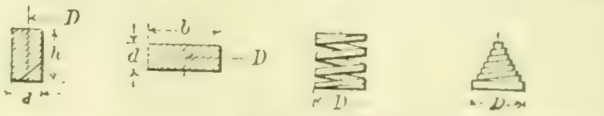
A METHOD of determining the size of spiral springs is given by H. Al. Siebeck in a recent issue of "Zeits. des Vereines deutscher Ingenieure," and we are indebted for the following translation to the Journal of the American Society of Mechanical Engineers. The efficiency of a spring depends on its greatest safe load and greatest steady deflection. The natural starting point for the computation of a helical spring is the extension diagram (Fig. 1) out of which can be obtained (*a*) deflection of a single coil in millimetres; (*b*) greatest safe load P_1 in kilograms which approaches more or less the greatest safe steady load in accordance with the variation in the number of deflections per unit time; (*c*) initial load P in kilograms which may be equal to zero or even negative. $P_1 - P$ represents therefore the actual useful load on the spring, and the coefficient of deflection of the spring k may be expressed as

$$k = \frac{H}{P_1 - P} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Therefore k is the compression or extension of one coil of the spring in millimetres for change of useful load equal to 1 kg. Practice has shown the extreme importance of correct choice of the coefficient of deflection k, and it is advisable to give the deflection diagram of the springs on drawings of machinery where springs are used, to facilitate their test and installation at the shops.

The calculation of springs is considerably simplified by the introduction of a certain relation between the mean diameter

TABLE I.—*Diameter of Wire and number of Coils in Cylindrical and Conical Springs with rectangular cross-section of Wire.*

	The Value of the Greatest Safe Load P_{max} of Table 1 must be multiplied by the Following Numbers *c* for Cylindrical and Conical Springs		The Number of Coils required n'_w with Coefficient of Deflection Unity of Table 1 must be multiplied by the Following Numbers *c*	
				
	h variable *d* constant	*b* variable *d* constant	For Cylindrical Springs	For Conical Springs
Reference Values of *a*	1	1	1	4
a = 1	1·13	1·13	1.41	5·66
a = 1·25	1·41	1·77	2·16	8·63
a = 1·5	1·70	2·55	2·94	11·75
a = 1·75	1·98	3·47	3.73	14·23
a = 2	2·26	4·53	4·53	18·11
a = 2·5	2·83	7·07	6·10	24·39
a = 3	3·40	10.19	7·64	30·56

of the coil D and the diameter of the spring wire d. Let this relation be $c = \frac{D}{d}$. The formula for the greatest safe load of the spring

$$P = \frac{\pi}{8} \frac{d^3}{D} K_d \quad . \; . \; . \; . \; . \; . \; . \quad (2)$$

may then be written in the form

$$P = \frac{\pi}{8} K_d \frac{1}{c} d^2 \quad . \; . \; . \; . \; . \; . \; . \quad (3)$$

The author shows that by accepting the maximum intensity of stress in wire K_d = 4,070 kg./qcm. (57,835lbs. per square inch), he remains always within safe limits; at the same time this allows him to express the formula in the following form, convenient for slide-rule calculations:

$$P = 1600 \frac{1}{c} d^2 \quad . \; . \; . \; . \; . \; . \; . \quad (4)$$

The coefficient of safety S_1 of a spring is often determined in practice from

$$S_1 = 1 + \frac{n_1}{150} \quad . \; . \; . \; . \; . \; . \; . \quad (5)$$

where n_1 is the number of double deflections per minute (or number per minute of deflections in one direction, *i.e.*, number of compressions or expansions).

For the computation of Table I. the author accepted certain standard values of $c = \frac{D}{d}$ as shown in the headline of the table, and $h = 1$.

TABLE II.—*Diameter of Wire and number of Coils in Helical Springs with Circular Cross-section of Wire.*

$\frac{d}{mm}$	$\frac{D}{d}$ = 4	5	6	7	8	9	10	12	14	16	18	20	22.5	25	27.5	30	35	40
	4.0	3 2	2.67	2.29	2.00	1.78	1.60	1.33	1.14	1.00	0.889	0.800	0.711	0.640	0.582	0 533	0.457	0.400
1.0	15.6	8.0	4.63	2 92	1.95	1.37	1.00	0.579	0.364	0.244	0.172	0.125	0.088	0.064	0.048	0 037	0.023	0.016
	9.0	7.2	6.00	5.14	4.50	4.00	3.60	3.00	2.57	2.25	2 00	1.80	1.60	1.44	1.31	1.20	1.03	0.900
1.5	23.4	12.0	6 95	4 37	2 93	2.06	1 50	0.869	0.546	0.366	0.257	0.188	0.132	0.096	0 072	0.056	0.035	0.023
	16.0	12.8	10.7	9.14	8 00	7.11	6.40	5.33	4.57	4.00	3.56	3 20	2.84	2.56	2.33	2.13	1.83	1.60
2 0	31.2	16.0	9.26	5.83	3.90	2.74	2.00	1.16	0.728	0.488	0 343	0.250	0.176	0.128	0.096	0.074	0.047	0 031
	25.0	20.0	16.7	14.3	12.5	11.1	10 0	8.33	7.14	6.25	5 56	5.00	4.44	4.00	3.64	3.33	2.86	2.50
2 5	39.0	20.0	11.6	7.29	4 88	3.43	2.50	1.45	0.910	0.610	0.429	0.313	0.220	0.160	0.120	0.093	0.058	0.039
	36.0	28.8	24.0	20 6	18.0	16.0	14.4	12.0	10.3	9.00	8.00	7.20	6.40	5.76	5.24	4.80	4.11	3.60
3.0	46.8	24.0	13.9	8.75	5.85	4.11	3.00	1.74	1.09	0.732	0.515	0.375	0.263	0.192	0.144	0.111	0.070	0.047
	49.0	39.2	32.7	28.0	24.5	21.8	19.6	16.3	14.0	12.3	10.9	9.80	8.71	7.84	7.13	6.53	5.60	4 90
3 5	54.6	28.0	16.2	10.2	6.83	4.80	3.50	2.03	1.27	0.854	0.600	0 438	0.307	0.224	0.168	0.130	0.082	0.055
	64.0	51.2	42.7	36.6	32.0	28.4	25.6	21.3	18.3	16 0	14.2	12.8	11.4	10.2	9.31	8.53	7.31	6.40
4.0	62.4	32.0	18.5	11.7	7.80	5.48	4.00	2.32	1.46	0.976	0.686	0 500	0.351	0 256	0.192	0.148	0.093	0.062
	81.0	64.8	54.0	46.3	40.5	36.0	32.4	27.0	23.1	20.3	18.0	16.2	14.4	13.0	11.8	10.8	9.26	8.10
4.5	70.2	36.0	20.8	13.1	8.78	6.17	4 50	2.60	1.64	1.10	0.772	0.563	0 395	0.288	0 216	0.167	0.105	0.070
	100	80.0	66.7	57.1	50.0	44.4	40.0	33.3	28 6	25.0	22.2	20.0	17.8	16.0	14 5	13.3	11.4	10.0
5.0	78 0	40 0	23.2	14.6	9.75	6 85	5.00	2.90	1.82	1.22	0.858	0.625	0.439	0.320	0.240	0.185	0.117	0.078
	121	96.8	80.7	69.1	60.5	53.8	48 4	40.3	34.6	30.3	26 9	24.2	21.5	19.4	17.6	16.1	13.8	12.1
5 5	85 8	44 0	25.5	16.0	10.7	7.54	5.50	3.18	2.00	1.34	0.943	0 688	0.473	0.352	0.265	0.204	0.128	0.086
	144	115	96.0	82.3	72.0	64.0	57.6	48.0	41.1	36.0	32.0	28 8	25.6	23 0	20.9	19.2	16.5	14 4
6.0	93.6	48 0	27 8	17.5	11.7	8.22	6.00	3.47	2.18	1.46	1.03	0.750	0.527	0.384	0.289	0.222	0.140	0.094
	169	135	113	96.6	84.5	75.1	67.6	56.3	48.3	42.3	37.6	33.8	30.0	27.0	24.6	22.5	19.3	16 9
6 5	101	52.0	30 1	18 9	12.7	8.91	6.50	3.76	2.37	1.59	1.11	0.813	0.571	0.416	0 313	0 241	0.151	0.101
	196	157	131	112	98.0	87.1	78.4	65.3	56 0	49.0	43 6	39.2	34.8	31.4	28.5	26 1	22.4	19 6
7.0	109	56.0	32 4	20 4	13.7	9.59	7.00	4.05	2.55	1.71	1.20	0.875	0 615	0.448	0.337	0.259	0.163	0.109
	225	180	150	129	113	100	90.0	75.0	64.3	56.3	50.0	45.0	40.0	36.0	32.7	30.0	25.7	22.5
7.5	117	60.0	34.7	21 9	14 6	10.3	7.50	4.34	2.73	1.83	1.29	0.938	0.659	0.480	0.361	0.278	0.175	0.117
	256	205	171	146	128	114	102	85.3	73.1	64.0	56.9	51.2	45 5	41.0	37.2	34.1	29.3	25 6
8 0	125	64.0	37.0	23 3	15 6	11.0	8.00	4.63	2.91	1.95	1.37	1.00	0.702	0.512	0 385	0.296	0.186	0.125
	289	231	193	165	145	128	116	96.3	82 6	72.3	64.2	57.8	51.4	46 2	42.0	38.5	33.0	28 9
8 5	133	68 0	39 4	24 8	16 6	11 6	8 50	4.92	3.09	2.07	1 46	1 06	0 746	0.544	0.409	0.315	0.198	0.133
	324	259	216	185	162	144	130	108	92.6	81.0	72.0	64.8	57 6	51.8	47.1	43.2	37.0	32.4
9.0	140	72.0	41.7	26.2	17.6	12 3	9.00	5 21	3.28	2.20	1.54	1.13	0.790	0.576	0.433	0.333	0.210	0.140
	361	289	241	206	181	160	144	120	103	90.3	80.2	72.2	64.2	57.8	52.5	48.1	41.3	36.1
9.5	148	76.0	44.0	27.7	18.5	13.0	9 50	5.50	3.46	2.32	1.63	1.19	0.834	0.608	0.457	0.352	0.221	0.148
	400	320	267	229	200	178	160	133	114	100	88.9	80.0	71.1	64.0	58.2	53.3	45.7	40.0
10	156	80.0	46.3	29 2	19.5	13.7	10.0	5.79	3.64	2 44	1.72	1.25	0.878	0.640	0.481	0.370	0.233	0.156
	484	387	323	277	242	215	194	161	138	121	108	96.8	86.0	77.4	70.4	64 5	55.3	48 4
11	172	88.0	50.9	32.1	21.5	15.1	11.0	6.37	4.00	2.68	1.89	1.38	0.966	0.704	0.529	0.407	0.256	0.172
	576	461	384	329	288	256	230	192	165	144	128	115	102	92.2	83.8	76.8	65 8	57.6
12	187	96.0	55.6	35.0	23.4	16.4	12.0	6.95	4.37	2.93	2.06	1.50	1.05	0.768	0.577	0 444	0.280	0.187
	676	541	451	386	338	300	270	225	193	169	150	135	120	108	98.3	90.1	77 3	67.6
13	203	104	60 2	37.9	25.4	17.8	13.0	7.53	4.73	3.17	2.23	1.63	1.114	0 832	0.625	0.481	0 303	0.203
	784	627	523	448	392	348	314	261	224	196	174	157	139	125	114	105	89.6	78 4
14	218	112	64 8	40.8	27.3	19 2	14.0	8.11	5.10	3.42	2.40	1.75	1.23	0.896	0 673	0.518	0.326	0.218
	900	720	600	514	450	400	360	300	257	225	200	180	160	144	131	120	103	90 0
15	234	120	69 5	43.7	29.3	20.6	15.0	8.69	5 46	3.66	2.57	1 88	1 32	0 960	0.722	0 555	0.350	0 234
	1020	819	683	585	512	455	410	341	293	256	228	205	182	164	149	137	117	102
16	250	128	74.1	46 6	31.2	21.9	16 0	9.26	5 82	3 90	2.74	2.00	1.40	1.02	0.770	0.592	0 373	0.250
	1160	925	771	661	578	514	462	385	330	289	257	231	206	185	168	154	132	116
17	265	136	78.7	49 6	33.2	23.3	17.0	9 84	6 19	4 15	2.92	2.13	1 49	1.09	0.818	0.629	0.396	0 265
	1300	1040	864	741	648	576	518	432	370	324	288	259	230	207	189	173	148	130
18	281	144	83.3	52 5	35.1	24.7	18.0	10.4	6 55	4 39	3.09	2.25	1.58	1.15	0.866	0 666	0.419	0.281
	1440	1160	963	825	722	642	578	481	413	361	321	289	257	231	210	193	165	144
19	296	152	88.0	55 4	37.1	26.0	19.0	11.0	6 92	4 64	3.26	2.38	1 67	1.22	0.914	0.703	0.443	0.296
	1600	1280	1070	914	800	711	640	533	457	400	356	320	284	256	233	213	183	160
20	312	160	92 6	58 3	39 0	27.4	20.0	11 6	7.28	4.88	3.43	2.50	1.76	1.28	0 962	0.740	0.466	0 312
	1760	1410	1180	1010	882	784	706	588	504	441	392	353	314	282	257	235	202	176
21	328	168	97 2	61.2	41 0	28 8	21 0	12 2	7.64	5 12	3.60	2.63	1.84	1 34	1 01	0.777	0 489	0.328
	1940	1550	1290	1110	968	860	774	645	553	484	430	387	344	310	282	258	221	194
22	343	176	102	64 1	42 9	30.1	22.0	12.7	8.01	5 37	3 77	2.75	1.93	1.41	1.06	0.814	0.513	0.343
	2120	1690	1410	1210	1060	940	846	705	605	529	470	423	376	339	308	282	242	212
23	359	184	107	67.0	44.9	31.5	23 0	13 3	8 37	5 61	3.94	2.88	2.02	1.47	1.11	0.851	0 536	0.359
	2300	1840	1540	1320	1150	1020	922	768	658	576	512	461	410	369	335	307	263	230
24	374	192	111	70 0	46 8	32 9	24.0	13 9	8 74	5 86	4.12	3.00	2.11	1 54	1.15	0 888	0 559	0.374
	2500	2000	1670	1430	1250	1110	1000	833	714	625	556	500	444	400	364	333	286	250
25	390	200	116	72.9	48 8	34.3	25 0	14 5	9 10	6.10	4.29	3.13	2.20	1.60	1 20	0.925	0 583	0 390

The number of coils required for a spring corresponding to given conditions is obtained from the usual formula:

$$f = \frac{8 n_w D^3 P}{d^4 G} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

where the transverse modulus of elasticity G is taken equal to 800,000 kg./qcm. (11,400,000lbs. per square inch). By substituting in this formula h for $\frac{f}{P}$, and c for $\frac{D}{d}$, the author again obtains a formula for the number of coils in a spring in a form convenient for slide-rule calculations:—

$$n_w = \frac{10000}{c^3} dh \quad . \quad . \quad . \quad . \quad . \quad (7)$$

The use of Table II. can be illustrated by the following example. Required to find a spring for the exhaust valve of

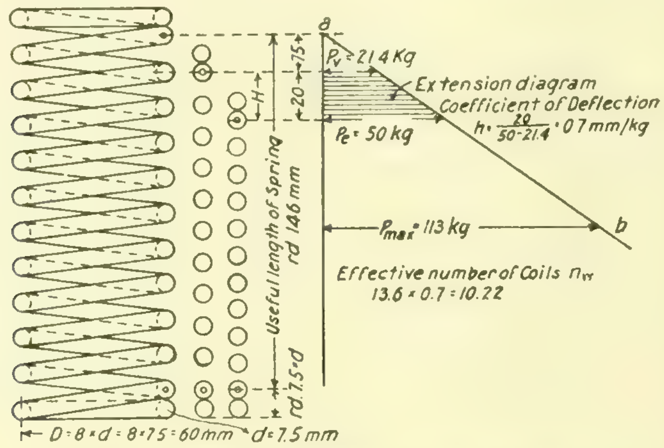


FIG. 1.—EXTENSION DIAGRAM OF HELICAL SPRING.

a 4-cycle internal-combustion engine, 360 revs. per minute. The number of double deflections per minute $n_f = 180$. According to equation (5), the coefficient of safety

$$S_f = 1 + \frac{n_f}{150} = 1 + \frac{180}{150} = 2.2$$

The deflection diagram is drawn, as in Fig. 1, with a coefficient of deflection $h = 0.7$ mm./kg. (0.0125in. per pound), in accordance with theoretically required accelerations and practical experience. For a valve lift of 20 mm. (0.78in.) the load P_e is taken as 50 kg. (110lbs.), and that gives, with a coefficient of safety $S_f = 2.2$, the greatest safe load

$$P_{max} = 2.2\, P_e = 2.2 \times 50 = 110 \text{ kg.} = 242\text{lbs.}$$

Referring to the upper figures of Table II., for values approaching that of $P_{max.}$ (they are underscored), it is seen that there are many such values, and that they lie practically along a diagonal line. The lower figures show the number of coils required with a coefficient of deflection unity, and since the coefficient of deflection was taken above as $h = 0.7$, the actual number of coils required may vary, according to the Table II., from 0.7×85.8 to 0.7×0.265, the last figure being, of course, practically out of question. The diameter of the wire may vary from 5 mm. to 17 mm. (0.196in. to 0.665in.), and the values $d = 7.5$, $D = 60$, and $n_w = 0.7 \times 14.6 = 10.22$ will probably be chosen as most suitable.

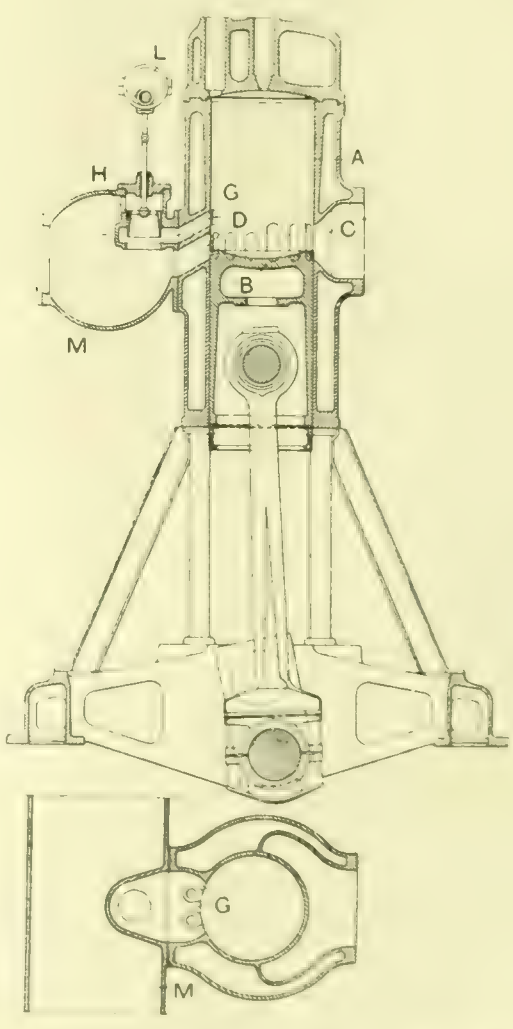
The values in Table II. are deduced for helical springs with circular cross-section. These values may be applied to springs with square or rectangular cross-section by multiplying them by values in Table I. corresponding to the nearest value of a.

In Table II. d is the diameter of the wire, D mean diameter of the coils, the upper figures indicate $P_{max.}$ = greatest safe steady load, the lower figures indicate n_w = number of coils required with coefficient of deflection unity.

Diesel Engines for Torpedo-boat Destroyers.—Presiding at the 11th annual general meeting of John I. Thornycroft & Co., held on Monday last, Mr. John E. Thornycroft said that as a result of the experience gained with Diesel engines, and with some marine Diesel engines constructed under a similar arrangement at the Southampton works, the directors felt confident in making an offer to the British Admiralty for the construction of a destroyer fitted with Diesel engines for cruising purposes. The offer was accepted, and the destroyer which they were building to their special design fitted with Diesel engines for cruising purposes was the first, and at present the only, vessel of this type ordered by the British Admiralty.

SULZER'S TWO-STROKE CYCLE INTERNAL-COMBUSTION ENGINE.

THE 2-stroke cycle internal-combustion engine shown in the accompanying sectional views has been designed by Sulzer Bros., Winterthur, with the object of increasing the output of this type of engine. The scavenging and additional combustion air are, it will be noticed, introduced through superimposed slots formed in the wall of the cylinder and extending over different portions of its circumference, the slots through which the scavenging and additional air are admitted being inclined upwards. The valve controlling the admission of additional air to the upper slots is disposed within the scavenging air pipe, and is controlled by a cam mounted on the engine cam shaft. Referring to the illustrations, A is the engine cylinder, B the piston, and C are the exhaust openings, which extend over half the circumference of the cylinder wall. The scavenging air is admitted through openings D, which also extend over half the circumference of the cylinder A, and further openings G are provided for the admission of the additional combustion air, three of these openings being shown. The openings G extend over about one-quarter of the circumference of the cylinder wall. Admission of the additional air is controlled by a piston valve H, operated by an eccentric L mounted on the engine cam shaft. By providing a different number of openings D and G it is possible so to control the air jets entering the cylinder that efficient scavenging and charging is ensured. To improve the scavenging action the openings D and G are directed in a different manner to the exhaust openings C, as shown. A further feature of the design lies in the fact that the valve H



SULZER'S TWO-STROKE CYCLE INTERNAL-COMBUSTION ENGINE.

controlling the admission of the additional air is arranged within the actual scavenging air pipe M. When the valve H is opened the air in the pipe M flows direct to the slots G, and in that way the losses due to throttling these openings or in transmission thereto are reduced to a minimum.

Lectures on Heavy Oil Engines.—A short course of four lectures on "Heavy Oil Engines," by Captain H. Riall Sankey, R.E. (ret.), M.Inst.C.E., will be given before the Royal Society of Arts, under the Howard Bequest, commencing on Monday evening, the 29th inst., at 8 p.m. Admission to the lectures is free to non-members of the society on production of a member's order, or by the personal introduction of a member.

CASE-HARDENING METHODS AND MIXTURES.

AN interesting contribution by Dr. L. Guillet, the well-known French metallurgist, on "The Present Condition of the Theory and Practice of Case Hardening," appeared in a recent issue of "Le Genie Civil," and we are indebted to "The Iron Age" for the following abstract.

A good case-hardening mixture must answer the following requirements: (1) It ought to bring about a regular penetration of carbon, because otherwise the most favourable carbon contents, 0·85 to 1·00 per cent., would be exceeded, and then harmful cracks would form in quenching. (2) In spite of this, the action must be quick enough so that the process does not require too long a time. (3) It must be uniform so that the same amount of carbonisation is produced all over. (4) It ought not to become exhausted too soon; that is, it must be suitable for the production of deeper carbonisations, and it should be possible to use it several times. (5) Notwithstanding opposite opinions, it ought to contain no sulphur-holding material.

The author does not recommend charred leather, as he considers it to work too actively. Apart from the composition of the case-hardening mixture, two very important points are to be considered; namely, time and temperature. It hardly needs mentioning that the temperature of the furnace must be known exactly, and with regard to time, careful and detailed experiments must be made to determine its influence under the special operating conditions.

The carbon of the steel to be case hardened, at least if it does not exceed 0·5 per cent., has no effect on the depth of the case. The following simple rule can be made for those elements which favour or retard the operation: Those which form double carbides with cementite favour it. They are chromium, tungsten, molybdenum, and, under certain conditions, vanadium. Those elements which remain dissolved in the iron, such as nickel, silicon, aluminium, and, in small amounts, vanadium retard it. With a certain amount of silicon and aluminium, case hardening is altogether impossible. These elements, however, play another rôle. As is well known, the microscope shows characteristic differences of structure in the special steels, which depend on the sum of the carbon percentage and that of the strange elements multiplied by a certain coefficient. These structures may be separated into two classes. The first shows pearlite, or pearlite and cementite, depending on the composition. The cementite may be more or less complex. The properties of the case-hardened material correspond, apart from the ductility, to those of similarly treated ordinary steels. To this class belong the tungsten and molybdenum steels. The other class of special steels show altogether different structures, according to their composition.

Nickel steels, for instance, show pearlite, martensite, and gamma iron; others, such as the manganese steels, pearlite, osmondite, and gamma iron; and finally the chrome steels, pearlite, osmondite, and complex carbide. If such steels are case hardened one can obtain, under certain conditions, either martensite or gamma iron from the pearlite. For example, with a 7 per cent. nickel steel containing 0·12 per cent. carbon, case hardening will produce a martensitic layer as soon as the carbon is raised to 0·90 per cent. If it is increased still further to 1·3 per cent., gamma iron is formed, and only with a carbon content of more than 1·65 per cent. does free cementite separate. In this way the same martensitic structure is produced, with a simple case hardening, that requires quenching in the case of ordinary steels. Finally, the author points out that the moderately hard gamma iron steels are not hardened by case hardening, because carbon has absolutely no influence on their properties; nor by quenching, because this makes them somewhat softer.

Through the case hardening the core is made more or less brittle because of the long annealing. The ductility is lower the longer the operation and the higher the temperature. The piece must be properly heat-treated to produce the desired final properties; namely, a hard outer surface with great ductility of the core. This heat treatment generally consists of two quenchings, the first one being for the refining of the core. The best quenching temperature for this work has been found to be between 1,000° C. and 1,025° C. This high temperature is used because the complete homogeneous solution of the carbon is reached in a much shorter time than at 900° C., which is the temperature theoretically necessary. This greatly reduces the danger of decarbonising the outer surface of the steel in the oxidising atmosphere of the furnace.

This first quenching does not give a satisfactory hardness to the case, and the second part of the treatment consists of a second quenching. In general 750° C. may be considered as the right hardening temperature, and the author draws the following rules for the practical treatment of ordinary carbon steels. The first rule is applicable to all cases, and should be considered for all case hardening about 850° C. (*a*) After the case hardening, cooling to 600° C. or lower. (*b*) First quenching from 1,025° C. in water for refining the core. (*c*) Second quenching from 750° C. in water for the real hardening.

The second rule is only applicable for case hardening carried out at temperatures below 950° C., and when high ductility is not required. (*a*) After the case hardening, cooling to 600° C. or lower. (*b*) One quenching in water from 750° C.

This second rule can only be used successfully when no trace of free cementite is present in the case. Its usefulness is restricted to special cases.

With regard to the influence of the elements, the general rule is that those which increase the amount of carbide, such as carbon, manganese, tungsten, and molybdenum, also increase the brittleness of the core after case hardening, and also favour the formation of free cementite. The carbon in ordinary steels should be from 0·10 to 0·15 per cent.; in no case over 0·20 per cent. In special steels it is often as high as 0·30 per cent. The manganese should not be over 0·40 per cent. if a single quenching is to be used, but a somewhat higher percentage may be allowed if two quenchings are to be employed. Silicon increases the brittleness in all cases, and is to be considered as a harmful element, as it also decreases the thickness of the case. It should not exceed 0·30 per cent.

Nickel is one of the chief elements in case-hardening practice. However, it introduces some troubles, because it hinders the process somewhat, and because the hardness of the case is somewhat lower than that possible of attainment with ordinary steels. On the other hand, nickel gives the great advantage that it opposes the crystallisation of the steel at high temperatures and the consequent brittleness. Because of this the first quenching for refining the core is often not necessary. However, such a quenching, if carried out at a suitable temperature, noticeably increases the tenacity of the core. With a 2 per cent. nickel steel, the following temperatures are recommended. (1) Heating to and quenching from 1,000° C. (2) Heating to 750° C., and quenching from 700° C.

A single quenching from 700° C. gives the greatest hardness in the case, but not the greatest tenacity in the core. Quenching from 750° C. gives a somewhat higher tenacity, but a slightly lower hardness in the case. This heat treatment has the advantage of simplicity, but as mentioned before, does not give the highest values for hardness and tenacity. A 6 per cent. nickel steel should be treated at the following temperatures, because of the lower change points: (1) Quenching from about 850° C. (2) Quenching from about 675° C.

Since this high nickel percentage almost completely prevents the brittleness of the core, a simple quenching from 700° C. is sufficient in most cases.

A steel containing 7 per cent. nickel and 0·12 to 0·15 carbon requires absolutely no quenching after case hardening, yet one ought not to expect extraordinary hardness in the case, as the outer layer contains some gamma iron.

Steels with 1·0 to 1·2 per cent. chromium are used in cases where an especially hard case is required. It has a similar effect to manganese; that is, it accelerates the cementation, but also favours the crystallisation of the core. A double quenching is, therefore, absolutely necessary. Manganese has the advantage compared with chromium that it does not make the case so liable to spall off in hardening. Tungsten and molybdenum act similarly to chromium and manganese, but are seldom found in case-hardening steels. Vanadium is sometimes used, from 0·2 to 0·3 per cent., usually with 0·4 to 0·7 per cent. chromium, and appears to raise the tenacity of the core somewhat after quenching. The chrome-nickel steels are the special steels mostly used, and with a low chromium

content their heat treatment is about the same as that of correspondingly pure nickel steels.

The case-hardening mixture recommended by Dr. Guillet is composed of 60 parts wood charcoal and 40 parts barium carbonate. It is easily made, is not very expensive, and can be used again and again if only the composition is regulated from time to time.

Very often it happens that certain parts of the object to be case hardened have to remain soft, and so should be protected from the influence of the mixture. These parts are usually covered with a layer of refractory material of such a nature that it holds together well and does not melt. Often graphite is added to prevent small cracks forming at the high temperatures, and whenever possible the covering is reinforced with wire. Care must be taken in the case hardening of semi-hard steels because the refractory material brings about slight decarburisation. Another method used is to shrink on a ring of soft iron, the thickness of which is naturally greater than that of the case to be made. After the process it is easily broken off with a hand hammer.

For difficult pieces the following rather costly method is recommended: The whole piece is first case hardened, and then what is necessary is removed from quenching. At these places the piece must therefore be correspondingly thicker, and should be made at least 0·5 mm. more than the depth of the case expected.

Finally, the method patented by the firm of de Dion and Bouton may be used, which consists in covering the particular places with a coating of copper. The place, previously well cleaned and freed from grease with ether, is treated with a solution of copper sulphate. This gives a precipitate of copper which resists the cementation very well. A nickel coating can also be used, but this requires electro-plating, which is usually too costly. The process probably requires too much care for ordinary shop practice, as the slightest damage to the copper allows case hardening not only of the damaged place but of the whole neighbouring zone.

THE EFFECT OF TEMPERATURE IN THE CARBONISATION OF COAL, AND ITS BEARING UPON THE CONSERVATION OF OUR COAL SUPPLIES.*

BY PROF. VIVIAN B. LEWES

THE destructive distillation of coal is at present carried out in this country for the commercial production of (1) metallurgical coke, (2) coal gas, (3) smokeless fuel, and the object in each case being different, the means adopted for carrying out the carbonisation varies.

In making metallurgical coke, the desired result is to obtain the highest proportion of carbonaceous residue in the hardest, purest, and structurally strongest form, in order to resist crushing and to be less friable in the blastfurnace, and the resulting gases and vapours are looked upon as by-products, the value of which has only of late years been recognised as worth recovery. At the present time by far the largest proportion of the coal so treated is still carbonised in beehive ovens without recovery plant, but this apparently indefensible waste is largely due to this form of oven being suited for producing the best coke from highly bituminous coals, and is therefore largely retained in use in the North of England, whilst the South Wales coal, being less bituminous, lends itself better to carbonisation in the horizontal types of oven and recovery plant. The characteristics of the process in making metallurgical coke are: (*a*) Large charges, (*b*) high temperature, (*c*) long period of carbonisation.

In making coal gas the object kept in view by the gas manager is to produce the largest volume of gas per ton of coal that will comply with the Parliamentary standard of quality prescribed by his Gas Act, and in this case coke and tar become the by-products. During the last 15 years the incandescent gas mantle has become so generally adopted that the need for a rich candle power gas for consumption in flat flame and argand burners has ceased to exist, and the general standard of candle power for a town supply is now 14 candles. Up to four years ago, practically the only method adopted in order to get this candle power and the largest possible volume of gas was to push the temperature of the retorts to the highest limit which was economically possible with the material employed, and the average yield of gas per ton of coal was about 11,500 cub. ft.

On the Continent, however, it began to be realised that the useful limit of the horizontal and inclined retort had been reached, and the Dessau vertical retorts were then introduced to deal with coal in large charges, whilst three years ago a still more important advance was made at Munich, which was to carbonise the coal in chambers of such size that from three to eight tons could be dealt with at a time, and installations on the plans of Ries, Koppers, and others are being rapidly laid down on the Continent. Up to the date of these departures from ordinary practice all successful gas processes had dealt with small charges of coal, heated rapidly to a high temperature, but it has now been shown that with these new methods of carbonisation up to 13,000 cub. ft. of gas can be obtained per ton of coal.

In England a great advance has been made over Continental practice by the introduction of continuous vertical carbonisation, which gives the nearest approach yet attained to ideal conditions, and whilst giving a gas yield per ton of 13,000 cub. ft. to 13,500 cub. ft. per ton of gas, does away with all smoke and nuisance at the gasworks, whilst it has also been found that by filling the old horizontal retorts with the charge of coal and increasing the length of time of carbonisation, results as good as the ones given by the Continental processes can be obtained. Taking the ordinary gasworks practice as apart from the modern forms of carbonisation, its characteristics are: (*a*) Small charges, (*b*) high temperatures, (*c*) short period of carbonisation.

During the last five years an attempt has been made to introduce a smokeless fuel known as "Coalite," which consists of bituminous coal carbonised at about half the ordinary gasworks temperature for such a period as to leave in the coke some 10 per cent. or 12 per cent. of volatile matter, this giving a form of fuel superior in every way to both coal and coke, inasmuch as it is easy of ignition, smokeless, burns into a clear, bright, and very hot fire, and has a cheerful flame. In the manufacture of this material the gas made is only about 5,000 cub. ft. per ton, but is of high candle power and high calorific value, whilst the tar increases in quantity and undergoes great change in characteristics. The chief points of this process are: (*a*) Small charges, (*b*) low temperatures, (*c*) short period of carbonisation.

The effects of temperature, time and mass, all have an important bearing upon the quantity and composition of the products formed during the carbonisation, and these again vary widely with the coal used, but with the ordinary run of bituminous coals it may be stated as follows: When coal is rapidly heated in thin layers to a high temperature the coke is of medium strength, whilst the tar formed is characterised by the presence of aromatic hydrocarbons, and the gas contains a medium amount of illuminants. When coal is heated for a short period to a temperature just sufficient to bring about free decomposition, the tar increases largely in quantity, and is characterised by the presence of paraffinoid hydrocarbons in place of the benzenoid, whilst the gas is small in quantity and rich in illuminants, and the coke soft and friable. When coal is slowly heated in mass to a high temperature, the operation being spread over a considerable space of time, the coke is hard and resistant, whilst the hydrocarbons in the tar contain both benzenoid and paraffinoid compounds, and the volume of gas is smaller and of poor quality.

In the ordinary gas manufacture the first set of conditions prevails, and when the manufacturer was content to make 10,000 cub. ft. of 15 to 16 candle gas per ton of Durham coal, he obtained tar rich in benzine, toluene, and anthracene, which in the early days of the coal tar industry commanded a high price, the English market, however, being at a later date spoilt by the amount of benzine produced from the recovery plants of the German coke ovens.

When a few years ago increased temperatures began to be used, the tar underwent a serious deterioration, naphthalene and free carbon being present in quantities which so depreciated its value that the price fell to about ¾d. a gallon. With the introduction, however, of the vertical chamber and fully charged retort into gas-making, the action of mass comes into play, and the tar shows at once an alteration in its characteristics, paraffinoid hydrocarbons making their appearance,

* From report of British Science Guild on "Natural Sources of Energy."

and the naphthalene and free carbon falling in quantity, this being due to the fact that no matter how high the temperature of the vertical retort or chamber the heat can penetrate but slowly into the mass of carbonaceous material, so that it is always distilling towards the centre at a low temperature, which slowly rises until the maximum temperature is attained, by which time practically all the hydrocarbons have been driven off. There is no doubt that if the gas and tar vapour had not to traverse a certain amount of highly-heated carbon and wall surface in its escape, the gaseous products would be of very nearly the same character as in low-temperature carbonisation. The gas under these conditions is increased in quantity, but is poor in illuminants, owing to decompositions taking place in passing through the incandescent carbon.

As has been before shown, these methods of carbonising coal have arisen from the demand for perfectly distinct products, and in considering any scheme by which an economy in coal might be effected, it is necessary to clearly bear in mind how these needs can best be satisfied. Coke, capable of resisting pressure and not easily friable, must be had for metallurgical work; coal gas for lighting and power must have a sufficient thermal and illuminating value; fuel for the open fireplace must be easy of ignition and free burning, and the problem upon which any economy must depend is how best to attain these desiderata in the most rational way.

If carbonisation of coal at the pit's mouth and distribution of the gas, as proposed by Thwaite, Martin, and others, could be adopted, the perfect solution of the problem would be a combination of high and low-temperature distillation plants to supply the metallurgical coke and smokeless fuel needed, whilst the poor coke oven gas, enriched by the low-temperature gas, would yield an ideal gas supply. Such a scheme, however, would so seriously interfere with vested interests that it is improbable that it would ever be adopted, and, such being the case, the only practical economy is to be found in doing everything possible to accelerate the present tendency to replace all the old beehive ovens by modern type coke ovens fitted with recovery plant, and in the gasworks to, as far as possible, improve the character of the coke and tar by adopting carbonisation in bulk rather than by pressing the temperatures.

If the gas companies were not so antagonistic to low-temperature carbonisation one of the most important steps that could be made would be for them to manufacture low-temperature coke to replace bituminous coal as a domestic fuel, and to dilute down the rich low-temperature gas with water gas, which can now be made by the more modern processes at from 3½d. to 4d. per 1,000, a proceeding which would enormously enhance the value of the other by-products, cheapen the gas, and save the waste now due to the combustion of bituminous coal in domestic fires by giving a fuel which could be used in all existing grates, whilst an incidental advantage would be that the sulphur in the gas would be reduced to a small fraction of the present amount.

During the last 10 years the rapid advance made by gas as a fuel in gas stoves, cookers, &c., has considerably reduced the consumption of coal for domestic purposes, and if the whole of our fuel could have the smoke-forming tar and fertilising nitrogen extracted at our gasworks, it would mean not only a great economy, but also a cleansing of our town air.

The Road of the Future.—The road of the future was discussed by Sir John H. A. Macdonald, who is a member of the Road Board, at a recent meeting of the Royal Institution. It might, he said, seem extravagant to say that in another decade the main roads would have become practically mudless, dustless, and smooth ways; but those who had studied the matter, held the hope confidently. Would it not be well, he continued, to endeavour to provide an elastic skin or carpet to lie between the vehicle and the bearing crust? Could they find some material for the exposed surface of the road which should be resilient, yielding to traffic, but resuming its form and surface. Recent laboratory experiments indicated that this would be accomplished. It was expected that with such material laid on the top of the main road the crust would be practically permanent, the upper protecting sheet being re-made and re-laid when necessary. The result would be that the rolling noise of the vehicles would be silenced and shock reduced. The engineers at the Road Board had already decided on experimental roads of this nature.

DETERMINING SIZE OF A COOLING RESERVOIR FOR CONDENSER WATER.

In a paper read before the American Society of Mechanical Engineers on "The Reduction in Temperature of Condensing Water Reservoirs Due to Cooling Effect of Air and Evaporation," Mr. W. B. Ruggles described tests made with the idea of determining if possible a fairly reliable factor by the use of which the necessary size of a cooling reservoir for condenser water could be predetermined for any assumed power and weather conditions.

In 1908, while designing the mill for the Crescent Portland Cement Company at Wampum, Pa., it was found necessary to install a cooling device for the condensing water from the engines. After a diligent search, no data were found as to how large a reservoir had to be to give the necessary cooling effect to the water, so that it might be used continuously. A dam, however, was built 275ft. long and 18ft. high, of skeleton reinforced concrete construction which would impound about 6½ acres of water

Three tests were made during the year 1911, each of one week's duration, in order to determine the heat radiation from the surface of the reservoir. These tests were made in May when the temperature was moderate, in July when the temperature was high, and in November when the temperature was low. Readings were taken of the temperature of the river water, the intake water to the power-house, the tail water from the condenser, and of the air. The vacuum, the power, the amount of water pumped from the river to the reservoir, and the rainfall were also recorded. Unfortunately the temperature of the rain was not taken, but it has been assumed the same as the temperature of the air, so that the figures for that are only approximate, but a difference of 10° in the temperature of the rain would not alter the result by more than two-tenths per cent.

The engines used in the power-house are three compound condensing engines, 26in. by 52in. by 36in. There are two compound compressors, the steam cylinders of which are 12in. and 21in. diam. respectively, the air cylinders 11½in. and 24in. respectively, the stroke 24in. The steam from all of these is condensed in a barometric condenser equipped with a dry vacuum pump, and the circulating water supplied by a direct-connected centrifugal pump driven by a synchronous motor; an engine-driven circulating pump and a second dry vacuum pump being installed as reserve.

The water from the condenser flows about 50ft. through a tile pipe into the east side of the reservoir about 100ft. from the north end. A dyke was built south of this inlet to the reservoir extending about 50ft. towards the centre of the reservoir and then north nearly to the north end. This compels the circulating water to flow up and around the end of this dyke and down towards the dam, a distance of about 1,100ft., before it reaches the intake to the power-house.

Water to supply the reservoir is pumped from the river by a centrifugal pump direct connected to a 150 h.p. motor. The pump delivers an average of 2,324·25 galls. of water per minute, and it is found that about 8 hours pumping per week is sufficient to make up for the evaporation and seepage in the reservoir. The water from the river pump is delivered into an open well situated on top of the plateau where the mill is located. It flows by gravity from this well through a 24in. tile pipe into another concrete well located in the reservoir about 800ft. north of the dam. From this well it flows through a No. 24 tile pipe laid on the bottom of the reservoir to within 6ft. of the dam. The intake water for the boiler feed and condenser is drawn from this well, so that the water must flow up through the concrete tile pipe from the bottom of the reservoir at its deepest point. While water is being pumped from the river, there is a flow south through this tile pipe, and when not pumping the water is drawn in the opposite direction through it. The average horse-power developed in the engines during the 21 days of these tests was 2,446.

The results of the tests during these three weeks are as uniform as could be expected, the heat lost per square foot of surface being slightly less per 1° difference of temperature in cold weather than in warm weather. This difference is undoubtedly due to an increased amount of evaporation during the warmer period. The average humidity for the different

weeks during which the tests were made was 58·5 per cent. in May, 62·3 per cent. in July, and 71·2 per cent. in November. Table I. gives the results in detail of the tests made.

It appears from the tests that under the conditions mentioned, with engines using 15lbs. of water per horse-power hour and a vacuum of 26in., a reservoir having a surface of 120 sq. ft. per horse-power would be ample for cooling and condensing water.

TABLE I.—*Test of Heat Radiation from Surface of Condenser Water Reservoir at Plant of Crescent Portland Cement Company, Wampum, Pa.*

Area of reservoir, 288,000 sq. ft.; average depth of reservoir, 5·36ft.; capacity of reservoir, 1,543,680 cub. ft. = 96,480,000lbs.

Date of Tests.	Week ending May 7th, 1911.	Week ending July 12th, 1911.	Week ending November 27th, 1911.
Amount of water pumped from river, lbs.	10,458,956	29,050,875	4,648,140
Average temperature of river water, deg. Fah.	57·5	77	36
Average temperature of intake to power house, deg. Fah. ...	72·75	91·43	61·71
Average temperature of tail water from condenser, deg. Fah.	101·36	129·43	90·71
Average temperature of reservoir, deg. Fah.	87 05	110 00	76·71
Average temperature of air, deg. Fah.	51·00	78·43	33·30
Average difference of temperature between water and air, deg. Fah.	36·05	31·57	43·41
Change in temperature of reservoir during test, deg. Fah.	0·25	7·00	2·00
Three 26in. by 52in. by 36in. compound condensing engines, h.p. hour	397,807	411,320	426,936
Two 12in. by 21in., 11½in. by 24in. by 24in. air compressors, h.p. hour	46,536	46,536	46,536
Average vacuum at 30 in barometer, in.	26·4	22·2	26·6
Average water consumed by engines, per h.p. per hour, lbs.	14·46	15·64	14·41
Average water consumed by compressers per h.p. per hour, lbs.	18·85	20·12	18·83
Steam condensed by engines, lbs.	5,752,289	6,433,045	6,145,148
Steam condensed by compressors, lbs....	877,204	936,314	876,273
Latent heat of steam condensed, lbs.	1024·7	1007·1	1026 0
Heat delivered to reservoir by engines, B.T.U.	5,894,370,000	6,478,720,000	6,304,922,000
Heat delivered to reservoir by compressors, B.T.U.	898,871,000	942,961,000	899,056,000
Heat to raise river water to average temperature of reservoir, B.T.U.	309,062,000	958,679,000	189,226,000
Heat given up or retained in reservoir uring test, B.T.U..	24,120,000	675,360,000	192,960,000
Heat reduction in reservoir due to rain, B.T.U.	21,630,000	56,700,000	46,200,000
Heat absorbed by air and evaporation during seven days, B.T.U	6,438,429,000	5,730,942,000	6,564,509,000
Heat absorbed by air and evaporation per sq. ft. of surface seven days, B.T.U....	22,356	19,899	23,495
Heat absorbed by air and evaporation per sq. ft. per hr., B.T.U.	133·1	118·4	139·8
Heat absorbed by air and evaporation per sq. ft. per hr., per 1 deg. difference B.T.U.	3 69	3 71	3·22

Turbines for Torpedo-boat Destroyers.—The Wallsend Slipway and Engineering Company have secured the order to build the turbine machinery for the two torpedo boat destroyers recently ordered by the Admiralty from Swan, Hunter, and Wigham Richardson, Ltd., Wallsend The latter firm are constructing five of these boats, and the Slipway Company will engine the lot. The hulls of two similar vessels ordered from the Parsons Turbine Company, Wallsend, will be built by the Palmer Shipbuilding Company, Jarrow

NOTES ON STRUCTURAL STEEL DESIGNS.*

BY ALBERT REICHMANN.

STRUCTURAL steel nowadays is used so very extensively in the construction of our railroads, industrial buildings, office buildings, apartment buildings, and in almost every means of conveyance, that it represents a large part of the capital outlay in our railroad, industrial, and real estate undertakings. For this reason it is of the utmost importance that the most rigid economy be exercised in its use. By an economic design is meant a design wherein the cost of material and labour entering into the construction of said design will be a minimum. In other words, the writer considers a well-designed structure one which will most efficiently perform its function with a minimum outlay of capital and the lowest annual maintenance charge.

One of the most important features of a material to be used in construction work consists in the ease and simplicity, together with the safety and reliability, with which one member can be attached to another. In the case of wooden construction it is almost impossible to make a connection of one member to another with any degree of certainty and use ordinary factors of safety. In the case of reinforced concrete, or, more properly speaking, concrete reinforced with steel, where the joints are largely dependent upon the adhesion of the concrete to the steel, the question of connections is an uncertain problem. In structural steel, owing to its homogeneous nature and uniformity of strength, it is possible to mathematically determine the value of connections of one member to another with reasonable margins of safety and secure a perfectly safe structure. Owing to the importance of securing reliable connections of one member to another, it is perfectly natural that the type of connections used in steel structures should be one of the most important subjects to be considered in structural steel designs. It will be observed that the question of connections is, therefore, given very careful consideration in this paper.

The first iron and steel bridges designed by our American engineers were typically American. That is to say, our type of construction was radically different from that used by other nations. The question of cost was given the most careful study, and justly so, as the railroad companies which purchased these structures had a very difficult time to make both ends meet. In those days the rolling stock of our railroads was very light; the volume of traffic was very small, and the trains did not move over the railroads with the high speed of to-day.

The type of structure referred to is the pin-connected span. When first introduced it was built of any length, ranging from 30ft. upwards. It was very popular owing to the small amount of metal required in its construction, the ease with which its members could be transported over great distances, and the facility with which it could be erected. These bridges were built at a time when the science of building structures of metal was in its infancy. As a consequence most of the old-time bridges were built with very inferior details. Owing to the rapid increase in the weight of the rolling stock of the railroads, they were soon taxed to their capacity and unfortunately sometimes beyond their capacity. As a result it did not take long for these old-time bridges to develop imperfections and it soon became apparent that the pin-connected bridge was not the ideal type of structure to be used in every case.

The next step was the introduction of the plate-girder bridge and the riveted truss bridge, and it soon became common practice to build plate girders for all spans from 20ft to 75ft. in length, and from 75ft. to 125ft various forms of riveted trusses, and spans over 150ft of the pin connected type In other words, we began to follow the practice of European engineers in the building of our shorter span bridges.

Now let us analyse why we departed from the old-time practice of building pin connected bridges and substituted the use of the riveted bridges. In the first place the old-time pin-connected span was used without consideration of span length. The shorter pin-connected spans, owing to their extreme lightness, the small moment of inertia of their tension

* Paper read before the Western Society of Engineers.

members, poor lateral bracing, and generally inferior details, vibrated excessively under traffic. The fact that these small pin-spans were used out of the sphere which naturally belonged to them, led a great many engineers to abandon the pin-connected span almost entirely, and of recent years we have adopted more extensively the use of the all-riveted span for our longer-span bridges. It has occurred to the writer, however, that in many cases we have substituted riveted spans for our long-span bridges where a pin-connected structure would have been preferable.

The ideal span to build would be one that is free from vibrations and without secondary stresses, but as this is impossible, the problem then is to select that type of design which has the minimum number of objectionable features. For an ordinary simple truss span there are four types of construction to be considered:—

First, the truss with built-up chords and diagonals and riveted connections throughout, or what is ordinarily called a riveted span. In this type of construction the span should be made as deep as good designing will permit. The dimension of the chords and web members should be made as narrow in the plane of the truss as permissible. By increasing the depth of the trusses the connections of the diagonals to the chords become smaller; the deformation of the truss under load becomes smaller and consequently the secondary stresses become smaller.

The problem of selecting the proper dimensions of the various members forming a joint requires a great deal of skill and judgment. In the first place the various members should be slender, so as to be as flexible as possible, in order to reduce the secondary stresses due to the bending of the member. On the other hand, with slender members it is exceedingly difficult to concentrate the rivets in the connections. This calls for the rivets to reach far out into the members; hence the use of large gusset plates. The longer the connection becomes, the more uncertain the action of the rivets, and therefore the more objectionable the connection. The size of the gusset plates may, in many cases, be reduced by connecting the main member to both sides of the gusset plate by means of an auxiliary connecting plate. By this means the rivets connecting the main member to the gusset plate take double shear and thus the number of rivets can be reduced in proportion.

The slenderness of members calls for compression members with small moments of inertia, and therefore they are not so economical as a column as one with a greater moment of inertia. In the case of tension members it means thicker material, and, therefore, more waste due to deductions on account of rivet holes.

Thus we are confronted with the problem of selecting members having large dimensions of their cross-section in the plane of the truss, with the possibility of their connections being concentrated to a minimum, and, as a consequence thereof, of having large secondary stresses due to bending of the connecting members. Or, on the other hand, selecting a cross-section with the least width possible, which in turn calls for small moments of inertia; that is to say, the members are not economical compression members, nor are they economical tension members, as the material becomes too concentrated. The great problem is, therefore, to know just where to draw the line in the selection of the various members.

In order to somewhat overcome the effects of the secondary stresses in riveted-truss spans, some of our specifications call for their partial elimination by lengthening and shortening the various truss members, amounting to the respective distortions due to dead load plus one-half the live load, and reaming of the chord splices, while the chords are assembled in a straight line, and then forcing them in their proper position before the connections of the diagonals to the chords are drilled or reamed. This is all right as far as it goes in the shop, but when the structure is actually being erected it is an altogether different proposition. If the chords were first riveted together and then put on their camber blocking before they were connected to the diagonals, these results might in a measure be obtained.

Before a long fixed span can be swung it is necessary to rivet all the tension splices in the chords, so that it is very probable that a large part of the refinement that was put on this work in the shop is lost in the field.

Second, the truss with built-up continuous chords and built-up diagonals, pin-connected throughout. The vertical posts and diagonals are connected to the chord by means of pins, which in the case of a continuous chord become very small, owing to the fact that the pins merely transmit the increment of the stress to the chords. It is sometimes found desirable to rivet such posts and diagonals, as in case of reversal of stresses in these members, in order to avoid the wear in the pin holes. In such cases the stresses to be transmitted to the chords are very small indeed; consequently the connections are small and, therefore, secondary stresses are also very small. This type of construction can be designed by making the chords sufficiently shallow in order to make the same flexible and the diagonals sufficiently wide in the plane of the truss, so that they are sufficiently strong to rotate upon the pin and overcome the pin friction when the structure deflects. It is believed that this type of construction has a minimum amount of secondary stresses.

The only objection to this type of span is that it weighs more than a span with eye-bars used as tension members, and that the tension chords must be spliced in the field before the span can be safely swung, which in many cases is very objectionable, as in most long-span bridges it is desirable to make the span safe in the least time possible.

Third, the truss with the chords built-up and made shallow in order to be flexible; diagonal eye-bars, pin-connected.

Fourth, the truss with bottom chords and diagonals made of eye-bars. While this type of construction is pin-connected throughout and theoretically articulated, the joints are actually more or less rigid, due to the friction of the bearing of the eye-bars on the pins. In order to reduce to a minimum the secondary stresses due to pin friction, it is desirable to make the bars as wide as permissible and still not exceed the allowable bearing value of the eye-bars upon the pins.

It is extremely difficult to determine the amount of secondary stresses in a pin-connected bridge, due to the weight of the bridge itself, inasmuch as it is impossible to determine the frictional resistance upon the pins which the various members encounter in righting themselves, while the camber blocking is being removed and the span swung.

While the action of eye-bars in a structure is not perfect—that is to say, that bars have more or less secondary stresses—nevertheless, they are one of the safest articles used in the construction of a bridge. When we are using an eye-bar we can feel that we are using something about which our knowledge is reasonably complete. It seems to the writer, however, that it is the common practice of engineers either not to use eye-bars at all or else to use them right up to the limit of their capacity as determined by full size tests. They seldom figure out what amount of economy could be obtained by using an eye-bar with a somewhat lower unit stress on the same basis that they used a riveted member. In the case of a built-up tension member, there is a large amount of material which is wasted, inasmuch as it does not enter into or carry part of the primary stress, viz., such material as is added to take care of the deductions from the section, necessary on account of rivet holes, and material added for lattice-bars, batten plates, &c. If they realised that they could add considerable material to their eye-bars and still use them with economy, they might not be so adverse to their use. This material added to the eye-bars would reduce the normal stress in the eye-bars to such an extent that the secondary stresses could be entirely ignored.

The vibration of pin-connected spans may be reduced in several ways. First, by making all of the members built-up, with, comparatively speaking, large moments of inertia in the plane of the truss; second, by making the eye-bars sufficiently wide so that their deflection, due to their own weight, will not be too great; third, by weighing down the bridge by means of a ballasted floor. The writer cannot help but feel that when we come to our longer span bridges, the pin-connected type bridge is the proper one to build. The main advantages of a pin-connected span with eye-bar tension members are that it weighs less than other types of construction and can be built in the shop with extreme accuracy so that there is little possibility of encountering trouble in erection through faulty work-

manship. Erection can proceed with greater rapidity than with the riveted span, and the writer believes that less skill is required in designing a pin-connected span than a riveted span.

Lateral Bracing.—There is a feature in long span bridges which should be considered very thoroughly, and that is the question of lateral bracing for the compression chords. In the shorter span bridges the loads allowed for wind bracing are ample to provide sufficient material to take care of the actual wind stresses, and also to hold in alignment the compression chords. However, in very long span bridges, the question of providing sufficient lateral bracing for the compression chords to hold them in proper alignment, so that the compression chords will act in unison throughout their entire length, and in reality form one compression member when considered in a horizontal plane, should be carefully considered. In this respect the lateral bracing, in addition to performing the function of wind bracing, also performs the same function that the lattice bars do to the individual compression members. However, in the case of an ordinary member the lattice bars connect continuous members, whereas the lateral bracing must hold in alignment members which are not thoroughly spliced, and are, therefore, more liable to be out of true alignment on account of imperfect workmanship.

It is not an easy matter to determine the amount of lateral bracing which it is necessary to provide to hold the compression chords in proper alignment, owing to the fact that we have not made sufficient tests of large size compression members to determine just how much material is required to hold in proper alignment the main sections of a compression member.

This same question of uncertainty applies to the proper bracing of the top flange of our through plate girder bridges. The writer is well satisfied that a large number of our designers do not have the same margin of safety in the compression flange of their through plate girder bridges as they have in the tension flange. Some recent tests of plate girders show that the ultimate strength of the top flange is about the elastic limit of the material. In order to make the top flange of a through plate girder bridge the same strength as the bottom flange, we should have some formula to guide us in the proper proportioning of the top flange. A formula for this purpose can be developed only by a series of experiments. However, in the meantime it seems to the writer that we should apply our column formula to these flanges. Of course, the value of intermediate supports should be given proper consideration.

Another feature in plate girder designs, which the writer is inclined to believe will cause engineers some regret, is that they have not as a rule increased the thickness of their web plates in the same ratio that they have increased their flange areas. This is especially true of the long plate girder spans. When the large web plates are rolled at the mills, the edges of the plate cool first which causes the plate to become "dished." In order to eliminate this dishing or buckles in the web, it is necessary to put these web plates in the bending rolls until the buckles are eliminated. After this the plates are straightened for use. There can be no question but what there are heavy secondary stresses in all these large web plates. In addition to this the web plates are more exposed to corrosion than any other part of the structure, and if there is any deterioration in this structure, the web plates will show the greatest portion of this deterioration.

In many cases stringers and the shorter span plate girders could be built not only better, but also cheaper, by omitting stiffeners altogether, except at end connections or bearing points and in cases where necessary on account of other connections, and putting a like amount of material in the web, thereby obtaining a much stronger web and adding some to the strength of the flanges.

It frequently happens that heavy portal or sway bracing is attached to the upper part of bents, leaving the lower portion unbraced, and due consideration is not given to the bending which this portal or sway bracing might induce into the columns; the columns are merely provided with ordinary lattice bars below the portal or sway bracing instead of being provided with proper web plates or cover plates to transmit the shear to its proper destination.

Lattice bars should be eliminated where it is practicable, inasmuch as their function consists merely in holding members together, and they do not assist materially in transmitting the main stresses, whereas, if a solid plate were used it would form a part of the member as well as take care of any local shear that might be manifest.

In order to get accurate workmanship in large compression members, they should be so designed that they can be completely assembled in the shop before riveting. This practically means that even some of the smaller compression members should have lacing bars with at least two rivets at each end, in order to keep in proper alignment the members while they are being riveted in the shop. The larger members should have sufficient diaphragms to ensure the proper amount of rigidity.

There is a tendency among engineers to over-rivet their compression and tension members to make the material act as a unit, and it often happens that the material is weakened by this means. Material should be used as it comes from the mills with as little labour on it as possible.

In many cases the specifications call for symmetrical sections, but do not mention the fact that the connections should be symmetrical or at least an equal number of rivets on each side of the centre line of the member.

Some engineers are inclined to lay down rules to others which they themselves are not following, for instance, in trough floor construction used extensively for track elevation purposes. These troughs are filled with concrete and become inaccessible for painting and inspection. The writer believes that much better results might be obtained by using I-beams and reinforced concrete decking on top of the I-beams with ballasted floor on top of the concrete. In this way the structural material is always accessible for painting and inspection.

In the designing of mill buildings, especially where high-speed travelling cranes are used, special attention should be paid to the proper distribution of the lateral forces induced by the travelling cranes throughout the building. In cases of this kind, the bottom chords of the roof trusses should be provided with a good lateral system extending the full length of the building, so that the lateral forces will be thoroughly absorbed throughout the structure.

Nickel Steel.—Of recent years some of our engineers have been advocating the use of nickel steel and other steels of high ultimate strength. Inasmuch as the modulus of elasticity of nickel steel is the same as that of carbon steel, the structures designed with these steels of high ultimate strength, where the unit stresses are from two and one-half to three times those used for ordinary carbon steel, the deformation and deflections will be from two and one-half to three times those of structures built of ordinary carbon steel. As the deformation of the structure increases, the secondary stress also increases in proportion. What is more, even if the secondary strains have been rectified for the dead load, the deflections due to the live load will be much greater in proportion in structures of nickel steel than in those of carbon steel, for the reason that the weight of the live load in this case is much greater in proportion to the weight of the dead load than is the case where ordinary steel is used. In addition, the deflections caused by the passing of the live load over the structure are much greater owing to the increased unit stress employed.

For the above mentioned reasons, structures built of steel of high ultimate strength should be designed with the minimum secondary stresses. One of the worst features in connection with the use of nickel steel has been that some of our engineers have used carbon steel in conjunction with nickel steel. Take the case of a simple truss span, where the chords are made of nickel steel and the lateral bracing is made of carbon steel. The two chords are tied together by the lateral bracing forming one compression member, and any deformation which takes place in the chords due to the compression of the same must be borne proportionately by the laterals. This means that the lateral bracing may be stressed up to its elastic limit, while the chords themselves are not stressed beyond their usual requirements.

In stating that nickel steel and carbon steel should not be used together, is meant in such parts of the span that act in unison. For instance, there can be no objection to the use of carbon steel in a nickel steel structure for floor beams and stringers, or such members as act independent of the main

structure, provided ample provision is made for the stringer connections to expand. These are points, however, which can be taken care of in the design of the structure.

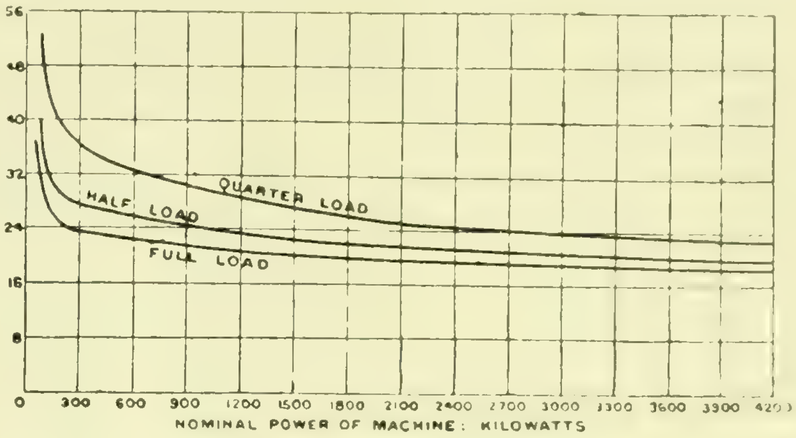
Secondary Stresses.—The future development of our bridges depends upon the careful consideration and elimination, as far as possible, of the secondary stresses. It will be observed that in none of the various types of spans considered is it possible to eliminate entirely the secondary stresses in the chords. The secondary stresses may be reduced by the selection of the proper section for the diagonals and their attachments to the chords. Secondary stresses are developed in trusses through the connections of the lateral bracing and the floor system. In a through bridge the elongation of bottom chord produces an elongation in the bottom laterals, resulting in heavy secondary stresses in both the floor beams and laterals when they are attached to the stringers and intermediate points. In a deck bridge the top chord being in compression is reduced in length, while the bottom flange of the stringers is elongated more or less, for which reason the stringers should be provided with extension joints at the floor beams in order to avoid excessive secondary stresses.

To minimise the effect of secondary stresses in a truss, it is well to omit knee bracing and sway frames at intermediate panel points. The main posts of a truss should be made the full depth of the truss wherever possible; in other words, bracing to increase the efficiency of posts and the use of substruts, materially increases the secondary stresses. Floor beams should be made deep and centrally connected to the posts. In order to avoid chord stresses to be transmitted to stringers, their end connections should be made flexible. This can be done by using a wide gauge of the outstanding leg of the angle connecting the stringer to the floor beam. When a truss with subdivided panels is used the unit stress of the floor beam hangers should be very low so as to keep down the elongation in same, as the elongation of the hanger produces heavy secondary stresses in the chords to which it connects.

Aside from the make-up of the various members of a truss span and their connections, a great deal depends upon the type of span itself. Secondary stresses are very materially increased or decreased according to the type of the truss, whether it is a single intersection, a multiple intersection, or a multiple intersection with vertical posts or without vertical posts. Another source of secondary stresses in a truss is due to the fact that the bottom laterals are, as a rule, attached to the bottom of the post quite a distance below the bottom chord, so that the chord stresses in the lateral system must travel through bending in the post into the bottom chord. Besides this defect, laterals are not generally run in centrally with the chord, thereby inducing uneven distribution of chord stresses.

EFFICIENCY IN STEAM ENGINES.

In his report on "The Efficiency in Steam Engines," presented to the British Science Guild, Sir Charles Parsons, C.B., F.R.S., states that in all steam engines the heat of the fuel is conveyed to the working fluid by conduction through the metal walls of the boiler or superheater, and the limits of the temperature of the cycle on which the efficiency of the engine primarily depends, are fixed at the upper end by the temperature at which deterioration of the boiler, superheater, and engine become excessive, and at the lower end by the temperature and quantity of cooling water available for condensation, and with the materials for construction at present available the upper limit of temperature seems to have been nearly reached. The highest efficiency realised by any steam engine up to the present is about 12½lbs. of steam per kilowatt hour, which is equivalent to 9·0lbs. per shaft horse-power, or a little over 1lb. of good coal, or about ·85lb. of oil burnt under a good boiler. This result has been obtained with units of 10,000 h.p. working at full load, with a steam pressure of 200lbs. gauge, superheated to a temperature of 300° C., and exhausting into a vacuum of 1in. absolute of mercury. It represents a conversion of about 70 per cent. of the available energy in the steam into mechanical power, or a conversion of about one-fifth of the heat in the fuel into mechanical work. On average load, and in every-day work, however, the consumption may be taken from 20 to 50 per cent. greater. As regards large reciprocating engines, the consumption of coal may be taken at from 10 to 20 per cent. greater than the above figures, and as regards moderate and small-sized engines and turbines when condensing, the average consumption may be taken approximately at about double the figures given for large turbines. With higher steam pressures and higher temperatures of superheat there would be some reduction in consumption of steam, but only a slight reduction in coal, because of the greater number of thermal units contained in each pound of steam, and also because of the increase in radiation. The reduction in coal may be taken at 1 per cent. for every 14° C. increase of temperature of the steam delivered to the engine.



Steam Pressure 150lbs. per Square Inch.
Vacuum, at full load 27in., at half load 27½in., at quarter load 28in.
Barometer 30ins.

In practice a temperature is soon reached beyond which the increased deterioration of the superheater, boiler, and engines more than counterbalance the saving in fuel, so that finality in this direction is soon reached, and in fact has already been nearly approached. At the lower end of the cycle, the temperature of the condenser being determined by that of the circulating water, there is not much scope for improvement in this direction. There is, however, a probability of some improvement in boiler and engine efficiencies by the reduction of petty losses, which in the aggregate represent a loss nearly equal to the total energy realised as mechanical work. These losses are about equally divided between the boiler and the engine, and have for many years been the subject of much careful thought and investigation. The conclusion at present appears to be that the boiler and the steam engine may be improved to some considerable extent by small economic improvements in the method of combustion, in the efficiency of heat transfer in the boiler and superheater to the working fluid, and in the engine itself, but that no further substantial improvement is possible in the condenser.

The New Science of Aerology.—In "The World's Work" for April, an article under this title says that above the highest ice clouds which float more than six miles above the surface of the earth there is a region in which there are no storms. Here the air is cold and dry, and so tenuous that a human being could not live in it, if he should succeed in reaching so great an altitude. This region is called the "isothermal layer of the atmosphere." Everybody knows that the top of a mountain is colder than its base. Suppose we could travel far above the highest mountain peak—should we find the air continually growing colder as we ascended? A few years ago science would have answered yes; but now we know that this is not the case. In the year 1902, a French meteorologist, M. Teisserenc de Bort, discovered that in every case, after a height of about six and a half miles was attained, the steady fall in temperature abruptly ceased, often giving place to a slight rise in temperature for a certain distance upward. A new "shell" of the earth's atmosphere had been reached—the isothermal layer, or, as its discoverer now prefers to call it, the "stratosphere." The temperature at the bottom of the stratosphere averages, in European latitudes, about 68° below zero Fahrenheit. The stratosphere is not, however, uniformly high over different parts of the world; it is lowest over the poles and highest over the equator. Hence in equatorial regions the regular fall in temperature of the lower air with ascent of the thermometer continues to a greater height than elsewhere. This accounts for the paradoxical fact that colder air is found over the equator than anywhere else in the world. The lowest air temperature ever recorded —119° below zero Fahrenheit—was found at a height of 12 miles over the heart of Africa.

TREATMENT OF PRODUCER GASES.

In the treatment of the gases obtained from gas producers in which ammonia is formed in considerable quantities and provision is made for its recovery it has been proposed to separate the so-called fixed ammonia, that is to say, ammonium salts, chiefly ammonium chloride, by subjecting the gases, prior to their passage through the usual acid chamber or "saturator" for producing ammonium sulphate, to a preliminary washing with hot water, the ammonium salt solution thus obtained being either treated with lime for liberating the ammonia or with sulphuric acid for converting the ammonium chloride into sulphate, or evaporated to separate out the ammonium salt. In the case of separating out the ammonium salt, it has also been proposed to burn or roast the salt so as to char the organic matters that discolour it, and to then lixiviate the mass so as to separate out the ammonium salt. The sulphur in most coals causes some ammonium sulphate to be present in the washing water in addition to the ammonium chloride. A method of treatment has recently been patented by Messrs. Vickers, Ltd., of River Don Works, Sheffield, in conjunction with Mr. John Imrie, the chief object of which is to obtain the whole of the ammonium salts in the form of ammonium chloride of marketable purity. According to this process, the ammonium salt solution resulting from the preliminary washing of the producer or other gases with water is treated, either before or after concentration, with an appropriate quantity of calcium chloride or other substance capable of reacting with the ammonium sulphate to form ammonium chloride and an insoluble sulphate.

In carrying out the process, a preliminary washing chamber is employed in which the gases are led in at the upper part, and led out also from the upper part, the lower part or "well" of the chamber being flooded with water and provided with a power-driven paddle for spraying the water into the upper region of the chamber where the gases are. The water may be heated before being supplied to the washing chamber, or may be at the ordinary temperature; in the latter case it will soon become hot by contact with the gases and will then liberate any free ammonia that it may have temporarily held in solution, and in either case it will be maintained hot by the heat of the gases. In the exit passage from the washing chamber, baffle plates are provided to prevent any spray or water vapour from the chamber from being carried away and lost. Means may be provided to withdraw the liquid that accumulates in the neighbourhood of the baffles, since under some circumstances this liquid may be as rich in chloride and sulphate of ammonia as that in the well of the washing chamber or even richer than the latter.

At intervals the liquid in the washing chamber or the liquid collected near the baffles, or the liquid from both sources, is withdrawn, and after being first freed as far as practicable from the coal dust and tar, is then treated, either before or after concentration, with an appropriate quantity of calcium chloride or other suitable substance that is capable of reacting with the ammonium sulphate to form ammonium chloride. The precipitated calcium sulphate or other readily removable product of the reaction is then separated from the ammonium chloride solution, and the latter is subjected to any further evaporation necessary to crystallise out the salt. The salt at this stage may require to be purified owing to the presence of a certain quantity of tarry and other matter; this matter can be removed by calcining the salt at a low temperature, say, from 200° C. to 300° C., and by then treating the whole calcined mass with water, separating the salt solution from the insoluble matter, and recrystallising the salt. The process may also be applied to blastfurnace and coke-oven gases.

Crystal Palace Engineering School.—The "Wilson Premium for the best paper read before the Crystal Palace Engineering Society, which is affiliated to the Society of Engineers (Incorporated), during the present session, has been awarded by the Council to E. C. Coke, for his paper on "The Electrification of the L. B. and S. C. Railway." The premium was presented by Rear-Admiral Gordon Wilson Moore, Director of Naval Ordnance, on April 17th.

INDUSTRIAL AND TRADE NOTES.

Scottish Iron Combine.—After protracted negotiations the principal Scottish malleable ironmakers have agreed to amalgamate. The capitalisation will probably be about one million sterling, and the new company will control 15 works, with an annual output of 250,000 tons.

Petrol-driven Cars on the North-eastern Railway.—The North-eastern Railway Company has just introduced a petrol-driven car, which is to be used for inspection purposes by the executive and district officers. Hitherto the work has been undertaken with a coach drawn by an engine. The new cars, of which two have been built, are to be stationed at Newcastle and York respectively. Each vehicle is 23ft. 6in. long and 8ft. 6in. wide. There is a saloon 16ft. long, with driver's compartments at each end. Three speeds of 15, 22½, and 45 miles per hour are provided.

Propo.ed Combinations of Shipyard Trade Unions. The members of the Boilermakers' Society are being asked to vote this month on two separate proposals to combine with other shipyard trade unions. The more important of the two schemes is that of amalgamation with the Ship Constructive and Shipwrights' Association, the other is that of federation with the Liverpool Shipwrights. In the first case amalgamation means the constitution of a new joint society of boilermakers and shipwrights under one governing authority, with a new code of rules suitable for the members of both trades. In the other case the proposal is simply to set up a working arrangement between the two societies under which each would be left to manage its own internal affairs.

Boilermakers and the "Down Tools" Policy.—The Executive Council of the Boilermakers' Society, in their current monthly report, issue a warning to members against stopping work without doing all that can be done in the way of negotiations on a question in dispute in accordance with the provisions of the supplementary agreement. Members acting contrary to this instruction, they state, put themselves outside the pale of the rules of the society, and must themselves be held responsible for the consequences arising from such exclusion. In no case, it is added, should members require to wait longer than one week for a price to be fixed or a grievance to be redressed by the constitutional procedure now well known to all the members of the society. In conclusion the executive state that they and the district committees will put the rule into force against members who take the law into their own hands.

A Large Weighbridge.—A large weighbridge has just been laid down at the Parkhead Forge of Messrs. Wm. Beardmore & Co., Ltd. This is the most powerful weighbridge in Scotland, and it has been installed to cope with the tremendous increase in the weight of armour plates, naval guns, and general ordnance. The weighbridge has been specially designed by Messrs. W. & T. Avery, Ltd., of Birmingham and Newcastle. Two "live" platforms are laid down on the railway sidings with an intermediate "dead" space, allowing the largest rolling stock to be poised. Avery's patent combination steelyard is fitted, enabling the machine to register any load from 7lbs. up to 181 tons. This weighbridge, in view of its importance, has just been subjected to the severest Board of Trade tests. When fully loaded with 181 tons, the steelyard plainly indicated the addition of 30 ozs., showing a delicacy and sensitiveness of 0.00004 per cent.

Sir W. G. Armstrong, Whitworth, & Co., Ltd.—The annual meeting of Sir W. G. Armstrong, Whitworth, & Co., Ltd., was held at Newcastle-on-Tyne on the 18th inst., Sir Andrew Noble presiding. Moving the adoption of the annual report, which recommended a dividend of 12½ per cent. and the carrying forward of £201,000, the chairman congratulated the shareholders on the successful year, and said that their works at Pozzuoli, Italy, had been greatly developed. Recently they had laid down steelworks so that they could make their own forgings and castings for guns instead of purchasing them, and now employed 4,000 men, compared with 1,100 ten years ago. In March last they delivered the battleship "Monarch" to the Admiralty after making a record in rapid construction. She was the largest and most powerful vessel they had built for the Admiralty, but the Brazilian "Rio" and Chilian "Valparaiso" they were now constructing were larger and more powerful. The great and continued growth in the dimensions of the vessels had forced them to construct their new warship yard at Walker, and in 12 months they hoped to be able to lay down the largest type of battleship there.

Wireless Telegraphy Developments.—The Marconi Wireless Telegraph Company announces that it has made arrangements with the Marconi Wireless Telegraph Company of America to construct for that company a number of long-distance wireless stations, and that the two companies have signed a working agreement with the Western Union Telegraph Company, of New York, and with the Great North-western Telegraph Company, of Canada, which provides that the companies shall have the full benefit of those

companies' landline stations for the receipt and the delivery of their messages throughout the United States and Canada upon the most favourable cable-rate terms. The telegraph companies have in all about 25,000 offices throughout the United States and Canada. The Marconi companies are to erect long distance wireless stations providing direct communication between New York and London. Preparations are in hand for the construction of stations to give communication with the East from San Francisco, to the Hawaiian Islands, the Philippines, China, and probably Japan. The American company's programme further provides for a second long-distance station to be erected in the immediate vicinity of New York to communicate with Cuba, Panama, and South American countries.

London Chamber of Commerce and Labour Unrest.—The 30th annual meeting of the London Chamber of Commerce was held in London a few days ago. In moving the adoption of the annual report, the Chairman said that a special committee enquired into the whole question of the labour unrest and the proper remedies, and submitted some valuable information on causes and effects, as well as remedies, the need of which was strikingly exemplified in the dock and railway strikes of last year, and in the still more serious strike in the coal trade. On this vital question the recommendations of this and other Chambers of Commerce had not yet been given effect to, but the pressure of public opinion, stimulated by recent experiences, must in the long run bring about the adoption of measures, however drastic, which would safeguard the community as a whole from the recurrence of conditions which were fast becoming intolerable in a free country. Another special committee had reported on the question of misdescription and misrepresentation in trade. Here the recommendations of the Chamber had been accepted in principle by the Board of Trade, and before the year was over they might expect that the voluntary efforts of the Chamber would receive more active support of the Government in promoting the cause of trade purity.

Electrically-driven Air Pump.—In connection with a pneumatic cesspool emptying installation for service at a large hospital abroad, Messrs. Merryweather & Sons, of Greenwich, have recently supplied a new type of air pump, arranged to be driven by a small electric motor. The motor and pump are mounted on the same bedplate, forming a very compact set. The services of the pump will be requisitioned for exhausting the air from two portable tank vans, each of 350 galls. capacity, enabling the contents of the cesspool to be drawn up into the tanks through suction hose. The pump, which is known as the "Ravensbourne" pattern, is of the double-barrel type, constructed entirely of gun metal, with rubber disc valves arranged under separate covers so as to be instantly accessible. The pump barrels are placed opposite each other, and the plungers are driven by means of a crank and connecting rod. The electric motor gives 2 b.h.p. at 950 revs. per minute. In view of the fact that the plant was required for a hospital, special precautions have been taken in order to ensure noiseless working as far as possible, and the drive from the electric motor to the pump is therefore transmitted through a special wormwheel gearing, which is enclosed in a gun-metal casing forming an oil bath. This arrangement is so effectual that the appliance is absolutely noiseless in working. The pump can be operated alternatively by means of hand gearing, with detachable winch handles, this gearing being put in and out of action by means of a small lever.

The Shipyard Demarcation Agreement.—The text of the agreement regarding demarcation disputes which has been arrived at between the shipbuilding and engineering federations of employers on the one hand and shipyard trade unions on the other is given in the current monthly report of the Boilermakers' Society. The report states that the agreement has little resemblance to the one which the men's representatives asked from the employers, but that it is the most the employers would agree to. The trade unions concerned are to be asked to vote on the question whether they will accept the agreement or not. The agreement stipulates that there should be no stoppage of work on account of a demarcation dispute, that an endeavour should be made to settle the dispute immediately it arises in the works, and that failing such a settlement the recognised practice of the works should be continued pending a settlement by the committee appointed in terms of the agreement for dealing with disputes; that the decisions of the committee should be accepted by the parties as final and binding all decisions to continue for a period of 12 months and thereafter until brought up for review on three months' notice, that the application of the decision should be confined to the works in which the question arose, and that existing arrangements entered into between societies and employers, or recognised by employers, for the settlement of questions of demarcation of work should continue in force until otherwise agreed by the parties concerned. Both the employers' and the men's representatives have agreed to recommend acceptance of the agreement to their respective societies. The agreement, if accepted, will come into force on July 1st in the following districts: Aberdeen, Dundee, Edinburgh Leith, Clyde, Tyne, Wear, Tees, Hartlepool, Barrow, Liverpool, Birkenhead, and Hull.

Competition in the British Electrical Industry.—In an article on "Electrical Progress in Britain and America," by Mr. D. S. Martin, in the "General Electrical Review," reference is made to the severity of the competition among British electrical manufacturers. While healthy competition is necessary to stimulate activity, an excess of it is, the writer considers, altogether harmful, since it inevitably makes the question of price pre-eminent, and denies the manufacturer those financial resources which are requisite for the prosecution of research work. The author contends that even if British manufacturers were permitted by law to combine for the maintenance of prices, it is unlikely that any permanent improvement would result, and he submits that relief will be found only when two or three firms can shake off their rivals and establish themselves in a strong position. It may be necessary to employ a consulting engineer in a country where the manufacturers are engaged in cut-throat competition, but the present position is not a happy one for the manufacturer, in that he may be required to fill many contracts for motors differing only in minor details, but necessitating new drawings, tools, &c., the cost of which absorbs the profits. The Universities and the consulting profession contain many men who could be employed more advantageously by the manufacturers, but this cannot be done until the manufacturer makes sufficient profit to enable him to pay them the salaries they require, and he cannot get the profits out of his business until he has acquired the standing which renders a large part of the outside consulting work unnecessary. But under the regime of fierce competition no manufacturer can acquire this standing, and close surveillance of all by the consultant is the rule. It is this state of affairs which has resulted in the extraordinarily high standard of efficiency which has been reached in all departments of the electrical manufacturing business in Britain, in the workmanship of the machine, as well as in the ingenuity of the designer which enables him to extract the very last watt out of each pound. It is this same condition which will continue to prevent the British electrical manufacturer from performing his full share in pioneer work towards the bulk electric supply systems prophesied by Steinmetz and Edison.

Industrial Disputes in 1911.—An account of the proceedings during 1911 under the Conciliation (Trade Disputes) Act, 1896, is contained in the ninth annual report, just issued by Sir G. R. Askwith. The report states that last year was characterised by considerable industrial disturbance, the number of workpeople involved in disputes causing a stoppage of work being the highest in any year since statistics of trade disputes have been recorded by the department. This unrest was very marked in the transport trades, in which industry, during the months of June, July, and August, strikes broke out in most of the principal ports of the United Kingdom, the trade of some of the ports being brought, in consequence, almost to a standstill. In August a national strike of railwaymen also occurred. One of the most important developments dealt with in the report is the establishment of the Industrial Council after consultations with representative employers and workmen, in August and September, 1911, with a view to strengthening the existing official machinery for settling and for shortening industrial disputes. The number of cases in which action was taken under the Conciliation Act (1896) during the year 1911 was 92. Of the 92 cases, 57 were disputes involving a stoppage of work affecting in the aggregate about 565,000 workpeople. Last year's figures were more than twice as large as those of any former year, the previous largest having been 27 in 1910. During the year recourse was had in seven cases to the system of courts of arbitration established in 1908. The transport trades constituted the industry in which the largest number of cases occurred, 21 cases affecting those trades being dealt with, as compared with three in the previous year and 27 in the whole of the period 1896-1910. 18 of these cases involved a stoppage of work affecting nearly 345,000 workpeople. In the metal, engineering, and shipbuilding trades the number of cases (19) was considerably above the average of previous years. Twelve of the cases involved a stoppage of work affecting about 10,000 workpeople. In the early years application for intervention came mainly from one side only (generally from the workpeople), but in recent years there has been a tendency for the majority of applications to be made jointly by the parties or by organisations representing them. The total number of Conciliation Boards in existence at the end of 1911, so far as known to the Department, was 293.

Pit Cage Accident.—Another cage accident, fortunately unattended by loss of life, occurred at the Kiveton Park (High Hazel) Colliery a few days ago. The afternoon shift was being lowered down the shaft, and when about 15ft. from the bottom the cage suddenly dashed downwards, injuring four of the occupants.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1910.

Water tube steam boilers. Hindley, Hindley, & Stanford. 20132.

1911.

Apparatus for cleansing steam and heating boiler feed water. Morison. 2563.
Apparatus for controlling mechanism from a distance. Bloxam. 2819.
Process for making fuel briquettes. Forwood & Zimmer. 5288.
Rock-drilling machines. Smith, Innes, Joss, & Horne. 5462.
Water-jet ejectors. Morison. 7809.
Centrifugal ore separators. Peck. 7893 and 7894.
Detection of inflammable gases in mines. Sandy & Franks. 7998.
Valve operating mechanism for reciprocating engines, pumps, and brakes. Barnich, Richardson, Richardson, & Defordt. 7986.
Steam engines. Orbell. 8040.
Steam generators. Johnston & Womersley. 8177.
Rotary pumps. Nelson & May. 8322.
Shaft couplings. Simpson. 8366.
Means for magnifying small mechanical or electrical effects. Heurtley. 8397.
Combined heater and filter. Gambati. 8414.
Turbines. Corthesy & Corthesy. 8444.
Valve mechanism for air compressors. Astrom. 8626.
Rotary pumps. Internationale Rotations Maschinen Ges. 8675.
Rotary engines and pumps. Vaughan Sherrin. 8699.
Carburetting apparatus. Schmidt. 8882.
Mining machines. Jenson. 8895.
Mechanical device for automatically locking the second of two shafts so as to prevent its rotation other than through the action of the first. Ringrose. 9010.
Smelting or refining of metals in crucibles. Solomon. 9031.
Rolling of metal sections. Smith. 9086.
Apparatus for laying dust in mines. Mavor & Coulson, Ltd., and Mavor. 9312.
Two cycle gas engines. Crowe. 9956.
Water heaters and steam generators. Sauer. 10020.
Apparatus for foundry moulding. Moore & Rix. 10084.
Apparatus for recording the amount of time during which a machine is in operation. Boult. 10943.
Revolving cylinder internal combustion engine. Canda. 11330.
Transporting mechanism. McLacklin. 11462.
Firegrates for steam boiler furnaces. Curtis. 11687.
Vacuum gauges. Wood. 12156.
Quick gripping spanners and pliers. De Veulle. 12323.
Lubricating internal combustion engines. De Rusett. 12874.
Starting mechanism for explosion engines. McCormick. 12971.
Automatic governors for marine engines. McIlvenna. 13421.
Internal combustion engines. Douglas. 13535.
Carburetters for internal combustion engines. Davis. 13842.
Controlling device for railway signals. Reid. 14472.
Annular ball and roller bearings. Keiper. 15194.
Hydraulic presses and apparatus for breaking steel and other metal rails, billets, &c. Ward & Lash. 15374.
Centrifugal pumps or turbines. Rees. 16529.
Toothed gearing. Guillon. 17232.
Straightway valves. Harris. 17872.
Rotor wheels for centrifugal ejector pumps. Jaeger. 18211.
Radiators for heating buildings. Steffen. 18272.
Carburetters for internal combustion engines. Gottmann. 19322.
Road trains. Lake. 19782.
Valve gear for high speed internal combustion engines. Adlerwerke vorm. Heinrich Kleyer Akt Ges. 21823.
Steam distributing means for twin steam engines. Smal. 22022.
Furnaces for heating tools. Brayshaw & Brayshaw. 23066.
Valves. Lord. 23179.
Roller bearings. Lewis. 24648.
Hand tools for inserting and withdrawing ferrules from tube plates. Jenkins & Jenkins. 24672.
Crane like apparatus for use in connection with blastfurnaces. J. Pohlig Akt. Ges. 24924.
Gas producers. Clime. 25736.
Car couplers. Simons. 25798.
Process in the refining of iron and steel. Hjorth. 25915.
Carburetting apparatus. Schmidt. [illegible]
Internal combustion engines. Brandis. 26012.
Radiators for heating buildings. Karsten, Serritslev, & De Forenede Jernstoberier Aktieselskab. 26169.
Bearings for rotary shafts. Jackson and J. G. Jackson, Ltd. 26299.
Mechanical stokers. Bennis. 26590.
Pressure retaining valve devices. Turner. 26609.
Compressed air brakes. De Lipkowski. 26946.
Means or apparatus for obtaining power from the rise and fall of the tide. Philp. 27049.
Jet propulsion apparatus. Zelter. 29184.
Purifying the smoke from boiler furnaces. Mellor. 29346.
Bandsawing machines for metal. Noble and Lund. 29385.

1912.

Lubrication of internal combustion engines. Butterfield. 659.
Lubricating devices. Bavier. 1374.
Rotary pumps or motors. Nelson & May. 2331.

ELECTRICAL, 1911.

Control systems for electric motors for driving reversing mechanisms as applied to machine tools. Vickers, Ltd., and Ellson. 7882.
Electric motor controlled regulating devices for furnace dampers and valves. Rennert. 8151.
Wireless telegraphy. Bull, Arnesen, & Sizer. 8236.
Magneto electric machine. Lindos. 8340.
Remote control systems for electrically driven vehicles. Elektromotoren Werke Hermann Gradenwitz. 10551.
Electric furnaces. Planson, Zsvetaeff, & Tistchenko. 10858.
Electrical current controlling device. Berdon. 15149.
Electric furnaces. British Thomson Houston Company. 17060.
Magneto electric machines. Flint. 18702.
Electrical controllers. Bray, Markham, & Reiss, Ltd., Bray, Markham, and Reiss. 19365.
Arc lamps. Rogers & Rowe. 26511.
Apparatus adapted for use with an alternating current for signalling to a distance. Hartmann & Braun Akt. Ges. 26548.
Electrical heating apparatus. Byng & Archer. 28779.

METAL QUOTATIONS.

TUESDAY, APRIL 23RD.

Aluminium ingot	67/- per cwt.
,, wire, according to sizes, &c. ......from	102/- ,,
,, sheets ,, ,, ... ,,	120/- ,,
Antimony £27 -/- to	£27/10 per ton
Brass, rolled	8½d. per lb.
,, tubes (brazed)	10⅞d. ,,
,, ,, (solid drawn)	9d. ,,
,, ,, wire	8⅝d. ,,
Copper, Standard	£69/10/- per ton.
Iron, Cleveland	53/6 ,,
,, Scotch	59/6 ,,
Lead, English	£16/17/6 ,,
,, Foreign (soft)	£16/13/9 ,,
Mica (in original cases), small	6d. to 2/- per lb.
,, ,, ,, medium	2/6 to 4/- ,,
,, ,, ,, large	4/6 to 8/6 ,,
Quicksilver	£8/12/6 per bottle.
Silver	27 $\frac{5}{16}$d. per oz
Spelter	£25/17/6 per ton.
Tin, block	£202/15/- ,,
Tin plates	14/3 ,,
Zinc sheets (Silesian)	£29/-/- ,,
,, Stettin; Vieille Montagne	£29/7/6 ,,

British Foundrymen's Association.—The first meeting of the Newcastle and District Branch of the British Foundrymen's Association was held a few days ago at Newcastle-on-Tyne. The president, Mr. R. Wallis, in his address, laid emphasis upon the fact that all foundrymen should strive to attain high ideals in their work, and to keep an open mind on all subjects appertaining to their craft. All should cultivate the habit of training their power of observation, especially in relation to the behaviour of the various processes and phenomena coming under notice. The possession of a highly-cultivated power of observation enabled them to intuitively deal with the complex questions and results arising in a foundry with almost mechanical accuracy. The next lecture is to take place on April 27th, on "Modern Foundry Practice," by Mr J. Smith, of South Shields.

The Mechanical Engineer.

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Museums of Safety Appliances.

An interesting little year book has been issued by the American Museum of Safety setting forth its aims and recording some of the good work it has already accomplished. These are in many ways so admirable and advantageous that, in view of our position in the industrial world, it seems surprising a museum of safety appliances on the lines which have proved so beneficial both in America and on the Continent is not already established in this country. Berlin, Munich, Vienna, Paris, Milan, Stockholm, and many other cities have such institutions, and there is no doubt their educational value is great both to employers and workmen, as well as economically beneficial to the nation, for the death or maiming of workers in the prime of life, apart from humanitarian considerations, is a tax on industry. Our factory legislation by its efficiency and vigilance has, it is true, anticipated to some extent the educational efforts of the institution that has been established in the States, where industrial operations are conducted with a disregard for the safety of life and limb that has often evoked comment by its appalling character, and where they have consequently fuller scope. The magnitude of this waste of life and limb is illustrated by the fact that in the year 1907 35,000 workmen were killed and two million more or less seriously injured by industrial accidents in the United States. At the same time, such institutions are capable of exercising an influence which compulsory legislation cannot always command. The actual inspection and study of working appliances always tend to arouse a more wide and active interest than is possible by a factory by-law backed up by a Government inspector, and the voluntary adoption of any appliance is for similar reasons always likely to be more effective. The good work already done by the American Museum has been recognised by the granting of a special Charter of Incorporation by the State of New York. The Institution, like those on the Continent, is run on non-

commercial lines. No exhibits are sold, nor do the authorities engage in the promotion of any devices. The majority of the exhibits are not patented and are hence available for all, while no exhibit is accepted unless it has a safety feature and has been passed by the Board of Approval. There is no charge for space and all demonstrations are made by the staff and free to the public. Another feature is that the association is supported entirely by voluntary subscriptions from firms all over the States, who recognise the value of the work undertaken and testify it in numerous letters embodied in the year book. For instance, one large iron and steel works employing some 7,000 men states that in 1906 the fatalities from accidents numbered 47, whereas in 1909 after the introduction of a safety committee working in close touch with the Museum the fatalities were reduced to 12, the majority of which, it is stated, were accidents of a kind that could not have been avoided by any means. The statement of the Museum that one-half of the industrial accidents in the States could be prevented by the adoption of suitable appliances is strikingly confirmed by the superintendents of two large plants employing some 15,000 workmen, one of whom writing to the authorities after adopting its suggestions remarks, "We know it, for we have cut down the accident list at our plants by more than 60 per cent." The work of the Institution is not confined to the display and working demonstrations of exhibits, but includes also the publication and dissemination of illustrated pamphlets and literature amongst the army of workers. Notwithstanding the high rate of immunity generally enjoyed from industrial accidents in this country, and for which due credit should be accorded to legislative supervision, there is still in many directions room for improvements, and we cannot help thinking that a British Museum of Safety run on similar lines would prove advantageous to the community.

PARAFFIN AS A FUEL FOR MOTOR-CAR ENGINES.

At a recent meeting of the Institution of Automobile Engineers, Prof. W. Morgan and Mr. E. B. Wood described the results of some experiments in the use of paraffin as a fuel for motor-car engines. The problem was to run an ordinary touring car engine on paraffin, with sensibly the same ease, flexibility, economy, and power as on petrol, and to determine the paraffin of highest boiling point usable. The difficulties to be overcome were (*a*) the ordinary carburetter difficulties due to variation in mixture quality; and (*b*) the difficulties in vaporising the paraffin and holding it up as an explosive mixture. There was undoubtedly an apparently greater sensitiveness to mixture variation in the case of paraffin than in the case of petrol, due, probably, to difficulties of vaporisation and the rapidity with which deposition occurred. Whatever the cause, the need of accurate carburation was intensified.

In attempting to make a paraffin carburetter, the following principles were laid down by the authors: (1) All fuel should be completely evaporated before entering the engine, although partial condensation might occur after evaporation; (2) the fuel should be evaporated in the presence of some 10 to 20 per cent. of the total air required, and then mixed with the remaining air, and (3) the evaporated fuel, before mixture with the main air, should be superheated, with the objects of (*a*) producing a fog of extremely fine texture on dilution, and (*b*) producing a fixed gas. The necessity for observing the first principle was obvious merely on account of lubrication, particularly in the case of sleeve, piston, and rotary valve engines. Further, liquid paraffin on a highly heated surface, such as that of a valve, readily cracked, but the vapour might safely be heated to a much higher temperature without decomposition, and when cracking occurred would form products in such a state of division that combustion was easy, and deposition rarely occurred. Although evaporation might be complete in the vaporiser, yet on mixing such a charge with extra air a mixture of a fog-like character was formed. The paraffin condensed in this form had practically no wetting properties, and differed entirely from the coarser particles of liquid formed by spraying the fuel. High thermal efficiency could not be obtained unless the fuel was atomised as finely as possible; a completely vaporised condition, if possible, was the best. Fuel particles of any size took an appreciable time in burning, and hence burned inefficiently. The burning might easily be incomplete, and give rise to further inefficiency, and cause cracking, with deposit or foul exhaust. This action could take place in the case of petrol. With the paraffin in the fog condition, it was probable that on compression the fuel was evaporated, for the observers had failed to note in the case of engines running on such mixtures any evidence in the indicator diagram of want of sharpness in explosion or signs of delayed burning beyond those observable with petrol.

The second principle depended on the necessity of keeping the charge temperature as low as possible in order to maintain a high charge density, and to prevent pre-ignition. If evaporation of the paraffin in the presence of the whole air were attempted, it was necessary to raise the temperature of the whole charge to a temperature approaching that of the boiling points of the heavier fractions. This temperature was difficult to govern, and it was quite possible for some form of ignition to be set up in the overheated evaporating charge. The troubles and losses caused by this action would be proportionally greater when the whole of the air was concerned than when a fraction was involved. The 10 to 20 per cent. of air used in evaporation acted as a carrier in much the same way as steam or nitrogen when employed in the distillation of organic compounds somewhat unstable with heat. It lessened the tendency to cracking, with the accompanying deposit of tar and coke. In addition, this carrying air exercised a useful function in assisting the mixing of the evaporated charge with the main air with *minimum* deposition. Later work had shown that the third principle was very much open to question. There was no evidence that a finer fog resulted from mixing a rich charge at, say 550° C. with air than from mixing a charge at 300°, but there was evidence that where high superheat had been employed a dense readily depositing fraction occurred which caused the highly superheated charge to deposit in greater quantities than the cooler charge. The quantity of fixed gas produced was disappointing, and its character was such that its production was undesirable.

In spite of this the first attempts at making a paraffin carburetter were encouraging. It was placed on the exhaust side of the engine, with main and carrying air throttles connected. The fuel, with its fraction of air, was fed tangentially into a cylindrical chamber and delivered axially, passing directly through the superheater pipe down the centre of the exhaust pipe. The object of the circular vaporiser was to trap all unevaporated paraffin, and prevent it from entering the more highly heated superheater, and either escaping unevaporated or cracking on the hot walls. The circular evaporator was quite successful, and after considerable use no trace of deposit was observed in the superheater. The highly-heated charge, now mixed with the main air, was discharged straight along the induction pipe, so as not to impinge on any surface. The temperature of the mixture entering the cylinders varied from 60° C. to 80° C. Other modifications of the parts were used, but it was noted that for slow running the most successful results were obtained with the evaporator on the engine side of the throttle.

In running the exhaust was generally clean and odourless. The engine showed no signs of deposit other than those due to lubricating oil, except on two occasions, one when an attempt was made to start from cold on a mixture of petrol and paraffin, and another when an attempt was made to run the engine on crude oil. The highest *mean effective* pressure was 70lbs. per square inch. The plugs were clean, but showed signs of high temperature. In one case the electrode was found to be fused away. The engine was then running at 1,600 revs. per minute under four-fifths load. The engine was capable of high speeds, and yet could pull down to quite low speeds. Carburetters evaporating on the engine side of the

throttle were much more successful at low speeds than those evaporating outside the throttle. In conclusion, the authors said it would appear that there was a sharply defined limit to the grade of paraffin which might be burnt in an ordinary petrol engine, as the oil must be heated to the boiling point of its heaviest fractions, and yet this temperature should be below the ignition temperature, else a fraction of the air was burnt wastefully. The evaporation should be carried out in the presence of some 20 per cent. of the air necessary for combustion, and the mixture diluted afterwards to the necessary degree.

THE KINETIC AIR PUMP.

In the course of the discussion on the paper entitled "Some Considerations on the Choice of Auxiliary Plant for Power Stations," read by Mr. A. H. Finch, M.A., before the North-East Coast Institution of Engineers and Shipbuilders, and reproduced in our issues of March 1st and 8th (see pp. 269 and 306 ante), Prof. R. L. Weighton said that he had, within the past four years, given a good deal of attention to rotary air pumps of the class in which the power expended in driving them was "largely conserved in the form of heat," and furnished a brief description of what seemed to be a most prominent system of air pump, involving the rotary type. He said that about three years ago a specimen of rotary air pump—now known as the Kinetic air pump—was offered to the Armstrong College by its owners, on condition that a series of tests should be made upon it. This offer was accepted; the pump was coupled to the experimental engines, and the tests were made. The pump in question was unique in many of its qualities. Figs. 1 and 2 showed sections through two forms of the main part of the vacuum-producing portion of the apparatus; and Figs. 3 and 4 showed two alternative arrangements. The system comprised a small centrifugal pump, which circulated the feed water through the nozzles, as in Fig. 4, and another specially-arranged centrifugal pump, which extracted the feed water from the condenser, and discharged it into the suction source of the first-mentioned pump. Both of these pumps were driven from one shaft, any kind of high-speed rotary motor being suitable. Preference would probably, however, be given to a small steam turbine, the exhaust of which would be utilised as a steam jet in front of the water jets, as shown in Figs. 3 and 4. Fig. 3 showed a rotary feed pump mounted on the same shaft, and in association with a separate feed heater. The apparatus presented to the college was made of a size to suit the experimental engines, and the tests made were of a varied and exhaustive character. It always worked most satisfactorily, and gave no trouble of any sort whatever. As regarded the results obtained, sufficient time was not available to detail them, and Prof. Weighton referred only to certain points of special interest.

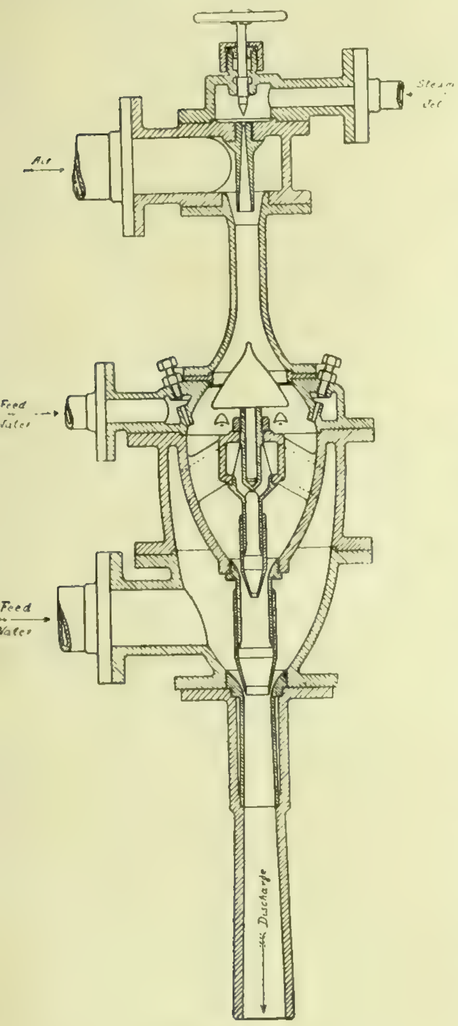


FIG. 1.—EXPERIMENTAL APPARATUS.

(*a*) *Vacuum.*—The air-rarefying powers of the Kinetic system were very high indeed. The air pump normally attached to the experimental engines was of the ordinary bucket and foot valve vertical type, driven by the main engines, and was of unusually large dimensions in relation to the engine cylinders. Under certain conditions, when this pump maintained a vacuum of 29 ins. the rotary pump maintained 29½ ins. Nothing whatever was altered except that the one pump was switched out by the closing of a valve and the other was switched in by the opening of another valve, so that the comparison was absolutely a fair one. Prof. Weighton then gave the following results, taken on March 3rd, 1910, in the presence of a party of technical visitors, these results being typical of what could be done by this pump at extremes of vacuum. He drew special attention to the fact that the "drop" ($t_s - t_o$) was negative to the extent of 4 with the

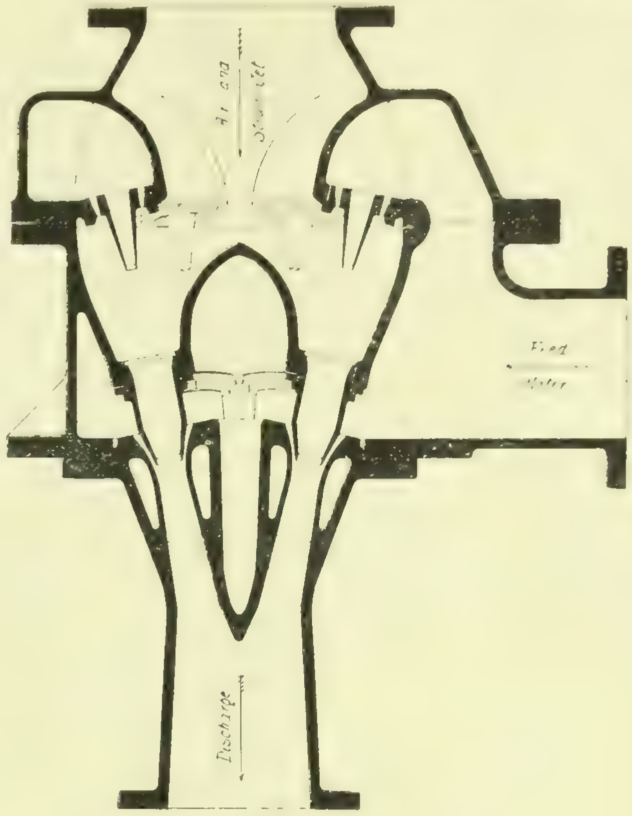


FIG. 2.—MULTIPLE NOZZLE APPARATUS.

new pump, and—in the same conditions—was positive to the extent of 17° with the ordinary pump. In all trials with this new pump the feed water was extracted from the condenser along with the air, no separate water-extracting pump being fitted for these experiments. The figures given in the following table were an average of three trials in each case.

It was to be distinctly noted that owing to the great quantity of condensing water used in both cases these results could not be regarded as representative of ordinary working. They were given merely to show the capabilities of the pump in conditions usually associated with extremely high vacua.

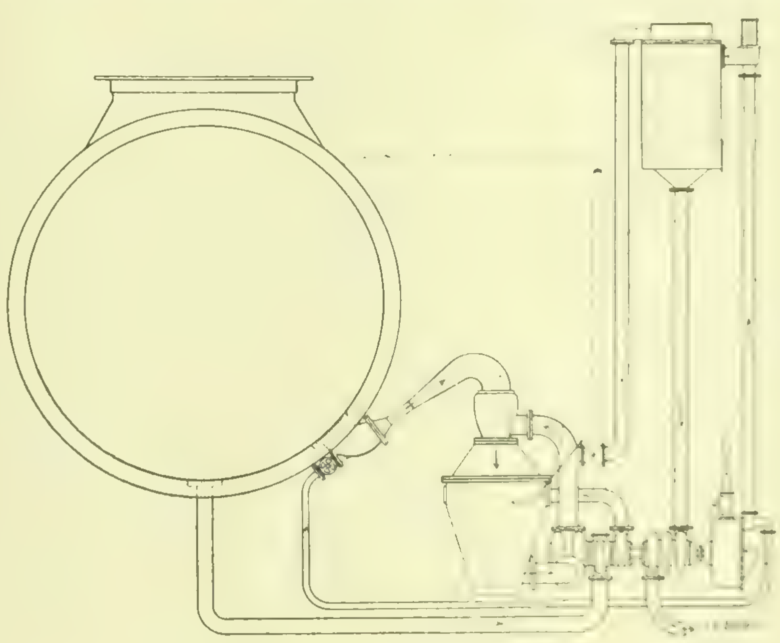


FIG. 3

But no matter what the conditions might be in practice, Prof. Weighton had always found that the condenser "drop" was diminished materially by the use of this rotary pump, as compared with the reciprocating type, and this he took as an index of greater rarefying capacity. Even with a very much higher

t_H than that given, the vacuum maintained by the rotary pump would not have been reduced.

Vacuum	t_V	t_o	t_H	t_I	$t_V - t_o$	Remarks.
28·88	82	65	73°	55	+17°	Reciprocating pump in action.
29·44	61	65	89·5°	54	− 4°	Rotary pump in action.
·56	21°	0°	16·5	1	21°	Differences in favour of rotary pump.

Vacuum reduced 30in. barometer.

t_V = temperature corresponding to vacuum.
t_o = temperature of condensing water at outlet.
t_I = temperature of condensing water at inlet.
t_H = temperature of hotwell or Kinetic tank.

(*b*) *Heat Efficiency.*—When the rotary pumps were driven by an auxiliary steam turbine, the exhaust of which was used in the steam jet of the air ejector, it was apparent that the efficiency of the apparatus was practically 100 per cent. The whole of the steam jet was condensed inside the ejector, and therefore the whole of its heat, both sensible and latent, was returned to the boiler; all the energy expended on fluid friction and on bearing friction in the rotary pumps, as well as on the high-velocity water jets, appeared as heat in the feed water, and was returned to the boiler. The only energy lost

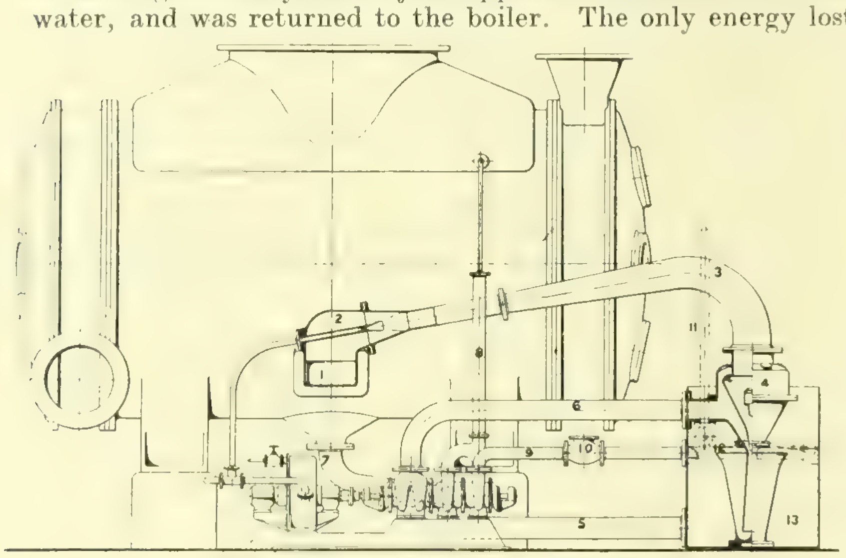


FIG. 4. CONDENSER WITH KINETIC AIR PUMPS.
1.—Air Suction Orifice on Condenser. 2.—Exhaust Steam Jet. 3.—Air Pipe to Kinetic Ejector. 4. Kinetic Ejector. 5. Suction Pipe to Kinetic Pump. 6. Kinetic Pump Discharge Pipe. 7. Condensed Water Pipe to Head Pump. 8.—Stand Pipe between Head and Pressure Pumps 9.—Pressure Pump Discharge to Tank. 10. Non-return Valve. 11. Feed Water Delivery Pipe. 12. Float Controlled Feed Delivery Valve. 13. Kinetic Tank.

was that small quantity representing the equivalent of the heat dissipated by radiation and conduction.

(*c*) *Relation between Hotwell Temperature and Vacuum.* An important feature in this system of air pump was that the temperature of the water used in the ejecting jets could exceed that corresponding to the vacuum by an amount varying from 15° to as much as 60°, according to the amount of air to be dealt with, and the amount of steam used in the steam jet. A vacuum of 29½ ins. could, if desired, be maintained with ejecting water at a temperature of 120°—a difference of 61° between t_H and t_V. This very important quality was, of course, due almost entirely to the particular combination of steam and water jets employed in the system. In this respect the apparatus acted as an air pump and a feed heater combined.

In working conditions the vacuum inside the ejector between the steam jet and the water-expelling jets was usually from 2in. to 1in. less than the vacuum carried in the condenser, and it was this difference which was most instrumental in the determination of the amount by which the hotwell temperature might exceed that due to the vacuum in the condenser. Further, it would be noted, there was no loss of feed water in this system. Water vapour withdrawn from the condenser along with air was condensed by the jets, and ultimately returned to the boilers, provision being made in the Kinetic tank for the separation and escape of the air prior to the water entering the suction pipe of the feed pump. For marine purposes, this was a significant feature. No special or independent source of water supply was required for use in the air ejector jets, these being entirely composed of the water of condensation from the condenser.

SOME ASPECTS OF DIESEL ENGINE DESIGN.*

BY D. M. SHANNON.

AT the last meeting of the Institution, a diagram in one respect remarkable, and here reproduced, Fig. 1, was shown. A similar diagram for a Diesel oil-engine installation is given in Fig. 2. One would naturally think that a motor which can convert Fig. 1 into Fig. 2 would have engaged the attention of marine engineers in this country in a much more

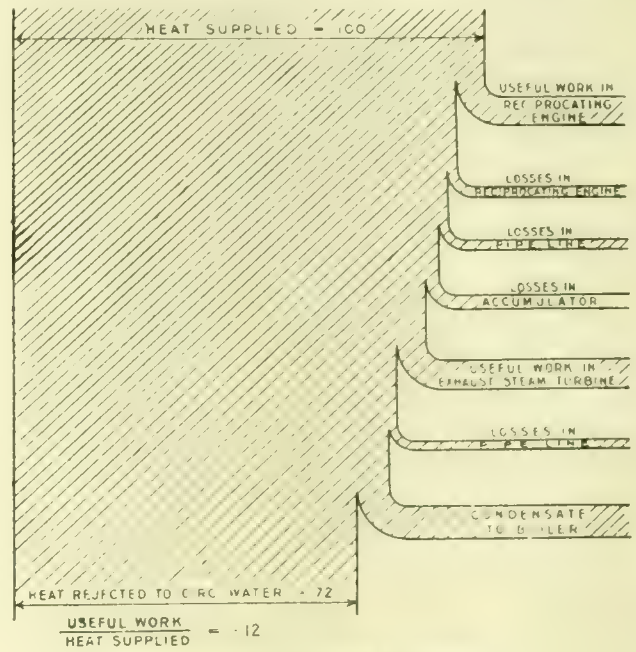


FIG. 1.—HEAT BALANCE DIAGRAM

serious manner than that which has been made evident during the last two years. This comparison, of course, is not altogether a fair one, for Fig. 1 does not take into account boiler losses, and it is probably not the best that can be done by the steam engine. The transformation naturally follows from the fact that the energy is being directly taken from the fuel on top of the engine piston and not passing through the series of losses and leakages shown on Fig. 1. This prime mover promises to work greater changes for the benefit of man than those which the steam turbine has wrought. The pity is that the changes now going on are chiefly of continental origin.

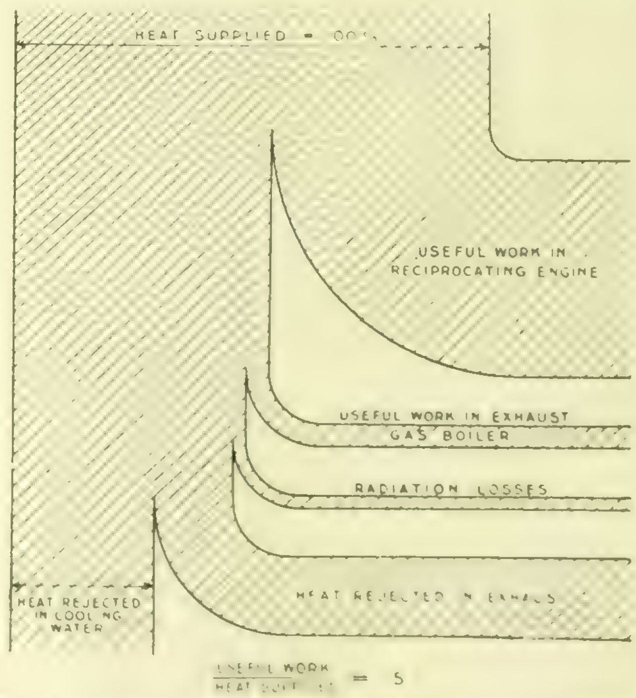


FIG. 2.—HEAT BALANCE DIAGRAM FOR A DIESEL OIL ENGINE

In passing, it might be well to warn those about to take up the manufacture of the Diesel engine that nothing but the best materials and workmanship will suffice. Otherwise there is the danger of doing a promising motor great harm in its infancy. These are points that are usually brought home very severely to steam engineers on first taking up the oil engine. The reason for greater accuracy and better material

* Paper read before the Institution of Engineers and Shipbuilders in Scotland, April [illegible] 1912.

is, of course, due in the first instance to the high pressures that have to be dealt with, and secondly to the small volume occupied by the power medium. In an oil engine one cubic inch of oil for power purposes is, on an average, equivalent to 5,500 cub. in. of steam used in a steam engine. Hence, the measuring and burning arrangements must be made with great accuracy; any slight variations from which might mean large variations in power and efficiency of the machine. Experience has shown that only a few thousandths of an inch here and there makes the difference between a good running motor and complete failure.

The oil engine, it should be remembered, is still in its infancy, and the greatest care is required in its design and manufacture. Oil engine workers recognise that the piston engine is only a temporary solution to the problem, and that a reversion to the turbine principle will be the natural outcome of the inherent limitations and disadvantages of the reciprocating form of motor.

Great efforts are being made with engines of the turbine form, and only those engaged in the industry know how enormous are the difficulties to be overcome. It is interesting to note that the only reason why oil engines have been practicable for so many years is the fact that the surfaces coming into contact with the flame receive a little rest between the explosions in which to dissipate the heat.

If the process be made continuous as in the turbine form of motor, then trouble from this source might be overcome by allowing one set of blades to cool down while another set carried on the work, or by trying a turbine of the bladeless form. Again, the steam turbine only shows superiority over the reciprocating engine when it is made condensing, and this advantage cannot be gained in the internal-combustion turbine over the reciprocating engine. There is also the difficulty of obtaining an efficient compressor of the turbine form, and it is not logical to carry out one part of the process with a piston machine and the other part with a turbine. This difficulty would be minimised with a producer which would produce gas at a pressure of, say, 150lbs. per square inch, or make a fixed gas from any class of cheap oil. Facts seem to point strongly against the success of the internal-combustion turbine working on any of the present cycles, and until a new cycle or a new heat carrier can be found, there is little hope of much progress being made in this direction.

A question that is greatly exercising the minds of engineers is: How big can the Diesel engine be made? Steam installations have already reached the enormous total of 90,000 h.p. concentrated in one ship, and at first sight this would seem quite hopeless to attempt with oil engines. Experiment, and the present means of manufacture seem to be the determining factors, and it is probable that the size of the crank shaft and not the size of the cylinder will limit the power of the oil engine. Considering that 2,500 h.p. has been put into one cylinder, I have assumed for the sake of argument that it is possible to put 2,000 h.p. into one single-acting 2-cycle cylinder, or 4,000 h.p. into one double-acting 2-cycle one. Since the volume of the cylinder rises as the cube of the dimensions and the area of the exhaust ports is roughly proportional to the square of the dimensions, it follows that there is an economic limit to the size of the cylinder on account of the increasing length of the ports in proportion to the stroke of the pistons. This limit is certainly over the powers assumed. By combining 12 single-acting 2-cycle cylinders, as in Fig. 3, or 6 double-acting ones, as in Fig. 4, then a total of 24,000 h.p. is reached for one shaft, and if three shafts are used this would amount to 72,000 b.h.p. in one ship. The pistons of this motor would be about 45in. diam., and the stroke 60in. The crank shaft would be 27in. diam., stressed to 11,000lbs. per square inch. The overall dimensions of these motors would be as shown in the illustrations, the two halves of the single-acting motor being in separate engine-rooms. By using high-tensile steel and a judicious arrangement of cranks, it would be possible to increase the power up to 30,000 h.p. for the same diameter of shaft by adding two extra double-acting cylinders, thus giving 90,000 b.h.p. in one ship.

The diameter of shaft given is limited by bearing pressure considerations; and the power, as already suggested, that can be passed through it, can only be increased by using a better quality of steel, and increasing the number of cylinders in a line, instead of increasing the diameter and stroke of the pistons. The large diameter of shaft in proportion to the throw would necessitate the pins, webs, and shaft being forged solid, thereby increasing the difficulties of manufacture.

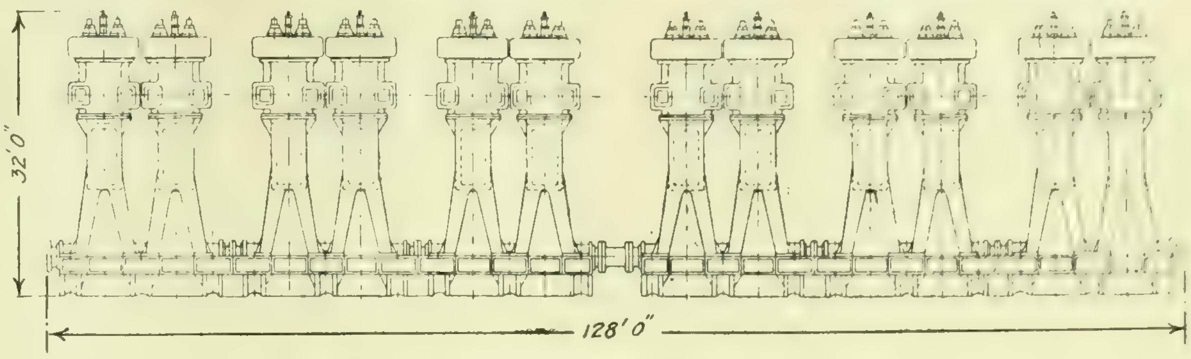


FIG. 3—TWO-CYCLE SINGLE-ACTING ENGINE, 24,000 B.H.P.

Figs. 3 and 4 are interesting, as showing where advancement along existing lines would lead to when really large powers are attempted, and they prove that the 2-cycle double-acting type is the only one that can be seriously considered. It is certain that the motor warships suggested by Mr. James McKechnie are much nearer realisation than most engineers thought possible at the time.

Some of the claims made on behalf of the Diesel engine are not quite accurate. The absence of ignition gear is not an advantage to the engine, but constitutes what is probably its greatest disadvantage. In place of simple electrical ignition gear, there is a very high pressure to deal with in the working cylinder, and a complicated two or 3-stage compressor to provide injection air at a pressure of 800lbs. or 900lbs. per square inch. This demands the finest workmanship and the greatest care in handling, and has proved the only weak point in some jobs that have otherwise been faultless.

Because the charge is not admitted until the piston is near the top dead-centre, it is argued that it is impossible to obtain preignitions. It is only necessary to have a leaky fuel-injection valve in order to obtain them, although in the Diesel engine they are not so violent as in engines working on the Otto cycle, for the reason that the pressures are much higher, and the changes in pressure are not therefore so noticeable. Further, the temperature to cause ignition is

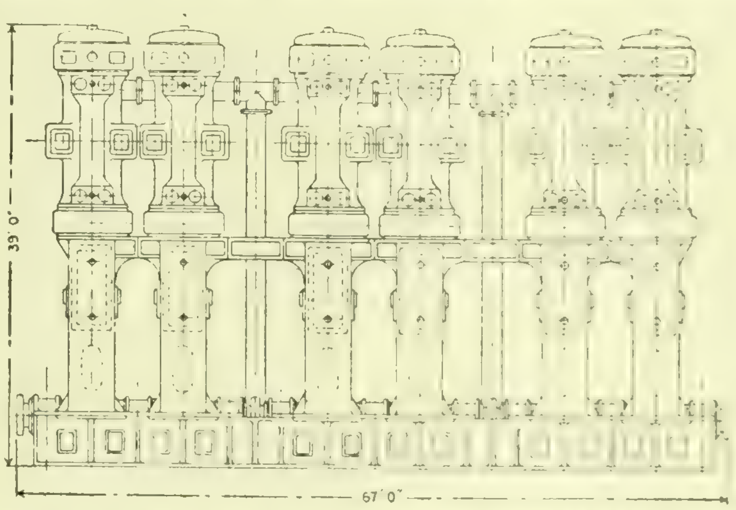


FIG. 4. TWO-CYCLE DOUBLE-ACTING ENGINE, 24,000 B.H.P.

only reached when the piston is near the top dead-centre. The real danger is that the high-pressure air would leak into the cylinder if the needle valve were to stick open, and the piston on rising would enormously increase the compression pressure. At least, to my knowledge, two engines have been completely wrecked by causes which could only be traced to this, and it is, therefore, imperative that Diesel engines of any size for marine purposes should be fitted with relief valves on all the cylinders. Again, there are no violent explosions in the Diesel engine when working, for although the changes

in pressure are great they are gradual, and do not give rise to shocks, as is experienced in engines working on the Otto cycle.

One of the greatest advantages of the Diesel engine is that however small the quantity of combustible matter injected into the cylinder may be it is certain to burn. Hence no

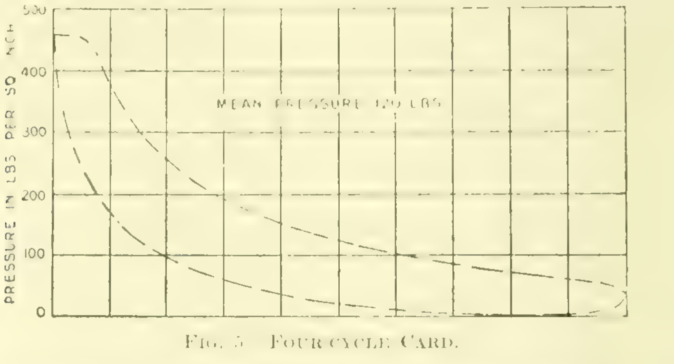


FIG. 5. FOUR-CYCLE CARD.

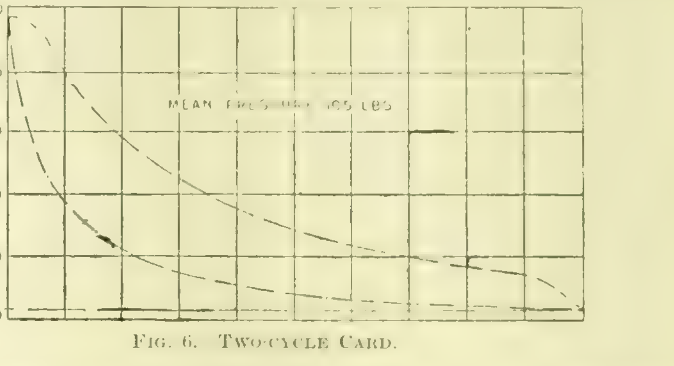


FIG. 6. TWO-CYCLE CARD.

weak charges can be sent into the exhaust system to cause trouble. This fact makes the Diesel cycle eminently suitable for dealing with gaseous fuels, especially for reversing engines, and I think that this is the correct line to work along in developing gas plants for ship propulsion. In a reversing engine working on the Otto cycle there are always one or two cylinders full of mixture, and at the point of reversal explosives are discharged into the exhaust. Then, again, it is wrong to introduce the fuel into the cylinder before the exhaust ports are closed, for no matter how great the precautions or attempts at stratification, it is quite impossible to prevent the escape of fuel during charging. At the finish of charging there is always some gas in the ports and clearances, and this is swept out through the exhaust during the next scavenging period. These things tend to make the efficiency of the large 2-cycle gas engine rather poor, and any development must take place by withholding the gas until the exhaust ports are quite closed. I am not aware if Diesel engines have been run with gas, but all that is necessary to test the idea is a pressure intensifier in conjunction with the existing multi-stage injection air compressor.

Crank Shafts.—Cranks should be arranged with regard to the following points, which are given in order of importance:

(1) Uniform twisting moment.

(2) Balance of the engine as a whole.

(3) Unbalanced couple between any two or more adjacent cranks to be as small as possible.

(4) The angle between two adjacent cranks to be as large as possible, so as not to have them both firing on the down stroke, and causing excesive pressure on the bearing between them. If there are two bearings between each crank this point has little significance.

(5) If the shaft is made in pieces, these should be interchangeable, in order to keep down the number of spare parts.

(6) In 4-cycle work, adjacent cranks should not be arranged on the same centre line, on account of concentrating the centrifugal and inertia loads.

(7) As far as possible avoid making the maximum twisting and bending moments occur at the same instant.

With regard to twisting moments, Tables I. and II. contain a fairly complete analysis of all engines of the four and 2-cycle single-acting types that have actually been built or proposed. The results of the 4-cycle engines are rather curious and these will be taken first, although it is rather late in the day to be considering a type that has not found favour for marine work. In drawing up these tables the effect of the compressor and scavenging cranks has been neglected chiefly on account of the great variety of positions these can be, and are, placed in. The constants, although quite good for preliminary design work are given rather for purposes of comparison.

In order that the effect of inertia on torque may be studied, three sets of constants have been given for each case, the first neglecting inertia, and the second and third allowing for inertias of 100lbs. and 200lbs. per square inch of piston area respectively. In all cases the curves from which these ratios were taken were carefully calculated from the indicator cards shown on Figs. 5 and 6, which are rather above average practice, and assuming a connecting rod 4·5 cranks long, as representing average practice. Figs. 7 and 8 show the primary twisting and bending-moment curves from which all the results given were obtained.

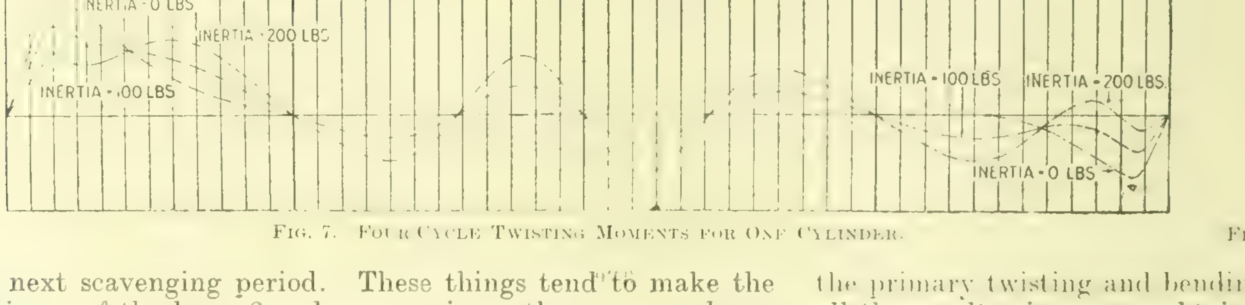


FIG. 7. FOUR CYCLE TWISTING MOMENTS FOR ONE CYLINDER.

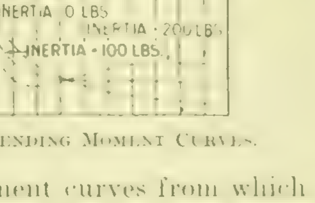


FIG. 8. BENDING MOMENT CURVES.

Incidentally it should be noted that balancing is a much easier problem than in steam work, on account of the greater number and flexibility of arrangement of cranks, and it is possible in nearly every case to obtain excellent balance without disturbing the equal phase difference of the working cranks, or adding balance weights to them.

To meet condition 1, the working cranks are always arranged at equal angles, and this in every case, excepting that one, two, and 3-crank engines, gives complete primary balance. The compressor and scavenging cranks are usually arranged to give the minimum disturbance to uniformity of twisting moment, and are balanced separately with the aid of balance weights.

Condition 4 can best be investigated graphically, and for this purpose Fig. 9 is given. The resultant is due to (a) inertia loads of the reciprocating parts; (b) centrifugal loads of revolving parts; (c) weight of parts; and (d) gas pressures. This is given for one cylinder, and since there are two bearings, the vertical scale will require to be halved to

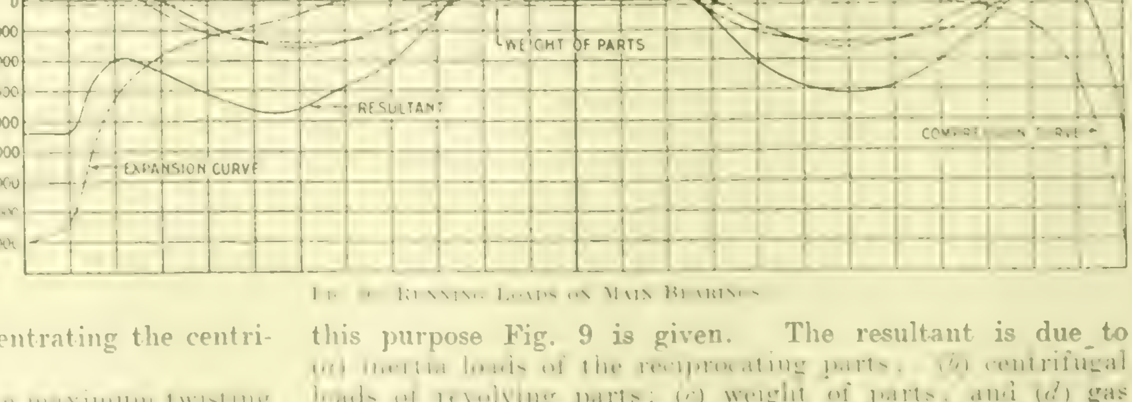


FIG. 9. RUNNING LOADS ON MAIN BEARINGS.

obtain the result for one bearing. Hence, by combining curves like (*a*) Fig. 9, for two adjacent cylinders at the proper crank angle, the combined effect on the bearing in between can be ascertained. In 2-cycle engines having one bearing of normal length between the cylinders, it is not safe to arrange the cranks nearer to each other than 90°.

TABLE I.—*Four-cycle Single-acting Engine.*

1	2	3	4	5	6	7	8	9	10	11	12	13
No. of Cranks	Crank Angles	Order of Firing	Crankshaft	Values of R & R1						Absolute height of max TM curve		
				Inertia = 0		Inertia = 100 lbs		Inertia = 200 lbs				
				R	R1	R	R1	R	R1	0	100 lbs	200 lbs
1	0	1		14.2 (1)	14.2	10.8 (1)	10.8	9.1 (1)	9.1	2.46	1.88	1.58
2	360°	1 2		7.1 (2)	7.1	5.4 (1)	4.6	7.1 (2)	7.1	2.46	1.88	2.46
2	180°	1.2		7.1 (2)	7.1	5.4 (1)	4.5	6.8 (2)	6.8	2.46	1.88	2.37
3	120°	1 2 3		4.7 (3)	4.7	4.2 (2)	3.78	5.15 (2)	4.3	2.46	2.14	2.67
4	180°	1.2 4.3		3.5 (4)	3.5	2.7 (1)	2.34	5.15 (4)	5.15	2.46	1.88	3.58
4	90°	1 2 4 3		4.3 (4)	4.3	4.15 (4)	4.15	4.4 (3)	4.25	2.98	2.68	3.08
5	72°	1 3 5 4 2		2.66 (5)	2.66	3.35 (4)	2.8	3.9 (4)	2.8	2.44	2.92	3.4
6	120°	1 2 3 6 5 4		2.55 (5)	2.42	2.3 (5)	1.44	2.45 (2)	2.02	2.55	2.4	2.55
6	120°	1 5 3 6 2 4	SAME AS ABOVE.	2.55 (5)	2.42	2.17 (5)	1.44	2.6 (2)	2.02	2.65	2.26	2.69
8	90°	1 5 2 6 4 8 3 7		2.16 (5)	1.74	2.54 (5)	1.61	3.4 (5)	1.63	3	3.53	4.73
8	90°	1 6 2 4 8 3 7 5		2.16 (4)	1.74	2.4 (5)	1.61	2.9 (6)	1.63	3	3.33	4.02
12	60°	1 2 3 6 5 4 7 8 9 12 11 10	TWO SIX CYL ENGINES ARRANGED AT 60°	1.74 (7)	1.17	1.77 (8)	1.17	2.01 (10)	1.21	3.62	3.68	4.18
12	60°	1 5 3 6 2 4 7 11 9 12 8 10	SAME AS ABOVE	1.77 (7)	1.17	1.8 (10)	1.27	2.06 (10)	[illegible]	3.68	3.74	4.29

Condition 6 is satisfied by most engines, the only exceptions being the four, six, and 8-cylinder 4-cycle motors. In the four and 6-cylinder engines the only provision that can be taken is to make the centre bearing long enough, but in the 8-cylinder motor there is an alternative arrangement to that usually adopted in practice. In Table I., the first arrangement of the 8-cylinder motor is that used on the engines of the ship "Selandia," and the second, giving theoretically the same balance, has no two adjacent cranks on the same centre with only one bearing between them.

Fig. 10 gives the maximum twisting moments in each case, and in Fig. 11 is given the combined bending and twisting moments. It will be noted than in cases 1 and 2 the maximum twisting moment occurring in the shaft is that due to the first 5 cylinders, and that case 2 gives the lower twisting moment of the two. Also, in case 2, there is a further advantage, since the peak of the twisting moment curve is at a point where the bending moment is least, whereas, in case 1, the peaks of the bending and twisting moments coincide, stressing a shaft, at a particular point, to 3,000lbs. per square inch more than in case 2. In a great many instances shifting of the peaks was very marked, and advantage should be taken of this fact to so arrange the cranks to give a minimum diameter of shaft.

In columns 5, 7, and 9, Table I., the ratio, R of maximum twisting moment in the shaft to mean twisting moment has been given, and the small number in brackets immediately under denotes the number of cylinders giving this maximum. In columns 6, 8, and 10, R_1 is the ratio of the twisting moment for the total number of cylinders to the mean twisting moment. Ratios R will, therefore, be used for crank-shaft design, and ratios R_1 for tunnel-shaft design. Columns 11, 12, and 13 show how slowly the twisting moment increases, due to piling on cylinders in the case of 4-cycle engines. It will also be noticed that, in a number of cases, inertia makes very little difference in R_1, that in 4-cycle work inertia cannot be neglected, and that in some extreme cases there is an increase of 60 per cent. in the twisting moment due to inertia. A difference of 2,000lbs. per square inch in the stress of a shaft seems to be treated lightly in some designs of Diesel engines.

Table II., giving particulars of 2-cycle engines, calls for no particular comment, since many of the remarks with regard to Table I. apply to it also. It will be noticed that inertia, in nearly every case, reduces the twisting moment, and that one is quite safe in neglecting it altogether. In 2-cycle engines the arrangement of cranks is more elastic, since only in the first cases of the 5 and 6-cylinder engines is the primary balance of the working cranks complete, and the compressor crank, or scavenging crank, or both, must be arranged along with balance weights to produce balance. In the examples given, the working cranks have been arranged to reduce the unbalanced couple to a minimum, so that by properly arranging the scavenging crank an excellent balance will result. Fig. 12 gives the twisting moment curves of an 8-cylinder motor, and it will be seen that the resultant is of a particularly even nature, R_1 being practically 1.

TABLE II.—*Two-cycle Single-acting Engine.*

1	2	3	4	5	6	7	8	9	10	11	12	13
No. of Cranks	Crank Angles	Order of Firing	Crankshaft	Values of R & R1						[illegible]		
				Inertia = 0		[illegible]		[illegible]				
				R	R1	R	R1	R	R1	0	[illegible]	[illegible]
1	0	1		7.6 (1)	7.6	5.5 (1)	5.6	5	5	[illegible]	[illegible]	1.78
2	180°	1.2		3.8 (1)	3.64	2.9 (1)	2.15	2.5 (1)	2.25	2.7	2.06	1.78
3	120°	1 2 3		2.7 (2)	2.3	2.38 (2)	1.53	2.14 (2)	1.37	2.57	2.52	2.27
4	90°	1 4 2 3		2.22 (3)	1.65	1.93 (3)	1.65	2.1 (3)	[illegible]	[illegible]	2.74	[illegible]
5	72°	1 5 2 3 4		1.91 (3)	1.31	1.64 (4)	1.29	1.93 (4)	1.28	[illegible]	[illegible]	3.42
5	72°	1 3 5 2 4		1.91 (3)	1.31	1.68 (4)	1.29	1.46 (4)	[illegible]	3.35	[illegible]	3.47
6	60°	1.6 2 4 3 5		1.7 (5)	1.12	[illegible]	[illegible]	[illegible]	[illegible]	3.7	3.44	3.45
6	60°	1.4 5 2 3 6		1.71 (3)	1.12	1.48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.45
8	45°	1 7 5 4 2 8 6 3		1.64 (5)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	45°	1 8 6 4 2 7 5 3		1.48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

In crank shaft design it is generally assumed that the

maximum moments on the shaft occur when starting and before inertia has had time to come into play, and that this will be due to gas pressures caused by the working fluid. On account of the manner in which Diesel engines are started, however, this is certainly not the case. In a 4-cylinder engine the starting air is admitted over a crank angle greater than 90° in order that the engine will start from any position, and in a 6-cylinder engine the angle will be something more than 60°. The pressure of the starting air is generally about 500lbs. per square inch, and it can be shown that the stress due to admitting air over a crank angle of 90°, as is done in 6-cylinder engines, will stress an engine shaft to 14,000lbs. that would otherwise be only stressed to 8,000lbs. per square inch. This is rather barbarous treatment of shafts, and it would be much better to relieve the compression pressure to 150lbs. per square inch and use starting air through a reducing valve at that pressure, at the same time effecting a large saving in compressed air. On starting, cards showing pressures of 700lbs. per square inch have been taken from Diesel engines, this high pressure due to the starting air pressure mounting up before the pistons had time to get under way.

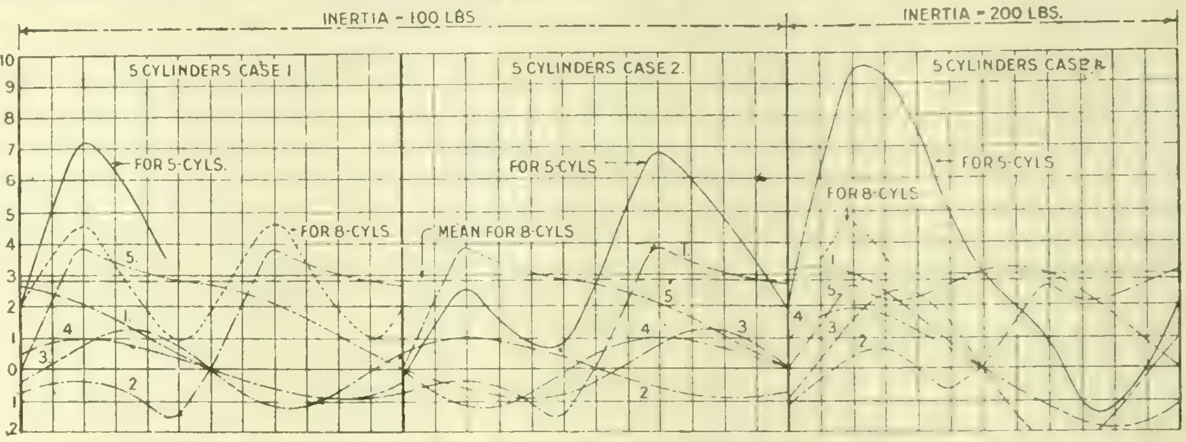


FIG. 10. FOUR-CYCLE EIGHT-CYLINDER ENGINE. TWISTING MOMENT CURVES.

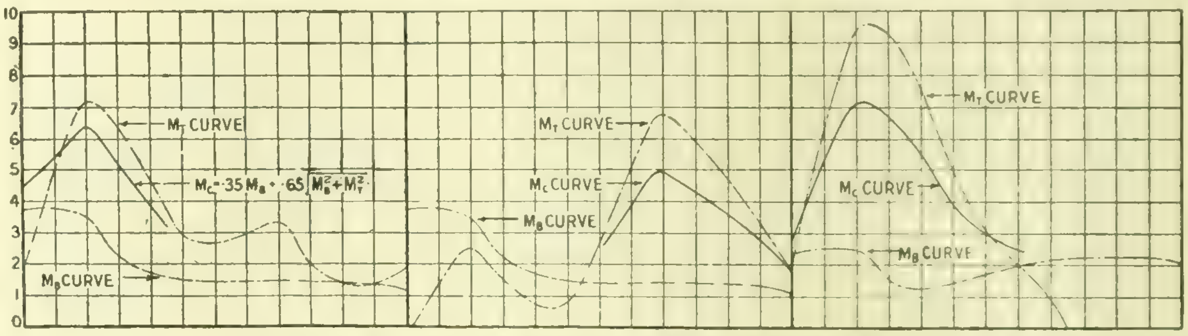


FIG. 11. COMBINED BENDING AND TWISTING MOMENTS.

In the following crank-shaft formula:—

Let d = Diameter of shaft in inches.
D diameter of cylinder in inches.
f = stress in pounds per square inch.
P mean pressure in cylinder in pounds.
P_m maximum pressure in cylinder at instant of maximum twisting moment.
120lbs. per square inch approximate.
n number of working cylinders.
$R_m = \dfrac{\text{maximum twisting moment.}}{\text{minimum twisting moment.}}$
$a = \dfrac{\text{distance between centres of bearings.}}{\text{diameter of cylinder.}}$
2 for most engines.
$b = \dfrac{\text{piston stroke.}}{\text{diameter of cylinder.}}$
1·2 for high-speed engines and
1·4 for low-speed engines.

Then $x = PbnR_m$ for 4-cycle single-acting engines.
$= 2\,PbnR_m$ for 2-cycle single-acting engines.
$= 4\,PbnR_m$ for 2-cycle double acting engines.

$$y = \frac{P_m a}{x}$$

Then

$$d = D\sqrt[3]{\frac{x}{f}\left\{\cdot 35y + \cdot 65\sqrt{y^2 + \cdot 4}\right\}}$$

$$\text{or } f = \frac{D^3}{d^3}\,x\left\{\cdot 35y + \cdot 65\sqrt{y^2 + \cdot 4}\right\}.$$

These formulæ, although rather complicated, take into account all the variables and constants. x and y can be worked out for a particular type of engine and tabulated for use in design work. It is deduced from the usual equation:

$$M_e = \cdot 35\,M_b + \cdot 65\sqrt{M_b^2 + M_t^2}$$

the amount of bending allowed for being equal to $\dfrac{WL}{8}$ where W = piston load, and L = distance between centres of bearings.

Main Bearing and Connecting Rod Caps and Bolts.—At (a) on Fig. 9 is shown the upward loads on the main bearing caps and bolts of a 4-cycle motor, assuming that there are no balance weights on the webs. Put into a formula the upward load for one cylinder will be:

$$P = \cdot 000028\,RN^2\left[W\left(1 + \frac{1}{n}\right) + W_1\right]$$

where R = crank throw in inches.
N = revolutions per minute.
$n = \dfrac{\text{length of connecting rod}}{\text{crank throw}}$
W = total weight of reciprocating masses in pounds.
W_1 = total weight of revolving masses (*i.e.*, crank pin, part of webs and revolving part of connecting rod).

In practice the load caused by W_1 is generally neglected or forgotten, although in many cases it amounts to 15 per cent. of the total load.

For the connecting rod bolts.

$$P = \cdot 000028\,RN^2\left[W\left(1 + \frac{1}{n}\right) + W_2\right]$$

Where W_2 = weight of revolving part of connecting rod minus weight of bottom end cap. Here, again, W_2 is generally

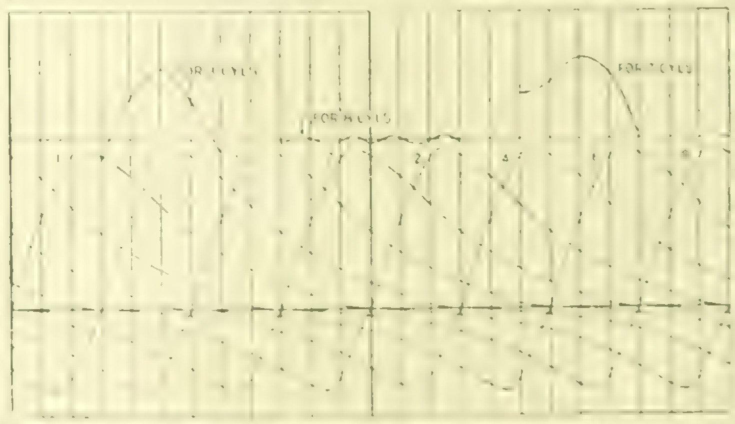


FIG. 12. TWISTING MOMENT CURVES. TWO-CYCLE EIGHT-CYLINDER ENGINE. INERTIA = 0.

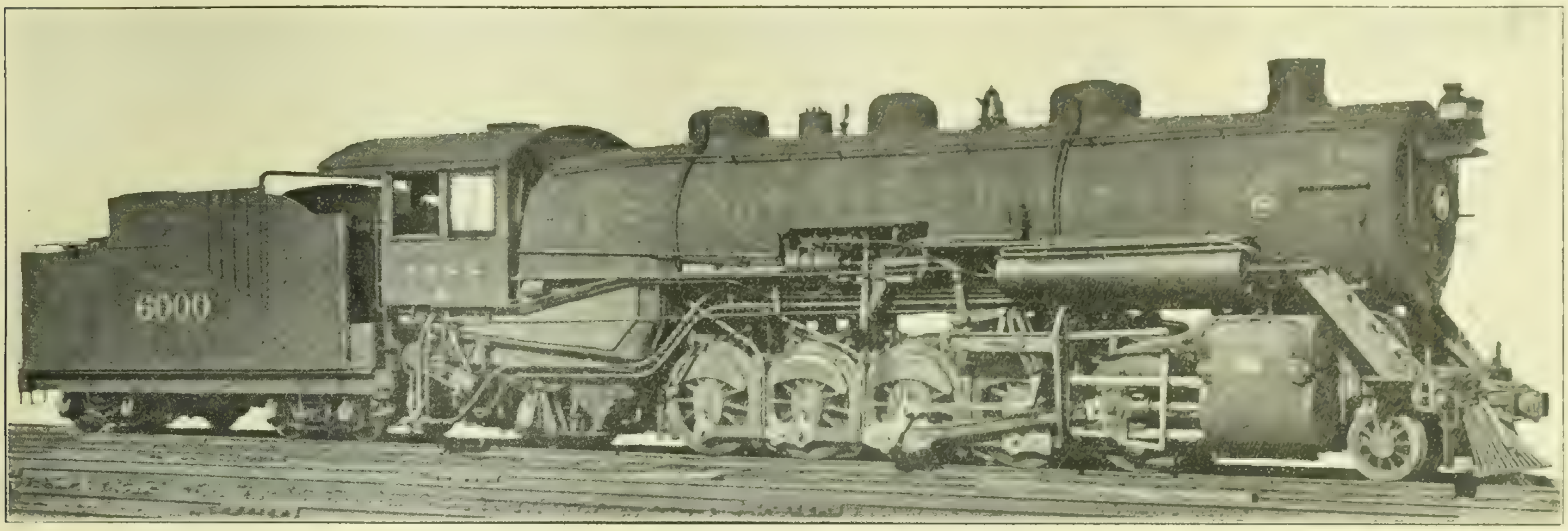
neglected, although its effects in high-speed engines are serious.

In 2-cycle single-acting engines these loads do not exist, but it is well to design the parts to withstand them since there is always the chance of a scavenging valve spring breaking and letting the valve stay open, thereby relieving all compression and allowing the full inertia and centrifugal loads to come into play.

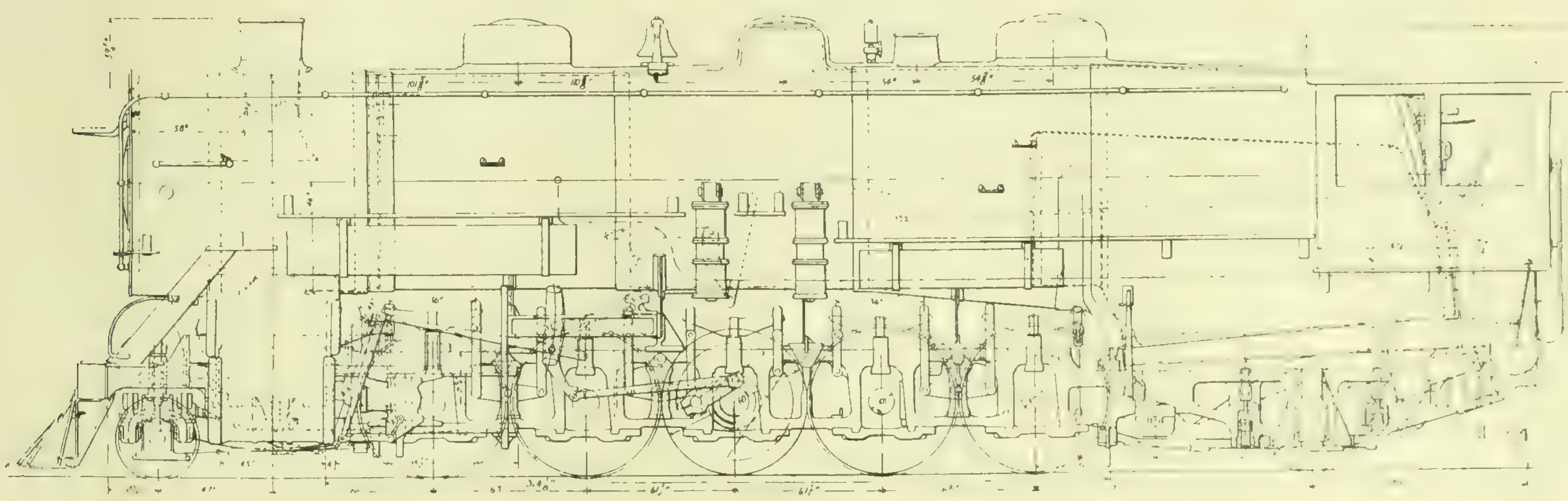
(*To be continued.*)

LARGE 2—10—2 TYPE LOCOMOTIVE FITTED WITH SUPERHEATER AND MECHANICAL STOKER.

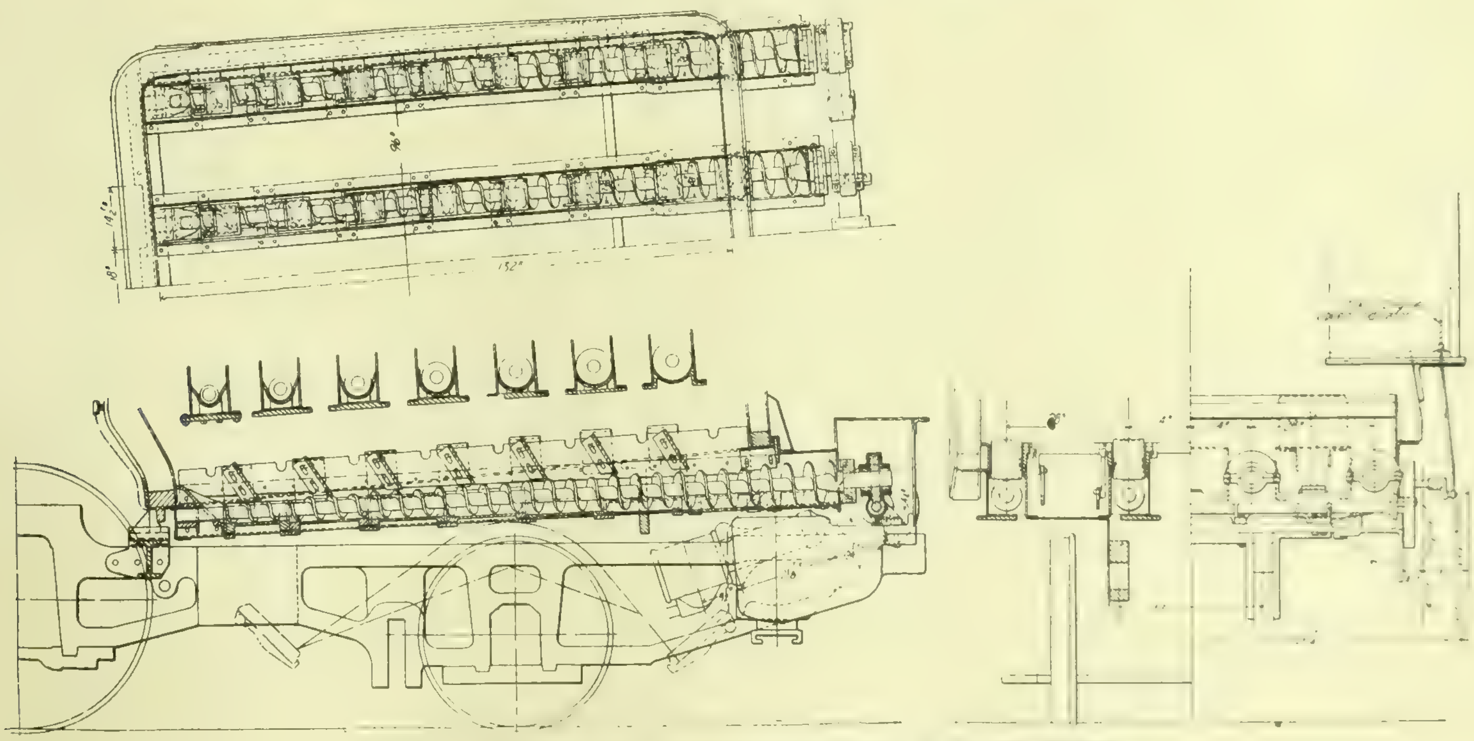
THE Baldwin Locomotive Works have recently completed, for the Chicago, Burlington, and Quincy Railroad, five locomotives of the Santa Fe, or 2—10—2 type, which are the largest engines ever built with all the driving wheels coupled in one group. The general construction of these engines, which are fitted with superheaters and mechanical stokers, is shown in the accompanying illustrations, for which, along with the following description, we are indebted to "The Railway and Engineering Review." They have a total weight of 378,700lbs., a tractive force of 71,500lbs., and carry approximately 60,000lbs. on each pair of driving wheels. The firebox is placed back of the driving wheels and above the rear truck wheels, and advantage is taken of the opportunity to deepen the throat. The engines, although they have a rigid wheel base of 20ft. 9in., are designed to traverse 21° curves. To facilitate this, the tyres on the main driving wheels are without flanges; the intermediate flanges have a play of $\frac{5}{8}$in., and the front and back flanges of [illegible]in. The truck wheel flanges have a play of $\frac{3}{4}$in.



2—10—2 TYPE LOCOMOTIVE, FITTED WITH SUPERHEATER AND MECHANICAL STOKER.



2—10—2 TYPE LOCOMOTIVE, FITTED WITH SUPERHEATER AND MECHANICAL STOKER.



2—10—2 TYPE LOCOMOTIVE. GENERAL ARRANGEMENT OF BARNUM STOKER

The boiler has a straight top, and measures 88½in. diam. at the front end. The barrel is composed of three rings, and the third ring is tapered, the slope being placed on the bottom. This construction was adopted because the firebox has a combustion chamber, and room had to be provided under the same to permit free circulation. The depth from the under side of the combustion chamber to the shell is approximately 7in., and the front water leg has a width of 6in. The crown of the combustion chamber is stayed by two T-bars hung on expansion links; otherwise radial bolts are used. A total of 501 flexible bolts are placed in the sides, throat, and back head.

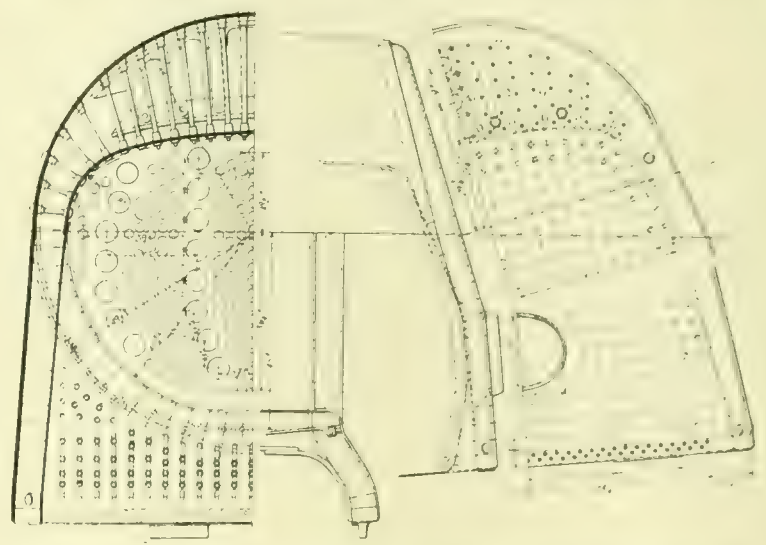
2-10-2 TYPE LOCOMOTIVE. ARRANGEMENT OF GRATES.

The locomotives are fitted with Emerson superheaters, and the elements are placed in 30 tubes, each 6in. diam. The superheater pipes are 1⅞in. diam. outside. The saturated and superheated steam headers are separate castings, and are bolted together in such a way as to allow a slight relative movement, thus providing for unequal expansion and contraction.

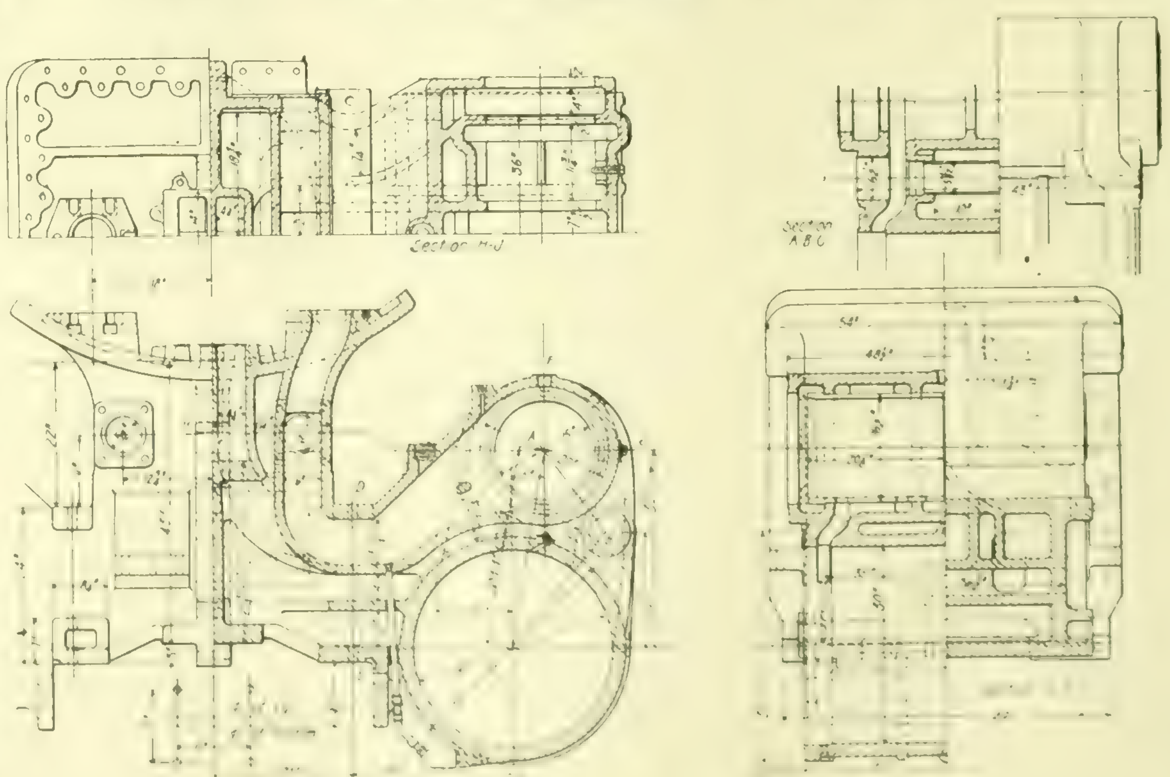
Barnum stokers also are applied to these locomotives, and the installation is of special interest owing to the large grate area (88 sq. ft.) which must be covered. This stoker is of the under-feed type, and the furnace is charged with coal by four screw conveyers which work in suitable longitudinal troughs. The conveyers are 28in. apart, measured transversely. The clearance between the conveyer and the bottom of the trough can be adjusted to secure the most satisfactory results. Each trough contains a series of inclined plates, which are placed above the conveyers, and as the coal strikes these plates it is fed upwards into the furnace. The plates are adjustable for height and inclination. The conveyers are worked by a transverse worm shaft, which is placed at the back end and is rotated by two small steam engines. On the tender is placed a coal crusher, which is driven by a 6in. by 6in. engine. The crusher delivers coal to a belt, which conveys it forward to a transverse trough placed above the foot plate. From this trough the coal is discharged into the longitudinal feed troughs. The fuel bin in the tender contains a coal pusher.

The fire door is not encumbered by the stoker equipment, so that if necessary the locomotive can be fired by hand. The grate is composed of three sections, which are placed between the adjacent stoker troughs. The bars of each section are connected to rock in two groups. Each bar is set in a rectangular frame, which can be tilted through a wide angle when the fire is dumped. Below each section of grate is placed an ashpan having two hoppers. There are thus six hoppers altogether, and they are provided with cast-iron drop bottoms. There is no arch in the firebox, but a brick wall, 24in. high and 9in. wide, is built in the combustion chamber. The front of the wall is 16½in. back of the tube sheet, and the vertical distance from the top of the wall to the under side of the crown sheet is about 38in.

The cylinders are of the usual design, each being cast in one piece with half the saddle. The cylinder barrel walls are 2in. thick. The live-steam passages in the saddle are connected by an equalising pipe. The steam distribution is controlled by double-ported piston valves, arranged for inside admission. These valves are 15in. diam., and are set with a lead of ¼in. Circulating valves of the Sheedy type are applied, and relief valves are tapped into the live-steam passages. The valve motion is of the Walschaert type, and is controlled by Ragonnet power gear. The valve rod crosshead works in guides which are cast in one piece with the back steam chest head.



2-10-2 TYPE LOCOMOTIVE. SECTION THROUGH FIREBOX AND ELEVATION OF FIREBOX END.



2-10-2 TYPE LOCOMOTIVE. CYLINDER SADDLE AND DETAILS.

Westinghouse-American brake equipment is applied to these locomotives. The tender is specially arranged to accommodate the stoker equipment. The principal features of these locomotives are indicated in the following table:—

Type	2—10—2
Service	Freight
Cylinders	30in. by 32in.
Valves	Balanced piston
Tractive power	71,000lbs.

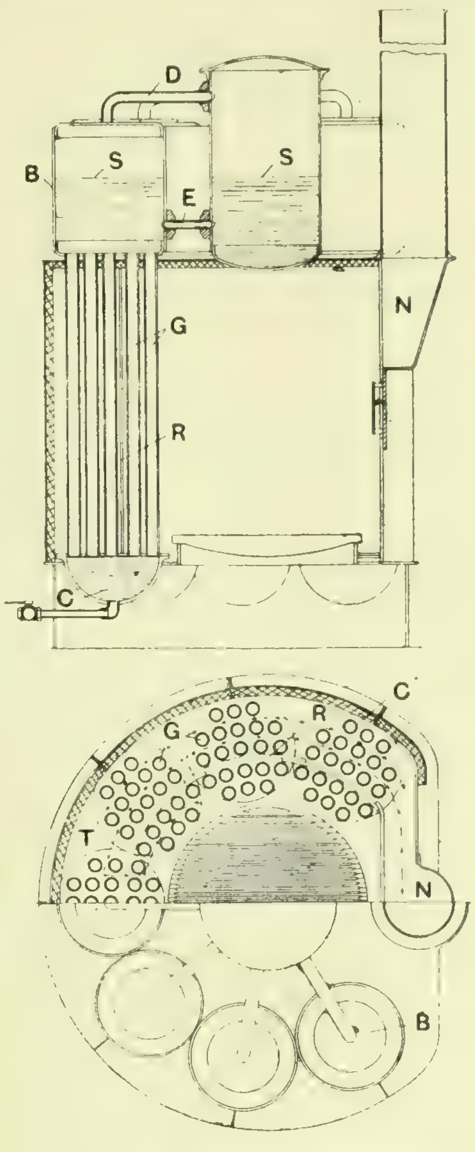
Boiler, type	Straight
Minimum diameter	88½in.
Working pressure	175lbs.
Firebox, size	96in. by 132in.
Grate area	88 sq. ft.
Kind of fuel	Soft coal
Tubes, number	30 and 285
Diameter	2¼in. and 6in.
Length	22ft. 7½in.
Heating surface, firebox	255 sq. ft.
Combustion chamber	65 sq. ft.
Tubes	4,841 sq. ft.
Superheater	970 sq. ft.
Total	5,161 sq. ft.
Driving wheels, diameter	60in.
Journals	11in. and 12in. by 12in.
Truck wheels, diameter, front	33in.
Journals	6in. by 10in.
Back, diameter	42½in.
Journals	8in. by 14in.
Weight, on driving wheels	301,800lbs.
Total engine	378,700lbs.
Total engine and tender	652,000lbs.
Wheel base, driving	20ft. 9in.
Total engine	39ft. 8in.
Total engine and tender	74ft. 4¼in.
Tender, wheels, diameter	33in.
Journals	6in. by 11in.
Capacity, water	10,000 galls.
Capacity, coal	15 tons

ELECTRICITY SUPPLY.

A LECTURE on "Electricity Supply: Past, Present, and Future" was delivered by Mr. A. Campbell Swinton at the Royal Institution on April 19th. The lecturer referred to the retarding effect of the first Electric Lighting Act upon the progress of the industry. The first electric supply station for supplying current for lighting purposes on a public scale in London was, he said, established in 1882 by the Edison Company on Holborn Viaduct. When this station was first erected, the dynamo was described by one of the technical papers as enormous, and further, that no less than 1,000 full-size, or 16 candle-power, incandescent electric lamps were maintained in operation from one of these machines. Mr. Swinton pointed out that it was on the banks of the Tyne that the steam turbine was first applied to the public supply of electricity, and referred to the order recently secured by Messrs. Parsons from the Commonwealth Electric Company, Chicago, for a turbo-generator set capable of giving a continuous output of no less than 25,000 kw. at unity power factor. The lecturer pointed out that there used to be great prejudice in this country against the use of overhead wires, but this was fast disappearing. In Cornwall power was transmitted over a distance of about 20 miles at a pressure of 10,000 volts, there being one overhead line across the River Hale carried at an elevation of 150ft. above the water, so that ships could pass underneath. It was believed that this was the highest overhead transmission line in this country. He explained that in the United States and Canada pressures were in use as high as 100,000 volts on overhead transmission lines, and that similar voltages were being adopted in Germany. Turning to future expectations, Mr. Swinton was of opinion that for large stations the steam turbine was likely to hold its own, though in the smaller stations, where units up to 500 kw. or 1,000 kw. were needed, the internal-combustion engine was undoubtedly gaining ground. At present 2,000 h.p. seemed to be about the maximum that could safely be obtained per cylinder from the internal-combustion engine, so that increased powers could only be secured by a process of multiplication, which, in the case of large units, led to complications. The efficiency of a steam turbine tended to increase with the dimensions at a much greater rate than with an internal-combustion engine. As to the possibilities of the gas turbine, the lecturer did not hold out much hope of success. He considered that the future of electricity supply lay with very large stations employing very big units of plant and combining the generation of electricity with chemical manufacture.

HINDLEY'S WATER-TUBE BOILER.

WE illustrate herewith a design of water-tube boiler of the unit type, the invention of L. A. Hindley, H. D. Hindley, and W. Stanford, Bourton, Dorset. The units of the boiler, which can be easily dismantled into comparatively light sections and easily re-assembled, are arranged round the firebox, and each comprises an upper header B, connected by tubes G to a lower chamber C. The steam drum S is situated on approximately the same level as the headers B and connected to them by pipes D and E. This drum is centrally disposed relatively to the units. Semi-circular baffle-plates R are placed in the positions indicated to direct the products of combustion in the direction shown by the arrows round some of the tubes in the part of the firebox around the passageways T into the flue N and up the chimney. In operation the generator is filled with water to the level shown. A large amount of heat is radiated to the tubes between the fire and the baffle-plates. Water is heated in the tubes and in the steam drum, and steam is generated partly in the headers B and partly in the drum S. The level of the water in the headers and drum is equalised by the pipes E, and the steam set free in the headers is carried into the steam dome by the pipes D. Fig. 3 shows an arrangement in which a superheater W is substituted for the steam drum. It will be seen that the arrangement is such that any unit can be readily inspected or detached and replaced, as there is no liner inside the furnace space to conceal the units or prevent access thereto, and there are only the two connections at the top that communicate with the steam and water spaces.



FIGS. 1 & 2.—HINDLEY'S WATER-TUBE BOILER.

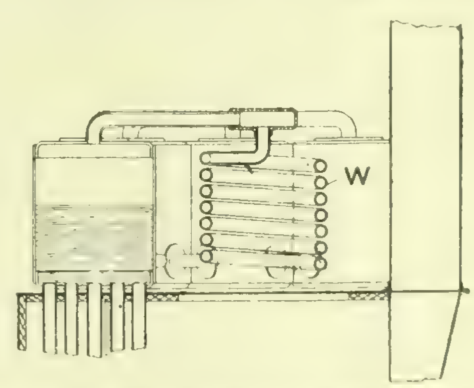


FIG. 3.—HINDLEY'S WATER-TUBE BOILER, FITTED WITH SUPERHEATER.

Pit Cage Accident.—An accident occurred on the 23rd ult at the Treeton pit of the Rothervale Colliery Company, Sheffield. A cage with a number of men was descending the shaft when it dashed to the bottom, landing with great force. Seven men, some suffering from broken limbs, had to be removed to hospital, while five others, also injured, but not so seriously, were removed to their homes.

AERIAL FLIGHT.*

BY HENRY REGINALD ARNULPH MALLOCK, F.R.S.

WHEN the president and the council of the Institution of Civil Engineers did me the honour of asking me to deliver the James Forrest lecture for the year 1912 on "Aeronautics," I thought, although having some first-hand knowledge, that it would be right to examine, as far as time permitted, the literature bearing on the subject. The "Bibliography of Aeronautics" published by the Smithsonian Institute of Washington in 1910 contains a list of nearly 14,000 books and papers, all dealing with ballooning or flying; and at the

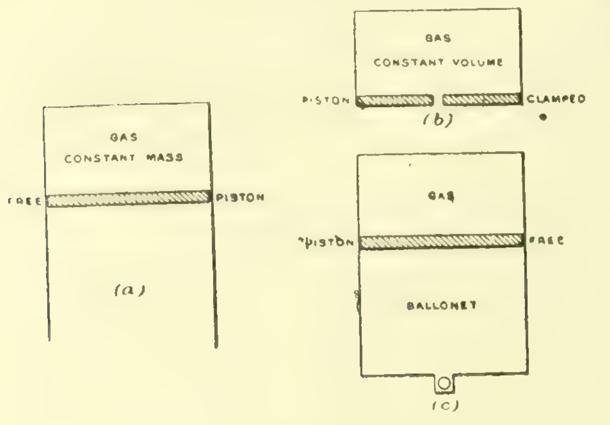


FIG. 1.

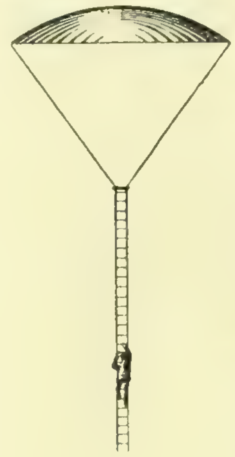


FIG. 2.

present time I suppose that this number has greatly increased, and I feel that the short hour at my disposal will be better employed in sketching the principles involved than in attempting to give a historical view of the progress of these two branches into which aeronautics has become divided.

Beginning with balloons, as having the priority in point of time, it may be remarked that the whole subject is included in the last 130 years, dating from the experiment of the Montgolfiers, who made their first ascent in 1788, but were at work for some years before this, and that other designs quickly followed containing in principle most of the appliances which are in use to-day. The ballonet, for instance, was proposed and tried by Charles and Robert. We find also designs for dirigible balloons of much the same shapes as are now familiar to us.

All attempts at propelling these vessels naturally failed for want of adequate power, and in some cases the proposed form of propulsion was impracticable, but in others a screw of nearly the same proportions as that now in use was actually tried. It was soon found, however, that the speed which could be developed by man-power or by any engine that the balloon could lift only amounted to a few miles an hour, less, that is, than the speed of a very slight breeze. Thus, so far as directing the course of a vessel was concerned, the mechanism was almost useless, and few further attempts at mechanical propulsion were made until the advent of the internal-combustion engine.

Within the last 20 years much has been learnt on the subject of air resistance, both with regard to form and surface friction, and it is now possible to predict with some certainty the power which is required to give any particular form a specified speed. The power which can be carried depends upon the available lifting force of the balloon and the resistance on its size and shape, and it will not be amiss to devote a short time to the consideration of the available lifting force of various types of balloons and how this force depends on, and changes with, the altitude.

Independently of outward form, balloons may be divided into two classes, according as the lifting gas carried is (*a*) constant in mass, or (*b*) constant in volume, and these again may be sub-divided according to the relation of the pressure or density of the enclosed gas to that of the surrounding air. All the conditions, however, may be conveniently represented by supposing that the gas is contained in a massless vertical cylinder closed at the top by a fixed cover and below by a movable piston. The piston may be supposed to be free or clamped, and to be acted on by the gaseous pressures only or by any other additional force.

(1) Taking first the case of a constant mass of gas. If the piston—Fig. 1*a*—is free, the pressure on both sides of it is always the same and equal to the pressure of the atmosphere at that level. The lifting force acting on the cylinder is therefore the difference of the weights of a column of air and of the enclosed gas of the area of the cylinder and of the height of that part of it which the gas occupies. This is true no matter what the absolute pressure of the air may be. A balloon of constant mass and unlimited extensibility would be realised in the case of a soap bubble if its size was sufficient to make the pressure due to surface tension negligible. Such a bubble, therefore, would always be acted on by a constant lifting force as long as the atmosphere outside had the properties usually ascribed to a gas, and if the atmosphere had the same temperature at all levels there would be no limit to the height to which the bubble would rise. If, on the other hand, the distribution of temperature was adiabatic, there would be a definite upper limit to the atmosphere which in dry air on this earth would be 20 miles above sea level.

(2) In a balloon made of any known solid material the expansion of the gas is resisted by the tension in the walls, and if these are inextensible the piston must be supposed to be clamped in its original position. If the walls are elastic, the effect on the density of the gas is the same as if a pressure were applied to the piston corresponding to the stress strain curve of the material at each stage of expansion. In both these cases the balloon will rest in stable equilibrium when such a height is reached that the difference of the densities of the internal gas and of the external atmosphere, multiplied by the volume of the cylinder at the time, is equal to the load carried, or, if there is no load, when these densities are equal.

(3) A balloon with constant volume and constant internal pressure is represented by supposing the piston to be clamped in its initial position (Fig. 1*b*). Such a balloon would be in stable equilibrium in the case (2), but at a lower level. But it is impossible with any known material, except on a small scale, to make an envelope strong enough to withstand the difference of internal and external pressure at great altitudes and at the same time light enough to be lifted by the gas.

(4) Balloons with constant volume and with internal and external pressures nearly the same are the only forms used on a large scale. The conditions of the ordinary balloon are represented by supposing the piston to be clamped but perforated (Fig. 1*b*), so that the gas can escape when the pressure is reduced. The limit to the height which can be attained in this case is reached when the difference of the weight of the enclosed gas and the same volume of outside air is equal to the load; but the equilibrium is then unstable, for any loss of level, however small, will cause the heavier outside

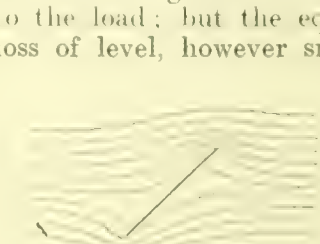


FIG. 3.

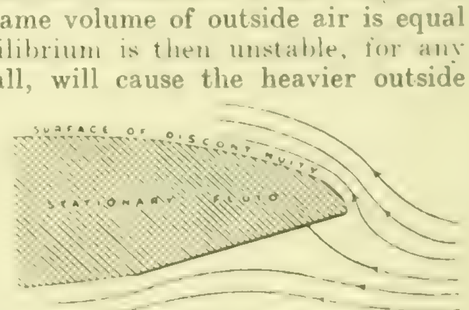


FIG. 4.

air to enter the cylinder and thus diminish the lifting force, which at the highest level was only just sufficient to support the load. An ordinary balloon, therefore, if left to itself, would rise to the maximum height and then come down with a constantly accelerating velocity, and it is only by parting alternately with ballast and gas that any desired altitude can be maintained.

(5) Another form of constant-volume balloon consists essentially of two compartments, one containing the lifting gas and the other being in communication with, but at a slightly higher pressure than the air outside, the difference being maintained constant usually by a centrifugal pump. This is the plan adopted in all non-rigid dirigibles where constancy of external form is a matter of importance. To represent these conditions we must suppose that the piston

* James Forrest lecture, delivered at the Institution of Civil Engineers, April 19th, 1912.

is free, and that the cylinder is closed at both ends, enclosing therefore a constant volume, but that the cover at the lower end is perforated and provided with a means of maintaining a small constant difference between the internal and external pressures. As far as lifting force is concerned, this type of balloon is similar to one of constant mass, the only difference being that, owing to the expulsion of the slightly compressed air in the ballonet, the lift, instead of being constant, increases with the altitude, but the increase is small. If such an altitude is reached that the whole of the air in the ballonet is expelled, the balloon is in the position described in case (3), namely, constant volume and constant mass. If, as in the rigid type of dirigible, the outward form is kept constant by a framework, it is not necessary to maintain an excess of pressure in the ballonet, but in all other ways, as far as lift is concerned, the rigid and non-rigid dirigibles

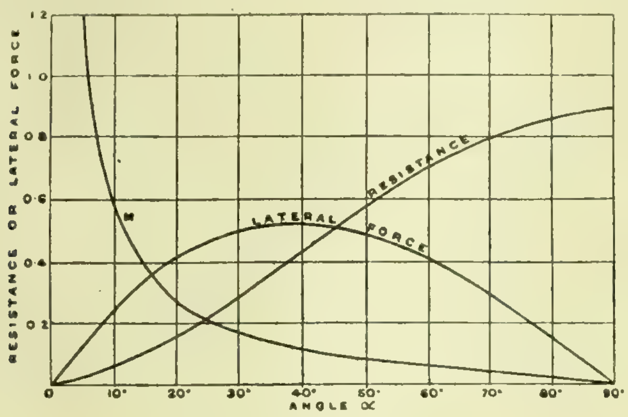


FIG. 5.—THEORETICAL VALUES.

are alike. The working altitudes of such balloons are limited by the volume of the ballonet, which must never be completely collapsed. For instance, if they are intended for use up to 5,000ft., at which level the atmospheric pressure is reduced by about one-fifth part, the volume of the ballonet must not be less than one-sixth of the whole volume of the dirigible, leaving five-sixths for the lifting gas.

I do not propose here to go into the questions of the relative merits of the rigid and non-rigid forms, questions which turn on structural details rather than on general principles, but something may be said on the nature of the envelope used for retaining the hydrogen, which is now usually employed for lifting purposes. The best information on the subject is due to work recently carried out at the National Physical Laboratory, at the request of the Advisory Committee for Aeronautics, and will be found in detail in their published reports. It appears that among the fabrics in use there are enormous differences in their retentive power, that is, in the rate of the diffusion of hydrogen through them irrespective of actual leaks, differences of nearly two-hundredfold appearing between the worst and best specimens. India-rubber coatings are the least satisfactory, allowing an escape in some cases of more than 0·7 cub. ft. for every square foot of material in 24 hours when new, and deteriorating as time goes on. The most retentive hitherto tested are various oiled skins, goldbeaters' skin, and some other artificial membranes. When the large surface, which all dirigible shapes expose to the air, is considered, it will be seen how important is the choice of material, and that with the best the necessary hydrogen renewal is not a small matter, even if no ascents are made, and may well be over 1,000 cub. ft. a day for a large vessel.

Much more than this, however, must be lost when the dirigible is in use. A thousand cubic feet of hydrogen gives a lifting force of about 75lbs., and the engines of one of the larger dirigibles will part with many times this weight in fuel and other ways in less than 12 hours. To keep the vessel at a constant height the lift has to be diminished or the downward force increased at the same rate. While travelling this may be effected to some extent by steering, but when stationary the balance can only be obtained by allowing the equivalent amount of gas to escape. To rise again an equal amount of ballast must be discharged. The number of ascents therefore which can be made without a fresh supply of hydrogen is limited by the quantity of ballast which can be carried.

It is of some interest to enquire what engine power is required to propel such vessels at the speeds they are credited with, namely, 35 to 45 miles per hour. Model experiments indicate that for "fair" shapes the resistance actually encountered is about one-tenth of the normal resistance of a plane whose area is the maximum cross-section of the vessel. The greater part of this resistance is due to surface friction, but for cylindrical shapes with long parallel sides the proportion is somewhat greater in consequence of the wake. As will be mentioned again later, the normal resistance of a plane in air is about $0{\cdot}00135 v^2$lb. per square foot, where v is the speed in feet per second. If we take the case of a vessel with "fair" lines whose maximum diameter is 40ft., the area of the cross-section is 1,250 sq. ft. nearly, and the resistance at 40 miles an hour (that is, at about 60ft. per second) is $\frac{1}{10} \times 0{\cdot}0035 \times 1250 \times 3600 = 1{,}600$lbs. The power required for the thrust therefore is $\frac{1600 \times 60}{550} = 120$ h.p.

The engines are not likely to convert much more than half their nominal horse-power into thrust, so that 240 h.p. engines would be required to give a speed of 40 miles per hour to an airship of this size and form. This rough calculation probably under-estimates the power required even for a ship with fair lines, and for cylindrical shapes which leave a considerable wake the defect will be greater. The general steering qualities of dirigible balloons are unsatisfactory, and this is perhaps more apparent in the large cylindrical vessels than in those which are fish-shaped, but in all cases the steering may be improved by the addition of fins. Even with these, however, it is difficult to keep a straight course.

We may now turn our attention to the more promising field presented by true flying machines—machines, that is, which are heavier than air and are supported by the reaction of a downward current of air called into existence by the engines in ordinary flying, or by the diversion of natural upward components of the wind in soaring. It is theoretically possible also to maintain flight—without expenditure of work on the part of the flying machine—in a horizontal wind whose velocity increases with the altitude or varies from place to place at the same level. In this case the flying machine has to descend in the direction of the wind and then turn and ascend against it. In each such cycle work is gained, and the work is obtained from the difference of wind velocities. It is not improbable that birds in some circumstances may actually soar by this means, but there are no detailed observations, as far as I am aware, on the subject. When a body falls without change of attitude either vertically or obliquely

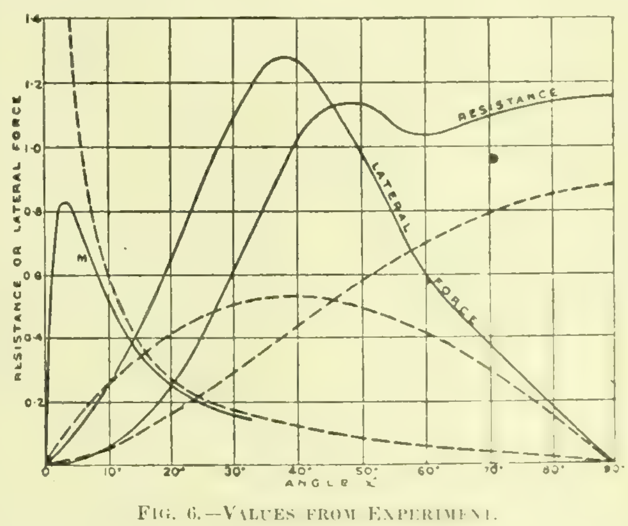


FIG. 6.—VALUES FROM EXPERIMENT.

under the influence of gravity, it acquires in time a constant velocity, and when this is reached the resistance is equal to the weight. The downward momentum imparted to the air in the unit of time is then $w\,v/g$, where v in this case is the vertical component of the velocity. At the same time the resistance to the vertical motion is $w\,v^2/2\,g$, and the power expended on the air is $w\,v^3/2\,g$.

The terminal velocity itself depends on the shape and area of the surface exposed to the air, and on the manner in which it is presented to the current. Thus it would seem at first sight that by increasing the area of the surface, and so diminishing the velocity of descent, the power expended might be reduced without limit. As will be seen later, however, air friction places a limit on the reduction of power

necessary for flight, independently of other practical limits imposed by sizes of the resisting areas which can be actually constructed. One or two examples may be given illustrating the dependence of the power required on the terminal velocity.

First, take the case of a parachute, which may be supposed to be massless and to carry a long ladder up which a man climbs (Fig. 2). If the man is to maintain a constant elevation above the ground he must be able to climb as fast as the parachute falls. Now, it is known from experiment that a surface such as a parachute experiences a resistance while falling through the air equal to about $\frac{14}{1000}$ of a pound for every square foot of area at a speed of 1ft. per second. If we give the parachute a diameter of 36ft. its area will be about 1,000 sq. ft.; and if we suppose the man to weigh 150lbs., the terminal velocity will be given by $v^2 = \frac{150}{14}$ or $v = 3{\cdot}3$ft. per second. This, of course, is much more than a man can do.

If we take a man-power as one-tenth of a horse-power, 55ft. per minute or, at the outside, 1ft. per second, may be taken as the rate at which he can raise his own weight for any considerable length of time. The area which, when loaded with 150lbs., drops at rate of 1ft. per second is $\frac{15{,}0000}{14{\cdot}0}$ or 10,600 sq. ft., that is, a circle of 113ft. diam. With such a parachute a man could, by climbing, keep himself stationary in the air.

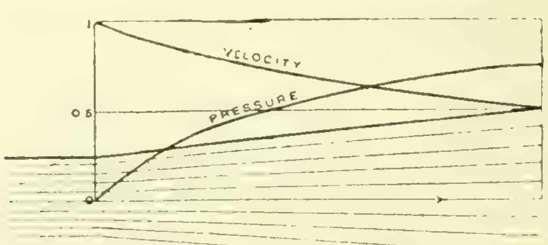


FIG. 7. -NON-FRICTIONAL FLOW.

It is not necessary, in order to impart this momentum to the air, that the surface should itself have this area of 10,600 sq. ft. The same momentum may be given by a much smaller inclined surface moving horizontally. If a perfectly efficient screw or inclined plane were a physical possibility, there would be nothing to prevent people from flying by their own muscular effort, and it is worth while to examine the causes which prevent the realisation of such a result. The reaction on an inclined plane in a current of air will sufficiently illustrate this without the introduction of complications which surround the question of the very similar reactions on screws.

Take the case of a thin, flat plate placed edgewise in a wind. If there is no surface friction between the fluid and the plane the latter offers no resistance, the pressure on both sides is the same, and the flow of the air stream is unaltered by its presence. If, however, the plane is inclined to the current, the mathematical solutions present two possible forms of flow, one of which would indicate that the plane experienced no resistance, but that the pressure was so distributed over the two surfaces as to form a couple tending to turn the plate broadside to the stream (Fig. 3), the other indicating a resistance, the pressure on the up-stream surface being raised, while on the down-stream surface the pressure remains unaltered, equal, that is, to the general pressure in the air at a distance. This form of flow is shown in Fig. 4, and it will be seen that behind the plane there is a body of still air, separated from the current by a surface of discontinuity.

Neither of these theoretical flows represents what actually takes place, but the second is sufficiently close to Nature to give a rough measure of the real resistance when the inclination of the plane to the direction of the current is a moderate angle, say, not less than 8° or 10°. Assuming for the moment, however, that the second solution is correct, we may calculate the wind speed required and the angle which a plane of given area must make with the direction of flow if a given quantity of momentum is to be generated in a direction at right angles to the stream.

From the theory of the flow shown in Fig. 4 it appears that the average normal pressure on the unit area of the plane is proportional to $v^2 \frac{\pi \sin \alpha}{4 + \pi \sin \alpha}$, where v is the velocity and α the angle which the plane makes with the stream. When this angle is small, this expression may be replaced by $v^2 \frac{\pi}{4} \sin \alpha$, and the actual normal force is $\rho\, v^2 \frac{\pi}{4} \sin \alpha$ per unit area of plane, ρ being the density of the air. Hence the components parallel and perpendicular to the flow are $\rho\, v^2 \frac{\pi}{4} \sin^2 \alpha$ and $\rho v^2 \frac{\pi}{4} \sin \alpha \cos \alpha$.

The first of these is the resistance and the second the lifting force, and their ratio is $\cos \alpha$. The downward momentum generated is then $\rho \frac{v^2}{g} \frac{\pi}{4} \sin^2 \alpha \cos \alpha$, thus leading to the conclusion that there is no limit to the lifting force which may be called into existence by a given resistance or by a given power by sufficiently reducing the angle α.

The general relations connecting the normal force, lateral force, resistance, and power expended when a stream of air flows obliquely past a long narrow plane—the long dimension being across the stream—are given in the following formulæ:

Let v denote the velocity of steam.
- α ,, ,, angle between the stream and plane.
- S ,, ,, area of plane.
- N ,, ,, normal force on plane.
- R ,, ,, resistance.
- L ,, ,, lateral force.
- H ,, ,, power required in foot-pounds per second.
- ρ ,, ,, density of air.

Then on the theory of the flow shown in Fig. 4:—

$$N = \tfrac{1}{2}\rho v^2 \frac{2\pi \sin \alpha}{4 + \pi \sin \alpha} \quad \ldots \ldots \quad (1)$$

$$R = \tfrac{1}{2}\rho v^2 \frac{2\pi \sin^2 \alpha}{4 + \pi \sin \alpha} \quad \ldots \ldots \quad (2)$$

$$L = \tfrac{1}{2}\rho v^2 \frac{2\pi \sin \alpha \cos \alpha}{4 + \pi \sin \alpha} \quad \ldots \ldots \quad (3)$$

When the angle is small enough for α to be sensibly equal to $\sin \alpha$ and $\cos \alpha$ is nearly unity, if we put $\frac{1}{2}\rho \frac{2\pi}{4} = A$,

$$L = N = A\,S\,v^2 \alpha \quad \ldots \ldots \ldots \quad (4)$$

$$R = A\,S\,v^2 \alpha^2 \quad \ldots \ldots \ldots \quad (5)$$

$$H = v\,R = A\,S\,v^3 \alpha^2 \quad \ldots \ldots \ldots \quad (6)$$

$$L/R = 1/\alpha \quad \ldots \ldots \ldots \quad (7)$$

As before said, according to this theory any power, however small, would be sufficient to carry any weight at any speed, provided there was no limit placed on the area of the plane. If the area were given it would always be possible to find a speed at which the load could be carried with the specified power. For instance, if it is asked what area of wing must a man weighing 150lbs. have in order to fly at 10ft. per second—6·8 miles per hour, supposing he can develop $\frac{1}{10}$ h.p.—roughly, about 60ft.-lbs. per second. The value of the constant A for air is 1/510, and from the equations (4) to (7) we find that the required area is $S = L/A\,v^2\alpha = 11{,}100$ sq. ft.; also that $\alpha = H/vL = 2{\cdot}3°$.

If we assume a wing area of 150 sq. ft. we find that for the same power the velocity required to support 150lbs. is L^2/ASH or 1,270ft. per second with $\alpha = H^2 AS/L^3 = 1{\cdot}1$ minutes of arc. Or, again, if we assume a velocity as low as 60 miles per hour—88ft. per second—we find that the power required is $L^2/ASv = 860$ft.-ibs. per second, or 1·55 h.p., and the corresponding value for α—namely, L/ASv^2—is 3·7°.

These examples, in which no resistance except that of the wings is taken into account, and which it must be remembered depend on a theory which excludes frictional forces, show clearly that even on these favourable assumptions flight by muscular power would be impracticable for human beings, if only on account of the great wing area or great speed which is required for the purpose. When, however, the actual forces which act on plane surfaces are examined experi

mentally, it will appear that it is not only impracticable, but impossible. The difference between the theoretical and experimental results will now be considered.

In Fig. 5 the ordinates of the curves are the L and R of the equations just given, and they refer to a plane whose breadth parallel to the stream is small compared to its length. The units in which these curves are plotted are such that 1 corresponds to the weight of a column of air of unit section whose height is the dynamic head required for the velocity. The ratio L/R, which measures the proportion of the lifting force to the resistance—or, in the case of flying, the lifting force to the propulsive effort—is simply a curve of contangents, M.

In Fig. 6 the curves and their ratio are the result of experiments made with planes moving in air and in water, and it may here be noticed that for most purposes the results obtained from water may be applied to air, and vice versâ, provided, of course, that the relative densities of the two fluids are taken into account.

Three points in particular stand out clearly in the experimental curves, namely: (1) That the actual resistance and lifting force are greater than the theoretical values; (2) that their ratio ceases to be a curve of contangents, and that it has a large and distinct maximum when α is somewhere about 5°; (3) that both the resistance and lift are very uncertain when α is within 10° or 15° on either side of 45°.

It appears that the M curve $\left(\frac{\text{lift}}{\text{resistance}}\right)$ is always less than cot α, but that it approaches cot α fairly closely when α exceeds 15°.

The curve of $\frac{\text{lift}}{\text{resistance}}$ or $\frac{\text{lift}}{\text{propulsive force}}$ is one of the most important matters in principles of flight, for the angle at which its maximum occurs indicates the best angle at

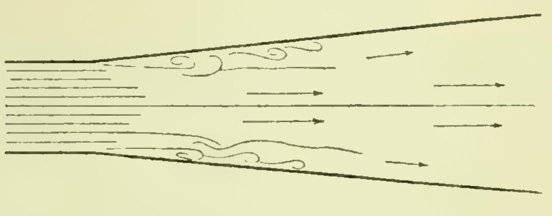


FIG. 8. FRICTIONAL FLOW.

which the wings can be set with reference to the path of the machine through the air, and the actual value of the maximum is a measure of the efficiency.

In most of the experiments which I have made this maximum had a value of 7 or 8, that is, the load sustained was about 7 or 8 times the propulsive force. Though occasionally considerably higher values were obtained—as much as 12—and though I have seen similar numbers recorded by other experimenters, I look on these results with suspicion.

The fact is that when the experiments are made with small models the quantity R is very small for the small values of α where the maximum occurs, and a very small error in the determination of this small quantity has a great effect on the ratio L/R.

It will be readily seen that since a propulsive force R is capable of supporting a load L when the angle of the supporting planes with the path is α, then, if the propulsive force is due not to the engines, but to the path having a downward inclination, so that $R = L\alpha$, the minimum value of R/L is the tangent of the least angle to the horizontal down which the flying machine or loaded plane can glide.

I think I am right in saying that no flying machine has been made with a gliding angle as flat as 1 in 7, and that 1 in 5 is more nearly what may be expected. Of course, in actual flying machines the resistance of the body and other parts not contributing to the support has to be overcome as well as the resistance of the supporting wings, and this, of course, makes the gliding angle less flat than it would be were there no extraneous resistance. The difference, however, between 1/5 and 1/7, which, roughly, is somewhat less than one-third of the propulsive force, will in most cases more than cover the loss due to body resistance, &c., and it may be concluded, therefore, that the evidence given, as far as regards actual flying machines, is in favour of a maximum value of L/R not exceeding 7.

We will now consider more closely the causes which produce the very marked difference between the theoretical curves given in Fig. 4 and the corresponding quantities as determined by experiment. It is well known that the fluid with which mathematicians deal, and which is supposed to surround the plane in Fig. 4, is an ideal body which is without viscosity—that is, opposes no resistance to shear—and that in contact with a solid it experiences no frictional retardation. In such a fluid pressure and velocity are connected by an invariable law, the sum of the potential and kinetic energies of any portion of the fluid remaining constant for all time.

This law, together with the necessary condition of continuity, which for an incompressible fluid merely implies that the volume of a given mass of fluid remains constant, no matter what shape it takes, constitutes the foundation of all the propositions regarding the stream lines of a perfect fluid which have hitherto been worked out, and for such a fluid the stream lines indicated in Fig. 4 are an exact solution of the problem.

Now real fluids differ from the perfect fluid in having both viscosity and surface friction. They require that work should be done if distortion is going on, and they adhere to the surfaces of solids immersed in them. Thus a plane which, if moving edgewise in a perfect fluid, would meet with no resistance, does meet with resistance in a real fluid on account of the adherence of the fluid to the solid surface and the consequent distortion produced in the neighbouring layers of the fluid.

It is true that for fluids such as water and air the viscosity is so small that the direct effects would hardly be noticeable. Indirectly, however, they have immense influence, and it is not too much to say that the most remarkable features in the flow of the winds, tides, and streams are due to the modification of stream-line motion set up by fluid friction and viscosity.

The indirect action referred to depends on the fact that when a stream is retarded by friction, the velocity is reduced although the pressure remains unchanged, and thus the fundamental relation which connects velocity and pressure in a perfect fluid is violated. As long as the stream concerned is of constant section and is neither accelerating or retarding, as for instance when the flow is through a straight pipe of uniform bore, the effect of friction shows itself merely by rendering the stream lines irregularly sinuous, in a way which has not yet been investigated, and as giving rise to a resistance which is proportional to a power of the velocity something rather less than the square, *i.e.*, to the 1·85th or 1·9th power.

When, however, the stream is divergent—so that in the absence of friction the velocities and pressures, although constant across each section, change from one section to another, but keep the total energy of the flow across each section the same—the effect of friction and viscosity is much more conspicuous.

In Fig. 7 fluid is supposed to be flowing outwards in a wedge-shaped channel, and the stream-line pressure and velocity at each section for a perfect fluid are shown in the curves. This relation is the only one which will allow a portion of fluid at P_1 v_1 to overcome the resistance due to the pressure gradient and arrive at P_2 with the velocity v_2. In a frictional fluid these relations hold fairly well for the central streams, which are little influenced by the sides, but the side streams, which have had their velocity reduced by friction, independently of the stream-line reduction, find themselves opposed by a pressure which is sufficient to reverse the direction of their flow, and these reversed streams, by usurping part of the channel, alter the character of the flow altogether, the result being that instead of an outward flow over the whole section of the channel, a rapid current traverses the central part with well-marked eddies on either side (Fig. 8).

The exact nature and form of these eddies are not at present amenable to mathematical treatment, but their general character and the fact that they are due to the reversal of streams whose potential has been degraded by friction was pointed out by the late W. Froude before the British Association meeting at Bristol in 1875.

(*To be continued.*)

COMPOSITION OF HIGH-SPEED TOOL STEEL.

BY E. T. EDWARDS.

IMPROVEMENTS in iron and steel making for the last several years have been of a broad character. Two branches of development are especially noticeable: (1) The application of electricity to the production of metals by means of the electric furnace; (2) the progress being made in the methods of heat treating high-speed steel and the changes in composition of the latter. The composition of present-day high-speed steels and their cutting qualities form the theme of this paper.

The history of high-speed steel began when patents were granted to Messrs. Taylor & White, in 1900, covering the manufacture of a brand of steel alloyed with tungsten, molybdenum, and chromium in specified proportions, and certain exacting heat treatments for them. Well remembered are the remarkable demonstrations of this steel made by the Bethlehem Steel Company at the Paris Exhibition. Tools for cutting metals were shown operating at a speed eight to 10 times greater than what was then the usual shop practice. Engineers watched these tests with the keenest interest, and Messrs. Taylor & White were highly commended for their achievements. But note the rapid trend of events. A decade has passed since this remarkable steel was patented; to-day it is not heard of. At a comparatively recent date the patents covering this product were held invalid, the court saying, with other comments, that "no satisfactory basis appears in the records for the assertion that the patents in suit lead up to or were the means of producing or introducing the present high-speed steels."

Steelmakers, encouraged with the success of this new steel, soon followed with superior steels that taxed the capacity of the machine tools in using them to their limit. This has necessitated improvements in machine design. Developments along this line of engineering have advanced to the stage where machine tools are now designed specifically to secure a high efficiency through rapid production at highest speeds with the greatest depth of cut and maximum feeds that the high-speed steels are capable of standing.

In a paper read recently before a railroad club the author concluded by saying: "The makers of machine tools have had to wake up to the fact that heavier and more powerful machines must be made to keep up with the working capacity of high-speed steel, and I venture to prophesy that heavy machinery is as yet in its infancy." This prophecy is proving true, for day after day we see ponderous and more efficacious machines turned out by the various machine tool builders, and the end is not yet.

Without referring to any scientific classifications of cutting tools of the various types of steel, let us for a moment compare the composition of the Taylor & White steels with those of later years and also present-day practice. Before we proceed in making this comparison, however, it seems necessary to refer to Mr. Taylor's groupings of high-speed steel historically, so that a better understanding may be had of the steels referred to.

"Group A is known as the era of carbon steels up to 1894.

"Group B is known as the era of Mushet or self-hardening steels, 1894 to 1900.

"Group C is known as the era of high speed steels from 1900 to ——."

The time left blank after 1900 by Mr. Taylor has now closed, and a new era has been reached. This we will group under D, and call the era that of superior high speed steels. The old era closed and the new era began when Dr. Arnold made the startling announcement in England, early in 1909, that a new high speed steel had been discovered that would do from four to seven times the amount of work done by other high speed steels and at increased speeds.

Relative to the composition of these various steels, Mr. Taylor, in his application for a patent, says: "I have not found any very material difference in the cutting speed when chromium, tungsten, and molybdenum are used in excess of the percentages last given. (Tungsten present in the proportions of 1 or more per cent.; or in the alternative, molybdenum present in the proportion of 1 or more per cent.; or again tungsten present in the proportion of 2 per cent. or over, together with molybdenum in the proportions of 1 per cent. or over.) For cutting very hard metal I have found a tool composed of a steel having not less than 3 per cent. chromium and not less than 6 per cent. tungsten, or in the alternative, not less than 3 per cent. molybdenum, to have a special value. I have worked with steels containing carbon 0·85 to 2 per cent. without notable difference in the character of the tool produced by my treatment."

TABLE I.—*Percentage of Various Elements in Steels succeeding the Taylor & White Steels.*

No.	C	Si.	Mn.	Cr.	Tung.	Mo.
1	0·41	0·10	0·07	3·11	9·00	...
2	0·53	0·19	Trace	6·13	11·07	...
3	0·60	0·20	0·15	6·00	12·00	0·50
4	0·59	0·30	0·20	4·00	13·00	...
5	0·40	0·10	0·15	5·00	13·98	...
6	0·77	0·11	0·19	3·17	16·57	...
7	0·71	0·36	0·06	3·48	17·53	...
8	0·79	0·20	0·10	3·50	...	9·26
9	0·97	0·10	0·26	6·03	18·00	...

The Taylor & White steels were soon followed by steels made by the leading steel-makers, in which the composition varied widely. The analyses in Table I. show relatively how the leading brands compared. Again the compositions have changed, and we are confronted with steels containing elements in the proportions as indicated in Table II. These are representative samples of the present-day superior high-speed steels.

It is just as interesting to note the increase in the feed and speed of to-day over those of previous years as it is to compare the changes made in machine design and composition of steel. Instances on record of the cutting speed of the Taylor and White varieties of steel refer to these as cutting cast iron on a planer at 50ft. per minute and on a lathe at 70ft. per minute. On soft steel speeds of 50ft. to 60ft. per minute are recorded on cuts of 0·04 sq. in. area; and speeds of 70ft. to 80ft. per minute on cuts of 0·02 sq. in. area are also recorded.

Among recent records made by the group C steels are the following: A high-speed steel tool, 3in. by 1¼in. in section, not long ago turned at 14ft. per minute with ⅛in. feed and $\frac{7}{16}$in. depth of cut a pair of locomotive tyres in 43 minutes. The tools were taken out in good condition. A 1¼in. square tool turned an open-hearth steel forging made from high chrome steel, annealed, at 66ft. per minute, with ¼in. feed and

TABLE II.—*Percentage of Various Elements in Present Day Superior High-speed Steels.*

No.	C	Si.	Mn.	Cr.	Tung.	Mo.	Va.
1	0·60	0·07	0·29	4·53	19·65	...	0·03
2	0·65	0·10	Trace	3·23	16·78	...	0·25
3	0·73	0·32	0·18	3·24	18·27	...	0·35
4	0·67	0·22	Trace	5·33	18·51	1·52	0·42
5	0·69	0·23	0·20	3·25	16·68	...	0·64
6	0·60	0·20	0·17	5·50	16·00	0·50	0·70
7	0·52	0·16	0·12	2·77	16·95	0·37	0·83
8	0·80	0·31	0·18	3·06	18·43	...	0·90
9	0·64	0·25	0·21	4·06	18·80	0·97	0·92
10	0·59	0·18	0·12	3·50	18·56	0·22	1·06
11	0·71	0·45	0·25	3·24	16·72	0·20	1·16
12	0·71	0·35	0·15	3·78	18·92	...	1·25

[illegible]in. depth of cut. Eight to 12in. diam. chrome steel shafts are regularly turned at 35ft. per minute, reducing the diameter [illegible]in. per cut and feeding at about [illegible]in. per revolution of lathe. Finishing cuts [illegible]in. deep with 0·1in. feed were regularly taken on the same steels at 90 to 95 per minute.

In these operations the cutting point of the tools for some time before failure discoloured to the same degree as they would had they been heated to 650 Fah., which shows the wonderful cutting properties even of this class of steel. Large amounts of these steels are still used, but they are being rapidly replaced by the new superior brands. It has been said, in forecasting the future of the high-speed steel industry, "that it will probably pay better to produce tools from cheaper

materials than those now used, that will run at a little less than the present degree of temperature to produce failure, than to experiment with costly alloys that may be found to work at rather higher temperatures." The author does not agree with this forecast: an illustration taken from everyday practice will show the fallacy of its reasoning.

TABLE III.—*Composition of Tool Steels Tested.*

No.	Carbon.	Tungs.	Chrome	Vanadium.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1	0·54	10·35	5·20	None
2	0·53	11·40	6·15	,,
3	0·55	14·59	5·50	,,
4	0·50	16·00	4·00	,,
5	0·61	17·15	3·90	,,
6	0·60	18·11	4·51	,,
7	0·61	17·49	4·90	,,
8	0·61	17·15	6·15	,,
9	0·59	19·95	4·75	0·15
10	0·64	20·03	4·76	0·27
11	0·94	18·40	4·45	0·40
12	0·88	16·00	5·90	0·15
13	0·66	20·25	4·93	0·60
14	0·68	18·00	3·50	0·85

A $\frac{15}{16}$in. diam. superior steel drill in test did the work that four regular high-speed drills would do, the drill only wearing about one-fourth as fast, while the speed and feed were increased 50 per cent. The superior drill was useless

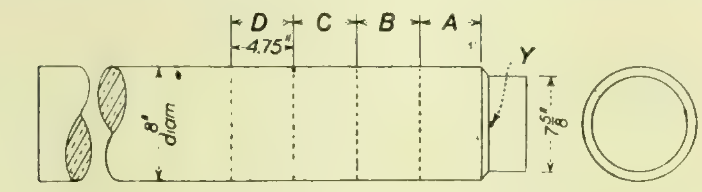


FIG. 1.—DIMENSIONS OF TEST BAR SHOWING POINTS WHERE CUTTING SPEED IS INCREASED.

after drilling 6,100ft. of material, the actual time required to perform the work being 490 hours. It was necessary to use two class C drills to do the same work, the time required being 762 hours. The superior drill cost 12s., while the class C drills cost 10s. each. A recent test for drilling cast iron with a superior steel drill is reported as follows: A 1in. drill running at 520 revs. per minute with $\frac{1}{16}$in. feed, drilled two holes through a 4in. block of cast iron and the drill had not perceptibly worn; this seems to be about the fastest on record.

TABLE IV.—*Series No. 1 of Tests on the Cutting Qualities of High-speed Steel.*

Tool No.	Cutting speed in feet per minute.							Total length of cut, ft.	Remarks.
	46	54	62	70	78	86	94		
1	150	150	150	30	...	...	...	480	Tool cut rough.
2	150	150	150	45	...	...	...	495	Tool burned out.
3	150	150	150	150	30	...	...	630	Tool burned out
4	150	150	150	150	15	...	...	615	Tool cut fair.
5	150	150	150	150	30	...	...	630	Tool cut fair.
6	150	150	150	150	0	...	...	600	Tool did not cut well.
7	150	150	150	52½	...	...	...	502½	Not good.
8	150	150	150	150	150	0	...	750	Good tool.
9	150	150	150	150	7½	...	...	607½	Did not cut smooth.
10	150	150	150	150	150	150	0	900	Tool burned out.
11	150	150	150	150	0	...	...	600	Tool burned out.
12	150	150	150	150	150	150	60	960	Made clean smooth cut.
13	150	150	150	150	150	150	120	1020	Chips deep blue.
14	150	150	150	150	150	150	74	974	Chips deep blue.

NOTE.—0 means the total failed when the speed was increased. 150 means a cut of 150 circumferential feet was taken before speed was increased. Numerals less than 150, given under any speed, means that the tool cut the distance indicated at that speed, then burned out.

As is commonly noted, whenever an important work is accomplished or discovery made, a theory soon follows setting forth a reason for the event. This has been true of high-speed steel also, as numerous theories have been given explaining that the results attained could be expected. It cannot be denied, however, that Messrs. Taylor & White have paved the way for the development of the present superior steels, whether it be conceded that they made a wonderful discovery or simply adopted an experimental rule that permitted them to surpass others in the race for its development.

By referring to the analyses of the now leading high-speed steels it will be noted that at least one element has been added to all steels; this element is vanadium. It is universal practice to use it; all the leading brands of steel contain various amounts. Broad claims are made as to the wonderful results following its use. Among other things it is said vanadium has triple force in cleansing, strengthening, and toughening all varieties of steel, and that it intensifies tremendously the powers of other elements. In other words, "it endows steel with life."

TABLE V.—*Series No. 2 of Tests on the Cutting Qualities of High-speed Steel.*

Tool No.	Cutting speed in feet per minute.							Total length of cut, ft.	Remarks.
	46	54	62	70	78	86	94		
1	150	150	150	150	90	...	...	690	Tool burned out.
2	150	150	150	0	...	...	...	450	Tool burned out.
3	150	150	150	150	40	...	...	640	Tool burned out.
4	150	150	150	150	150	0	...	750	Fairly smooth cut.
5	150	150	150	150	150	20	...	770	Fair, tool burned out.
6	150	150	150	150	150	0	...	750	Burned out.
7	150	150	150	150	150	7½	...	757½	Cut not smooth.
8	150	150	150	150	150	60	...	810	Good, smooth cut.
9	150	150	150	150	150	150	0	900	Tool burned out.
10	150	150	150	150	150	150	60	960	Smooth cut, burned out.
11	150	150	150	150	150	126	...	877	Fair.
12	150	150	150	150	150	150	80	980	Smooth cut.
13	150	150	150	150	150	150	164	1064	Smooth cut.
14	150	150	150	150	150	150	309	1209	Smooth cut.

The author's experience with the use of vanadium has led to the adoption of the following rules which show the important part played by this element, and how much it augments the properties that make for speed and endurance. Stating the effect of vanadium as an average of many tests, these results show that:—

0·3 per cent. vanadium allows 10 per cent. increased speed or 10 per cent. more metal removed in same time.

0·6 per cent. vanadium allows 20 per cent. increased speed or 20 per cent. more metal removed in same time.

0·9 per cent. vanadium allows 30 per cent. increased speed or 30 per cent. more metal removed in same time.

Stating the effect in terms of increased time between grindings of tools proves that:—

0·3 per cent. vanadium doubles the time between regrinding.

0·6 per cent. vanadium quadruples the time between regrinding.

0·9 per cent. vanadium cuts eight times as much metal between grindings if the same speed and feed is used.

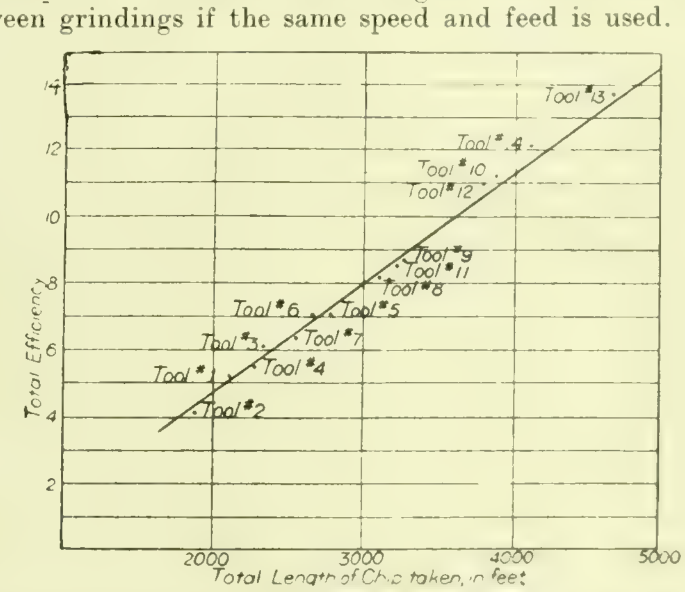


FIG. 2. DIAGRAM SHOWING RELATIVE EFFICIENCY OF VARIOUS TOOL STEELS.

A tool that will cut at 10 per cent. faster speed will last twice as long between grindings (if the speed is not changed) and a tool that will stand a 20 per cent. faster speed will run four times as long between grindings. A tool that will stand 30 per cent. faster speed before it reaches the breaking-down point will last eight times as long without re-sharpening. To make this clear each additional 0·3 per cent. vanadium adds 10 per cent. to the possible cutting speed or doubles the life of a tool working at the same speed and feed. As a result of these data it is apparent that it is not policy to use the old high-speed steels. If the machinery is not strong enough to

run at increased speeds, the tool will last eight times as long since it needs to be sharpened only one-eighth as often in removing a given amount of metal.

Much has been said and written about Mr. Taylor's paper, "The Art of Cutting Metals." It is certainly a masterpiece, based as it is on the longest and most exhaustive series of experiments conducted along this line. However, it would be impractical as well as almost impossible for the tool steel manufacturer to carry on experiments of this kind, day after day in the plant, to determine what composition of steel gives the best results under average shop conditions; yet it is necessary for the manufacturer to determine these things in order to keep abreast with the times. Nor does the tool steel testing machine designed by Ed. G. Herbert give all that is desired.

A method used by the author, and with excellent success, can be briefly described as follows: For making tool tests a large variable speed lathe driven by a 15-h.p. direct-connected Westinghouse motor is used. The lathe is so connected by interchangeable gearing that 144 changes of speed can be obtained. The tools to be tested are ground to a templet, so that absolute uniformity of clearance, rake, and shape is always assured. The tool, when set in the lathe, is always set at exactly the same height, this being about $\frac{1}{16}$in. above the lathe centre, as experience has taught that this always gives the best results on a large diameter bar, such as is used. Extreme care is taken in hardening that all tools are heated under conditions as nearly uniform as possible, that they are held at the same level in the hardening bath, and that they are transferred to the air blast to cool thoroughly under exactly uniform conditions, the method of hardening being to heat the tool to the proper temperature in a clear coke fire, then to harden by immersing one-half of the cutting point in oil and finally to cool in an air blast.

TABLE VI.—*Summary of the Four Series of Tests, showing Total Length of Chip for each Brand of Tool.*

Tool No. 1	2,128ft.	Tool No. 8	3,100ft.
Tool No. 2	1,972ft.	Tool No. 9	3,225ft.
Tool No. 3	2,440ft.	Tool No. 10	3,915ft.
Tool No. 4	2,225ft.	Tool No. 11	3,194ft.
Tool No. 5	2,817ft.	Tool No. 12	3,814ft.
Tool No. 6	2,782ft.	Tool No. 13	4,607ft.
Tool No. 7	2,559ft.	Tool No. 14	4,163ft.

The bars on which tests are made are of a special definite-composition alloy steel. They are first annealed and then heat treated to a uniform tough structure, of the same hardness, from the surface to the centre of the bar. The bars are made 8in. diam., and are discarded after the diameter has been reduced about 5in. In making the tests the depth of cut is set at $\frac{3}{16}$in. on a side; the feed is also set so that it is constant at $\frac{1}{15}$in. per revolution. The cutting speeds are then varied until the tool is worn out and the test completed.

TABLE VII.—*Series No. 3 of Tests on the Cutting Qualities of High-speed Steel.*

Tool No.	Cutting Speed in Feet per minute.							Total length of cut, ft.	Remarks.
	46	54	62	70	78	86	94		
1	150	150	150	52	...	...	...	502	Tool burned out.
2	150	150	150	67½	...	...	...	517½	Tool burned out.
3	150	150	150	150	0	...	...	600	Tool burned out
4	150	150	150	150	145	...	...	545	Tool burned out.
5	150	150	150	150	150	150	0	900	Cut fair.
6	150	150	150	150	150	52	...	802	Tool burned out.
7	150	150	150	150	150	40	...	790	Tool burned out.
8	150	150	150	150	150	150	0	900	Fair.
9	150	150	150	150	150	150	7½	907½	Fair
10	150	150	150	150	150	150	210	1110	Good cut.
11	150	150	150	150	150	150	17½	917½	Good cut.
12	150	150	150	150	150	150	157½	1057½	Not smooth.
13	150	150	150	150	150	150	211½	1128½	Good, smooth cut
14	150	150	150	150	150	150	45	945	Good, smooth cut

The method of procedure is this: After the tools are ground properly to gauge and hardened uniformly, they are set securely in the lathe, the lathe having been previously set so that the proper depth of cut and amount of feed result as soon as the cut is started. The tool then starts to cut at 46ft. per minute; this speed is maintained until the tool has traversed 150ft. in circumference along the surface of the bar. Then the speed is immediately increased to 54ft. per minute; it is then increased in increments of 8ft. per minute after each 150ft. of circumferential travel, until a speed is reached where the tool fails or breaks down. It is considered that a speed of 94ft. per minute, turning the special alloy bars used for testing purposes, is far greater than would be met in shop practice except in the most exceptional cases; when this speed is attained the tool is permitted to operate as long as it stands the work, or, in other words, until it burns out. The tool is then reground and the same cycle of tests is repeated until the tool again fails. The strictest precautions are taken in grinding so as not to blue the cutting edge or point of the tool. These tests are repeated until each tool has had four grindings; experience indicates that a tool usually gives the best results after the second grinding.

The sketch (Fig. 1) will help to make clear the method of procedure. The tool is started at the point Y, and cuts the distance A along the shaft, at 46ft. per minute. This distance is 4·75in., the diameter of the shaft being 8in. before the cut is taken, and corresponds to the cut-length of 150ft. the feed being $\frac{1}{15}$in. per revolution of lathe. When the distance A has been completed the speed is immediately increased to 54ft. per minute, and the distance B is turned, when the speed is again increased to 62ft. per minute, and the distance C completed. The speed is increased in increments of 8ft. per minute in this manner until a speed of 94ft. per minute is attained, as before stated. The tool is permitted to cut at the latter speed until the point is destroyed.

The record of tests will also illustrate the method of testing. These were tests precedent to a large number that were made to determine: (1) The effect of high or low carbons on the cutting qualities; (2) the results secured from varying the chrome present; (3) the effect of high or low tungsten; (4) the effect of the presence of varying amounts of vanadium. The carbon, tungsten, chrome, and vanadium present in each tool were as given in Table III., and they are branded by numbers for proper identification.

To estimate the value of each tool, we assume the formula for efficiency.

TABLE VIII.—*Series No. 4 of Tests on the Cutting Qualities of High-speed Steel.*

Tool No.	Cutting Speed in Feet per minute.							Total length of cut, ft.	Remarks.
	46	54	62	70	78	86	94		
1	150	150	150	6	...	...	...	456	Burned out.
2	150	150	150	150	10	...	...	610	Burned out.
3	150	150	150	120	...	...	...	570	Burned out.
4	150	150	15	...	...	...	...	315	Burned out.
5	150	150	150	67½	...	...	...	517½	Burned out.
6	150	150	150	150	15	...	...	615	Burned out.
7	150	150	150	60	...	...	...	510	Burned out.
8	150	150	150	150	40	...	...	640	Burned out.
9	150	150	150	150	150	60	...	810	Burned out.
10	150	150	150	150	150	150	45	945	Cut smooth, burned out.
11	150	150	150	150	150	50	...	800	Burned out.
12	150	150	150	150	150	67½	...	817½	Burned out.
13	150	150	150	150	150	150	495	1395	Good, smooth cut.
14	150	150	150	150	150	150	135	1035	Good, smooth cut.

$$\text{Efficiency} = \frac{A \times S^3 + L\ (1{,}000)}{1{,}000}$$

where—

A = area of chip; S = average cutting speed at which the tool failed; L = average length of cut taken at speed S. The efficiency of each tool from this formula is then as follows:

TABLE IX.—*Relative Efficiency of the Different Brands.*

Tool No. 1	5·30	Tool No. 8	8·26
Tool No. 2	4·28	Tool No. 9	8·64
Tool No. 3	6·06	Tool No. 10	11·36
Tool No. 4	5·61	Tool No. 11	8·57
Tool No. 5	7·20	Tool No. 12	11·05
Tool No. 6	7·05	Tool No. 13	13·52
Tool No. 7	6·42	Tool No. 14	12·14

The efficiency curve (Fig. 2) is drawn from these results, and illustrates graphically the relation of each tool. In these series of tests special attention was attracted to the last four tools, Nos. 11, 12, 13, and 14, as these tools continued to cut

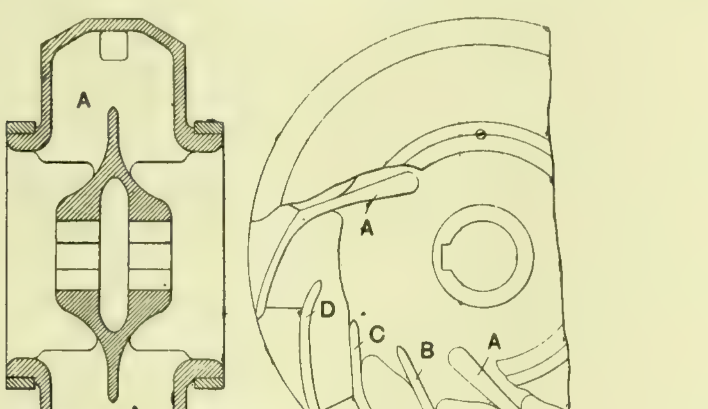
at the highest speeds. The extreme point attained a temperature that was distinctly "red in shaded shop light."

It must be borne in mind that these tools and all the tools tested, from which the results are given relative to the effect on the cutting qualities of various amounts of vanadium, were hardened under the conditions generally in use in shop practice. The method of hardening any tool steel exerts an enormous influence on the cutting qualities of that steel, as by heating to lower or higher temperatures or by varying the temperature or nature of the cooling bath, the character of the steel will without fail be altered. It will be found, however, in performing a series of tests that the tools giving the best results under one condition of hardening will invariably give the best results under all practical conditions of hardening.

Indications are that high-speed steel tools containing vanadium will run much longer between grindings in proportion to the quantity of vanadium they contain up to 1·25 per cent. Tools containing larger amounts than this have been used, but the added efficiency does not seem to warrant the extra expense of manufacture, excepting for special cases.—"The Iron Age."

IMPELLERS FOR CENTRIFUGAL PUMPS AND TURBINES.

THE Rees Roturbo Manufacturing Company, Ltd., of Wednesfield Road, Wolverhampton, have recently patented a design of impeller for centrifugal pumps and turbines, having for its object to secure as free a passage as possible for the water from the eye to the water space within the impeller without sacrifice of effective blade area or of efficiency in picking up the water. The arrangement is shown in the accompanying illustrations, of which Fig. 1 is a longitudinal section and Fig. 2 is an end elevation. There are three main blades A, and between each pair of main blades are three intermediate blades B, C, D, with their inner tips arranged in echelon. With this arrangement of blades cavitation losses at the inner tips of the blades, due to differences of velocity between the entering water and the blade tips, are, it is claimed, reduced to a minimum, and there is more efficient picking up of the water, both on this account and because there is no blanketing of one blade by another, or spilling of the water from one blade on to another. To keep frictional and cavitation losses a minimum, however the relative velocity of water and blade tips may vary, and also to reduce the liability of certain kinds of solid foreign bodies being caught up and entangled on the blade tips, the inner tips of the



IMPELLERS FOR CENTRIFUGAL PUMPS.

blades, and particularly of the main blades, are rounded, as shown in Fig. 2. Further, each of the intermediate blade tips is given that inclination appropriate to the relative velocity of the water and the tip for most efficiently picking up the water. These advantages are secured without sacrifice of effective blade area, since, although this area is reduced at the eye where the water pressure is small, it becomes increasingly larger towards the rim of the impeller commensurate with the increasing pressure of the water. Further, the settling chambers formed between the rear faces of the main blades and the tips of the intermediate blades both enable the water to be picked up very efficiently and facilitate the passage of suspended matter, rags, and other foreign bodies.

THE HEAT PATHS IN ELECTRICAL MACHINERY.*

BY HAROLD D. SYMONS AND MILES WALKER.

IF we wish to get the largest possible output from an electric generator or motor of given cost we must make a very close study of the possible methods of carrying away the heat which is produced in the iron and copper. The heat produced in any part (be it from I^2R loss or iron loss) has a definite path from the point of origin to the place where it is thrown out from the machine. Thus some of the I^2R losses in the armature conductors may have only to pass through a certain thickness of insulation to the air surrounding the coils, while the heat generated in the copper in the slots passes through the insulation to the iron, where it meets with the heat produced in the iron, and both together are conducted to the ventilating ducts and carried by the air to the exterior.

We can imagine lines of heat-flow drawn through the machine which follow everywhere the paths of the heat from the point of origin to the point of discharge. At some points there may be constrictions in the path which it is desirable to avoid, at others the heat stream flows easily without undue temperature gradient. Everywhere at right angles to the lines of heat-flow we can imagine isothermal surfaces constructed which enclose the points of highest temperature. If we are to even out these surfaces and lower the maximum temperatures, we must consider closely all the methods by which the heat is conveyed, whether it be by conduction, convection, or radiation.

The metals being good conductors, any heat produced in a mass of copper or iron distributes itself easily over the whole mass, but the insulating materials being poor heat conductors often cause excessive temperatures within the coils they enclose. It is desirable that the designer should have specific data as to the heat conductivity of every part of the machine in order that he may know what difference of temperature to expect between any two points in the heat path.

The authors have not been able to find any direct data on the heat conductivity of electric insulating materials mounted in the same way as one usually finds them in electrical machines. They therefore thought that it would be worth while to make measurements both of the specific conductivity of the commonly employed insulating materials and of the effect on the conductivity of introducing the air spaces and gaps such as are often unavoidable in electrical machines. Two classes of tests were made. First a test by means of laboratory apparatus on the specific heat conductivity of materials mounted in different ways. Secondly, tests made on electric generators under actual running conditions.

Table I. gives the heat conductivity of various insulating materials as measured. The first and second columns give the material and the state in which the material was tested. The third gives the thickness of the piece under test; the fourth the heat conductivity in gram calories of a centimetre cube of the material per degree C. difference of temperature between opposite faces of the cube. The fifth gives the conductivity expressed in watts per square centimetre, and the sixth column gives the watts per square inch passing through a 1in. cube of the material for 1° C. difference of temperature between opposite faces of the 1in. cube.

It was found that all the cellulose materials such as cotton, paper, &c., had a considerable temperature coefficient, the heat conductivity at a temperature of 100° being about 12 per cent. higher than at 30° C. The heat conductivity of mica was not found to change between 20° and 100° C.

Of all the fibrous materials commonly used in insulation the one having the highest thermal conductivity is empire cloth pressed into a solid mass free from air spaces. This is probably because the fibres of the empire cloth are completely filled with oxidised varnish, whereas many of the papers, even when closely compressed, contain air spaces. The difference in the conductivity obtained by winding the insulation on the copper cylinder very tightly and by winding it on loosely was very marked. It was found that micanite built up in the form of tubes containing about 11 per cent. of shellac has a very poor conductivity as compared with pure mica.

* Abstract of paper read before the Institution of Electrical Engineers.

Very often a field coil insulated on the inside with layers of insulating material does not fit tight upon the pole, so that a short air space exists between the insulation and the iron of the pole. It is interesting to enquire how far this air space hinders the passage of heat. A number of experiments were made, in which air spaces of different thicknesses were made between the copper tube in the testing apparatus and the insulating tube. These spaces were made by winding twine of different thicknesses in a wide spiral round the tube, and then winding the insulating material above the spiral. The thickness of the twine gave approximately the size of the air space. It is to be expected that a very narrow air space will have a greater thermal resistance per centimetre of thickness than a wider air space, and as the space is widened out we come at last to a constant resistance (for 1 sq. cm. area of surface), which is the reciprocal of the cooling constant ($h = 0{\cdot}0011$) for surfaces exposed to still air. The values obtained by our experiments do not agree very well with one another, as will be seen from Fig. 5, in which they are plotted.

For wide air spaces the resistance will depend on whether the space is vertical or horizontal, and if vertical it will depend on the number of horizontal baffles. In our case the air spaces were vertical and the pieces of twine which would have acted as baffles were spaced about ½in. apart.

Let us now see how this curve can be employed in practice. Suppose that we have a field coil which is insulated on the inside next the pole with treated fuller board of a thickness of 0·2 cm. From Table I. we find the thermal conductivity of this material (in watts per square centimetre, &c.) is 0·0014. The thermal resistance of 1 sq. cm. is therefore 0·2 ÷

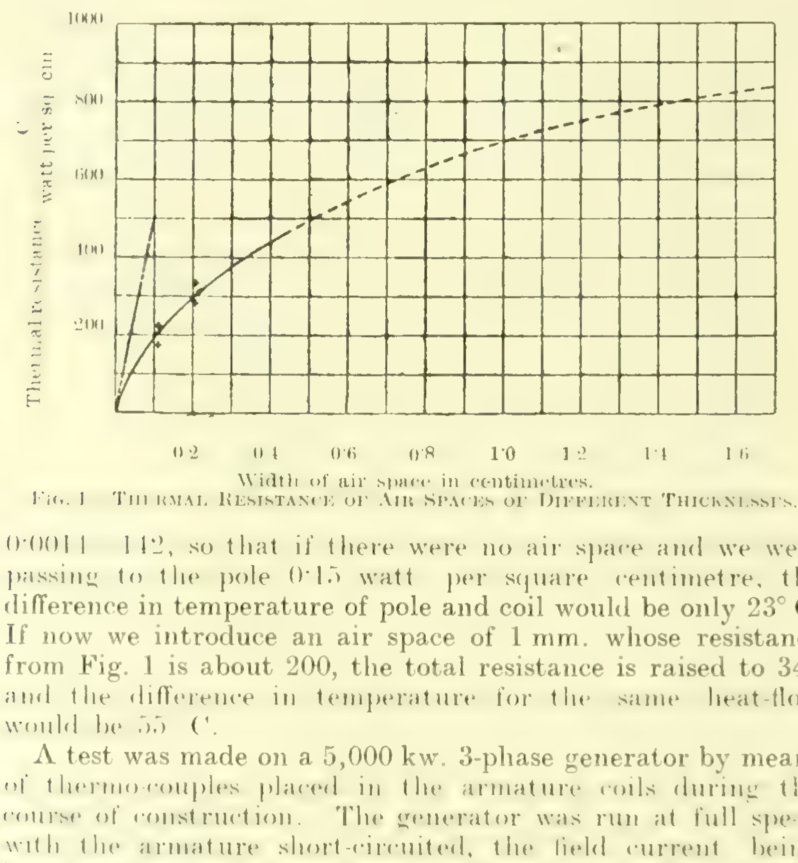


FIG. 5.—THERMAL RESISTANCE OF AIR SPACES OF DIFFERENT THICKNESSES.

0·0014 = 142, so that if there were no air space and we were passing to the pole 0·15 watt per square centimetre, the difference in temperature of pole and coil would be only 23° C. If now we introduce an air space of 1 mm. whose resistance from Fig. 5 is about 200, the total resistance is raised to 342 and the difference in temperature for the same heat-flow would be 55° C.

A test was made on a 5,000 kw. 3-phase generator by means of thermo-couples placed in the armature coils during the course of construction. The generator was run at full speed with the armature short-circuited, the field current being increased until the armature current was 328 amperes. The run was continued until the temperatures of all parts were constant. The temperature of the air admitted to the machine was 23° C., and the temperature of the copper inside the slot was 39° C., of the iron surrounding the slot 18·4°, of the outside of the coil 21·6°, and of the copper in part of a coil projecting 6in. from the iron 38°.

The total thickness of insulation amounted to 0·177in. The various insulating materials were then present in the following proportions:—Empire cloth, 0·07; mica, 0·03; varnish and air, 0·02; paper, 0·017; tape, 0·04. The heat conductivity of the insulation is easily calculated from the above figures. The total loss in the copper conductors per foot run of coil was 27·2 watts. In calculating this, allowance has been made for the rise in temperature of the copper due to the eddy currents produced in the conductors. The difference of temperature between the copper and iron is 20·6° C. The mean perimeter is 6·8in., so that the total area of insulation per foot run is 82 sq. in. With 27·2 watts per foot run this gives just over 3 sq. in. per watt. The specific conductivity for heat of the insulation works out at 0·00112 watts per centimetre cube per degree. This conductivity is considerably lower than the figure (0·002) found from tests on empire cloth and mica wound on a copper cylinder with the fewest possible air spaces, as can be easily understood.

With coils of rectangular section wrapped with empire cloth and mica, or paper and mica, in the ordinary method, one may expect to have a heat conductivity not higher than 0·00112 watts per cubic centimetre per degree. This figure is useful in enabling us to calculate the difference of temperature between the copper conductors in a slot and the surrounding iron, and checks very well with other results found in practice—for instance, on the armature of a direct-current generator whose conductors were insulated with manilla paper and mica to a thickness of 0·16 c.m. The temperature rise after a full-load run under conditions which made the square inches per watt 0·9 were as follows: Internal copper, 41°; iron, 22°. If we use the figure 0·00112 watt per cubic centimetre per degree, we would obtain a temperature rise of copper above iron of 20°.

It sometimes happens that the copper conductors on an armature or field magnet are grouped together so closely that very little air can circulate between them, and the total cooling surface of the group is too small to dissipate the heat generated in it. In this case one relies mainly for cooling upon the conduction of heat along the conductors to parts of the coils where the cooling conditions are better. A good illustration of this case is offered by the end windings of a 2-pole field magnet for a turbo-generator.

It is necessary sometimes to calculate what the temperature gradient will be, and what the maximum temperature rise will be in the centre of the group. The problem is somewhat complicated by the fact that the resistance of copper changes with temperature, and one ought to take account of this change of resistance because it makes the watts lost increase according to a compound interest law. Moreover, in most cases that arise in practice, part of the heat is radiated from the surface of the coils, and part is conducted along them. The following formula has been derived by the authors:—

$$T_x = T_{max.} \cos(4{\cdot}43 \times 10^{-5} \cdot I \times x),$$

where

I is the current density in amperes per square centimetre,
x is the distance from the hottest point in centimetres,
T_x is the absolute temperature at any point x,
$T_{max.}$ the absolute temperature at the hottest point.

An example will make this clearer. Suppose that we have a hot-bed of conductors so bulky that we can assume that the centre conductor parts with no heat laterally. All heat generated in it passes by conduction to points 20 cm. away from the centre, which we will suppose are maintained at 40° C. Each conductor is 0·1 sq. in. section, and carries a current of 250 amperes. What is the temperature of the hottest point?

$$I = 388 \text{ amperes per square centimetre.}$$
$$T_x = (40 + 273) = 313.$$
$$313 = T_{max.} \cos(4{\cdot}43 \times 10^{-5} \times 388 \times 20).$$
$$313 = T_{max.} \cos 0{\cdot}343 = 0{\cdot}941\ T_{max.}$$
$$T_{max.} = 332.$$

332 − 273 = 59° C. is the temperature of the hottest point.

Now consider the case where part of the heat generated is radiated from the surface of the group of conductors, and part is conducted to the ends. The temperature rise of the hottest point will be lower than if no heat were lost laterally.

There are three main cases occurring in electrical machinery in which it is necessary to calculate the rate of convection of heat from a solid surface to the surrounding air. (1) We have the case of an armature or field magnet of approximately cylindrical shape revolving within the stationary part of the machine. (Cooling coefficient denoted by h_r.) (2) We have the case of a field coil against which a draught of air is blowing. (Cooling coefficient denoted by h_f.) (3) We have the case of the iron surface of a ventilating duct, through which the air is passing at a certain velocity. (Cooling coefficient denoted by h_d.)

The laws of cooling of the solid surface are different in the three cases. The first case (the cooling of the revolving cylinder) is very complicated.

For ordinary direct-current armatures surrounded by ordinary field magnets, with normal air gaps, and with no more interchange of air than is naturally produced by the rotation of the armature, the formula given by Kapp—

$$t^\circ = \frac{550}{\frac{O}{W}\left(1 + 0\cdot1\ v\right)}$$

gives good practical results. Here O is the area of the cylindrical surface, W the watts to be dissipated, v the peripheral velocity in metres per second, and t° the ° C. rise above the surrounding air. Other writers give different values of the numerator 550, and change the value of the coefficient of v. Others change the index of the power of v.

For an ordinary armature surrounded by its field magnet the coefficient 0·1 seems to be about right. For the numerator the figure 550 seems to be rather high for iron-clad armatures. The figure 333 given by Dr. Ott seems to give good results for turbo-generators with forced ventilation.

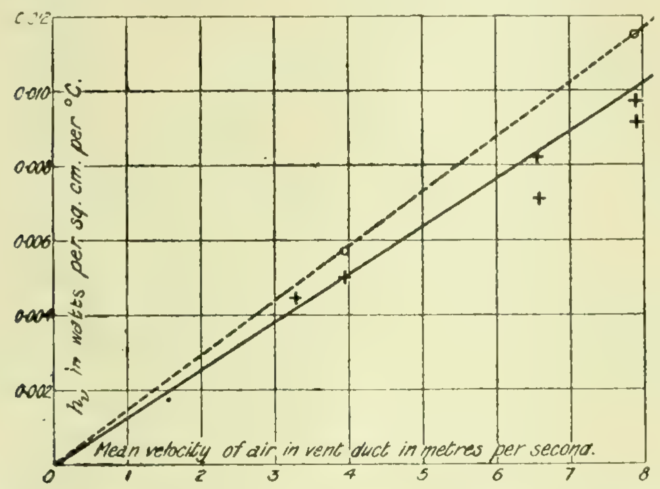


FIG. 2.—RELATION BETWEEN h_v, THE WATTS PER SQ. CM. PER °C. (DIFFERENCE IN TEMPERATURE BETWEEN IRON AND AIR), AND THE VELOCITY OF AIR IN THE VENTILATING DUCT.

In the case of field coils, an increase in the velocity of the current of air not only increases the intimacy of contact between the air and the surface of the coil, but at the same time increases the quantity of air passing the coil in a given time. We therefore have the index of the power of v greater than for the case of a revolving cylinder, the air surrounding which is not necessarily changed at a rate proportional to v.

In cases 1 and 2 there is a cooling of the surface by radiation, apart altogether from the passage of air; the formulæ should therefore give a value to h when v equals 0. In case 3, where two sides of a ventilating duct face one another, there is no dissipation of heat unless the air moves through the duct, and the rate of cooling is approximately proportional to v.

For the purpose of determining the relation between the cooling coefficient h_d, in case 2, and the velocity of the draught blowing on the sides of the coil, a number of experiments were made. In the case of cotton-covered wire the law is approximately—

$$h_d = 0\cdot0011\ (1 + 0\cdot54\ v^2).$$

In our experiments the draught did not exceed 700ft. per minute, or 3·5 metres per second. It is possible that at higher velocities the law may change, but the velocities investigated cover those generally obtaining in electrical machines.

The third case, the cooling of the sides of a ventilating duct, was investigated in some experiments on a turbo-generator. In case 3 we know that h_v must be zero when no air passes along the duct, and so far as our experiments go, h_v seems to be almost proportional to v. The dotted line (Fig. 2) with the two circles on was obtained by keeping all the conditions constant except that the velocity of the air was changed from 3·95 metres per second to 7·9 metres per second. The other points shown by crosses are from other experiments, and calculated for other parts of the machine. Probably the black line may be taken to give the law of h_v for the ventilating ducts for a turbo-generator.

In predetermining the temperature rise of a wire-wound coil, we must first find the temperature of the external and internal surfaces of the coil. These will be the temperatures at which the coil can dissipate to the surrounding medium all the heat generated within it. In the next place we must find the rise of temperature of the hottest part above the external surface by taking into account the heat conductivity of the layers of insulated wire and the watts per cubic centimetre generated within the coil.

Where the coil is entirely air-cooled, some rough estimate should be made of the mean velocities of air passing over the external surface and along the ventilating ducts, and from these the specific cooling constants can be arrived at from Fig. 3.

Where the coil is a fairly tight fit on the pole, we should take account of the thickness and nature of the insulation and calculate the number of watts which will be conducted to the pole for a given temperature difference in the manner indicated in the example given in conjunction with Fig. 1. The rate at which the heat will be conducted along the pole is sometimes of importance. For this purpose it is useful to remember that a temperature gradient of 1° C. per centimetre in wrought iron causes heat to flow at the rate of 0·7 watt per square centimetre. Account must also be taken of the means that are available for dissipating the heat from the pole itself.

By taking account of these matters and knowing the total watts lost in any particular coil, it is not difficult to apportion the loss between the outside, the inside, and the ends of the coil, and come to a fairly accurate estimate of the temperature which the outside surfaces must attain to get rid of the heat.

The next question that arises is: How much higher is the temperature inside the coil? A great deal of valuable data on the heating of shunt coils is given by Mr. E. M. Rayner in his "Report on Temperature Experiments at the National Physical Laboratory." A study of the curves and figures given will show that the distribution of temperature inside a wire-wound coil follows definite laws. The problem is somewhat analogous to the case already considered, where the heat is conducted along copper conductors and the law of distribution of temperature takes the same general form—

$$T_x = T_{max.} \cos p_1\, x,$$

where $T_{max.}$ is the temperature of the hottest point measured from the absolute zero, and T_x is the temperature of any point distant x centimetres from the hottest point along a line drawn in the direction of the flow of heat at right angles to the cooling surface. The value of $p_1\, x$ in practice is such that $\cos p_1\, x$ never assumes negative values.

After we have provided sufficiently well for the conduction of the heat through the insulation either to the air or to the iron surrounding it, the next question is how to provide

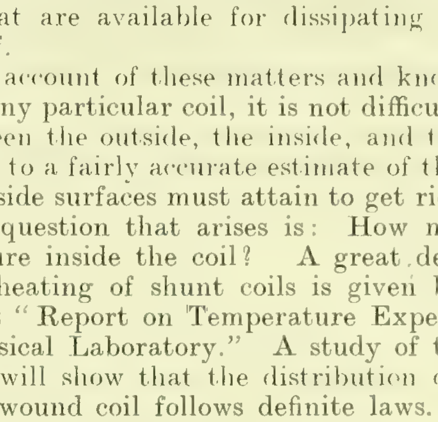


FIG. 3.—RELATION BETWEEN h_d, THE WATTS PER SQ. CM. PER °C., AND VELOCITY OF AIR WHEN AIR BLOWS UPON A CYLINDRICAL COIL.

sufficient cooling surface so that the heat may be communicated to the air and carried away by it. There are really two matters involved; one is the provision of sufficient air to carry away the heat produced, and the other is the provision of cooling surface exposed in such a way as to heat up the air which passes through the machine. We know that 1 cub. ft. of air per second (60 cub. ft. of air per minute), if raised in temperature 27° C., will carry away 1 kw. As a good deal of air sometimes passes through a machine without being raised much in temperature, it is usual to allow 100 cub. ft. of air per minute for each kilowatt loss.

In the open type of machine where the paths for the air are not very definitely prescribed, and where the quantity of air passing is usually unknown, only the very roughest empirical rules can be used for determining the temperature rise. Where, however, definite paths for the air are provided

in the machine, and where the quantity of air passing is known, the cooling effectiveness of the surfaces can be approximately calculated.

In the cooling of large machines, such as turbo-generators, there are two general methods of providing paths for the air. According to one method, the air is passed through axial holes both in the rotor and in the stator, and it is the internal surface of these axial holes which mainly constitutes the surface exposed. Sometimes the air is passed from both sides of the machine towards the middle, and in other cases the air is passed from one end of the machine to the other. According to the second method, the air is passed through a spider or through axial holes in the rotor, and thrown out through radial ducts in the rotor to radial ducts in the stator.

The first method has been commended on account of the fact that the iron punchings, whose conduction is better along the laminations than across the laminations, can convey the heat more easily to the air than where the ducts are of the radial type parallel to the plane of lamination. Another advantage of axial ducts is that they provide a more bountiful supply of air to the centre of the machine than is possible in a long machine. The object of the experiments was to determine exactly how the air received its heat as it passed through a turbo-generator and to determine the value of h_v (the watts per square centimetre per degree C. difference of temperature between surface and air). At the same time it was sought to determine how far the cooling of the iron was hindered by the poorer conductivity of the punchings across the laminæ than along the laminæ.

As the value of h_v is dependent upon the v, and as it is the velocity of the air in intimate contact with the surface that is of chief importance, we may gather that for a given quantity of air passed through the machine narrow ducts will be more effective than wide holes. The ducts, however, must not be too narrow or they will be liable to be stopped up by the accumulation of dirt. Holes if too wide allow the air to pass without coming in close contact with the iron. It has been found that ventilating ducts from 0·3in. to 0·4in. wide having smooth iron walls will keep clean for a great number of years if the velocity of air passing through them is sufficiently great. A velocity of from 5 to 10 metres per second is sufficient to prevent the accumulation of dust in the absence of oil spray. If any oil is allowed to enter with the air the accumulation of dirt will be facilitated. It has been found that round axial ventilating holes of 2in. or 3in. diam. whose walls are formed from the rough punchings accumulate the dirt very rapidly; this is particularly so with the holes in rotors, where the centrifugal force can press particles of dust together on the internal surface of the hole furthest from the centre.

In cases where one cannot get rid of all the heat from the cylindrical surface of the armature and where it is therefore necessary to provide further cooling surface, the radial ventilating duct is very effective. It enables an exceedingly large surface to be provided without unduly increasing the cost of the machine. The difficulty of getting a sufficient quantity of air through a very long machine with a small air gap can be met by providing certain channels in the frame from which the air is forced inwards down the ducts to the air gap and the rotor. Staggered with these channels are others which receive the air thrown outwards from the intervening sectors.

Tests were carried out on a totally-enclosed turbo-generator of 1,875 k.v.a. capacity, ventilated by means of fans at each end. The amount of air passed through the machine per minute was measured in two different ways: (1) An anemometer was used to find the mean velocity of air at the exit in feet per minute, and this multiplied by the area of the exit in square feet gave roughly the cubic feet per minute. (2) The total rise in temperature of the air in passing through the machine was measured, and from the known losses causing the heating the flow of air could be calculated. The first method was not as accurate as the second. It gave on the average an air velocity from 5 to 7 per cent. too high. We have therefore adopted the figures given by the second method. These are probably right within 5 per cent. The total losses going to warm up the air were: Windage 22·8 kw., excitation 8·5 kw., iron loss 43·5 kw.; total 74·8 kw.

The air entered the machine at an average temperature of 21·7° C., and was expelled at an average temperature of 53·2° C., giving a temperature rise of 31·5° C. The heated air did not represent the whole of the heat produced. The cast-iron frame presented a cooling surface of 10,900 sq. in. and had a mean temperature over the air of 28° C., so that it would radiate in almost still air about 2·44 kw. The cast-iron blocks upon which the frame rested would carry away not more than 1·5 kw. Let us say that 4 kw. was lost by the frame. This is such a small fraction of the whole that we need not estimate it very accurately. Then we have 70·8 kw. carried away by the air.

The temperature of the air in the various ventilating ducts and in the air gap was measured by a pair of thermo-couples, mounted on a long wooden rod, which could be moved about in the ducts while the machine was running. In the end bell the temperature had risen 9·8° C. and 10·2° C. respectively. The mean temperature rise of the air entering the ducts was 20·5° C., representing 46 kw.

The windage amounted to 22·8 kw. and the I^2R in the field to 8·5, so that we have 14·7 kw. in addition which must have been supplied by the iron loss, and communicated to the air mainly on the cylindrical face of the armature. A small amount—probably about 3 kw.—would be supplied to the air from the end plates of the armature. Deducting this, we have about 11·7 kw. conveyed to the air by the cylindrical face of the armature. As the air passes along the vent ducts the temperature rises, the mean being about 10·2 rise, representing 23 kw. Air passes into the annular space in the frame and picks up a little more heat from the punchings, giving a total temperature rise of 31·5°. The temperature rise of the iron was, on the whole, from 10·5° to 8·5° above that of the air passing through the ducts.

These experiments show that h (the watts per square centimetre of cooling surface per degree C. difference of temperature between surface and air) is almost exactly proportional to the velocity of the air, and is given by the equation $h = 0·00145\ v$, where v is the velocity of the air in the ventilation duct in metres per second.

The heat conductivity across the laminations was found to be 0·0174 watt per square centimetre per degree C. per centimetre, or 0·0042 calories per second per square centimetre per degree C. per centimetre, the thickness of iron being 0·041 cm. and that of paper 0·0033 cm.

The loss per cubic centimetre of iron was 0·055 watt, the machine being run at 30 per cent. above its normal field excitation. A more usual figure for 50 cycles would be 0·045 watt per cubic centimetre; for a packet 4·5 cm. thick the excess of temperature would be 6·5° C. and the mean temperature of the iron above the surface only 4·5° C. It is seen that unless the packets are made much thicker than is usual in practice, the temperature rise in the centre due to the poor heat conductivity across the laminations is not of very great importance.

We see, then, that in arranging for the cooling of large electrical machines the following matters must be taken into account:

Sufficient air must be provided to carry away the heat generated. If 100 cub. ft. of air per minute is provided for each kilowatt loss it will in general be sufficient. If the conductivity for heating of all parts is sufficiently good and the air is so distributed that none of it receives a temperature rise greater than 32° C., it may be that 60 cub. ft. of air per minute would be sufficient to keep the machine below 45° C. rise.

Sufficient cooling surface must be provided to communicate the heat to the air.

For ventilating ducts we may take the formula—

$$h_v = 0·0014\ v.$$

Where h_v is the watts per square centimetre of cooling surface per degree C. the difference of temperature between surface and air and v is the mean velocity of the air in the duct and metres per second.

For the cooling of the surface of rotors and the internal cylindrical face of stators we may take the formula

$$= \frac{333 \quad \text{watts per square cm.}}{(1 + 0·1\ r)}$$

To find the difference of temperature between an armature coil and the surrounding iron one can adopt the method given earlier, using the constants for the heat conductivity

of the insulated material given in Table I., and allowing for air spaces whose resistance is given.

To find the temperature rise of the surface of wire-wound coils upon which the air is blowing with a velocity of v metres per second we may take the formula

$$h_a = 0{\cdot}0011\ (1 + 0{\cdot}54\ v^2).$$

TABLE I.

Material.	How Mounted.	Thickness of Material Tested.	Thermal Conductivity. Per Square Centimetre per ° C. of Difference of Temperature per Centimetre Length of Path. In Calories per Sec.	In Watts.	Per Square Inch per ° C. of Difference of Temperature per Inch Length of Path. In Watts.
		Centimetres.			
Varnished cloth (Empire cloth)	16 turns, each 0·0175 cm. thick, very tightly wrapped	0·285	0·000604	0·00249	0·00634
Presspahn, untreated ...	2 pieces each, ·016 cm. (Bacon's method)	0·320	0·000410	0·00170	0·00420
Rope paper, untreated ...	24 turns, 0·014 cm. thick, tightly wound	0·350	0·000278	0·00115	0·00292
Rope paper and oil... ...	24 turns, 0·014 cm. thick, tightly wound	0·350	0·000341	0·00142	0·00371
Rope paper, treated with sterling varnish	Successive turns, 0·019 cm. thick, tightly wrapped ...	0·280	0·000405	0·00170	0·00420
Fullerboard, Varnished ...	Successive turns, 0·028 cm. thick, tightly wound ...	0·410	0·000339	0·00140	0·00350
Empire cloth and mica	Alternate turns of Empire cloth, 0·018 cm. thick, and mica, 0·075 cm. thick, tightly wound ...	0·310	0·000500	0·00209	0·00530
Empire cloth, mica, and tape ...	As in Fig. 7, containing air spaces ...	0·450	0·000270	0·00112	0·00285
Pure mica	3 pieces, each about 0·13 cm. thick, tested by Bacon's method...	0·401	0·000870	0·00360	0·00915
Built-up mica	Micanite tube containing 19 per cent. shellac	0·330	0·000246	0·00103	0·00260
Built-up mica	Micanite tube containing 11 per cent. shellac	0·360	0·000293	0·00120	0·00310
Linen tape, treated ...	Treated in insulating varnish and baked	0·390	0·000350	0·00146	0·00370

Junior Institution of Engineers.—Meetings will be held on Friday, the 10th inst., at 8 p.m., at the Institution of Electrical Engineers, Victoria Embankment, when a paper on "Notes on Telephone Exchange Equipment" will be read by Mr. Alex. J. Gayes; on Friday, the 17th inst., at 8 p.m., at 39, Victoria Street, Westminster, paper by Mr. G. C. Allingham on "Storage Battery Engineering"; and on Friday, the 24th inst., at 8 p.m., at 39, Victoria Street, Westminster, paper by Mr. S. H. Hole on "Brewery Plant."

Mining Institute of Scotland.—The annual meeting of the Mining Institute of Scotland was held on April 13th at Glasgow. Mr. James Hamilton, Glasgow, was elected president, and afterwards presided over the meeting. In the course of the meeting a ballot was taken in connection with the election of vice-presidents and members of council. The following are the successful candidates: Vice-presidents: Messrs. D. M. Mowat, John Gemmell, Douglas Jackson, William Walker, James B. Sneddon, and Wallace Thorneycroft. Councillors: Messrs. John Paul, Wm. Smith, George Gibb, Henry Rowan, Wm. Telfer, Daniel Burns, Robert Muir, James A. Clarke, Charles Latham, Sam. Mavor, Peter Milligan, Dugald Baird, Alexander Anderson, Wm. Clark, J. W. Gregory, Thomas J. Jamieson, Wm. Caldwell, and Mark Brand.

LARGE HYDRAULIC TURBINES.

PARTICULARS are given by Mr. Arnold Pfau, consulting engineer of the Allis-Chalmers Company, Milwaukee, in the current issue of "Engineering News" of the hydraulic turbines designed for use at the White River hydro electric station of the Pacific Coast Power Company, Seattle, which it is claimed are the most powerful yet constructed. Each turbine was designed to develop 18,000 b.h.p., at 360 revs. per minute, under 440ft. effective head. Each is capable of developing 20,400 b.h.p., with a maximum head of 480ft., and at the same speed. All parts of the turbine are designed to withstand the maximum pressure of 480ft. head, and the runaway speed of the rotors under this head brings no undue stresses. These turbines now carry 20,800 h.p. in service under the lower normal head, and this gives them the greatest capacity of any in the world. They are of an inward-flow reaction type, commonly called the "high-head Francis," and a spiral-case double-discharge arrangement was adopted. The operating water enters the spiral casing from below, and passes around this and out through the speed ring; immediately upon entering the runners it is divided along two paths with separate quarter turns and steel-plate draught tubes. The spiral casing is of cast steel, made to withstand a test pressure of 385lbs. per square inch. This casing is split in a horizontal plane through the centre line of the shaft. Fig. 2 shows that

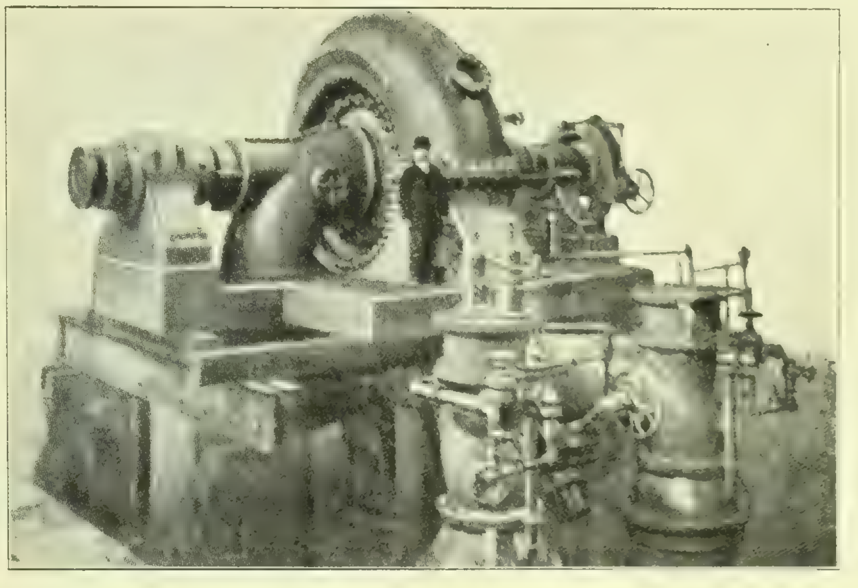


FIG. 1. 18,000 H.P. FRANCIS TURBINE.

opposite the inlet-pipe connection is an outlet branch for connecting the relief-valve pressure regulators.

High velocities are allowable in spiral cases under high head, but all obstructions to free water passage have to be avoided, and all friction contacts have to be kept outside of the casing for ready inspection and easy lubrication; in this case, therefore, the so-called "outside" gate rigging was adopted. The guide-vane pivots, on the side opposite the generator, carry levers which are connected to a shifting ring by individual links and steel pins. This ring moves in bronze ways bolted to the speed-ring flange. The shifting ring is provided with two lugs for the pins of the governor connecting rods, as may be seen from Figs. 1 and 2. Each rod is operated by a bell crank, and these are rigidly inter connected by a horizontal rod underneath the shaft and directly connected to the main control lever and piston, as shown in Fig. 2. The maximum force produced by the governor oil pressure upon the regulating piston is 50,000lbs., and all connections, including the shifting ring, are made strong enough to withstand this pressure.

If the guide-vane pivots were directly connected to the shifting ring, and any foreign matter should locate between two guide vanes to prevent closing them, then the governor would concentrate full force upon these two guide vanes and their pivots and levers, which would be damaged unless of dimensions that would seriously interfere with the proper design of the guide vane body, and increase the friction of the whole gate rigging. Therefore, the stems and levers are proportioned to resist only the forces of normal operation; the

connecting links between shifting ring and guide-vane levers have been made to break at predetermined overload. The guide vanes tend to close to a no-load normal-speed opening, so that two broken links will not materially affect the runner speed. The levers are easily removed, and the two links may be exchanged without shutting down.

The runner is a solid steel casting, machined all over. It is bolted to a flange of the shaft, and machined cover rings form a smooth guide for the discharge from the runner passages to the quarter turns. The shaft rests in two ball-and-socket bearings. It has a diameter of 16in. in the bearing at the generator end, and this is increased to 32½in. at the centre flange. The outer bearing serves as a thrust and steady bearing, with three collars forged with the shaft. Both bearings have babbitt-lined shells and oiling rings dipping into large reservoirs in the pedestals. The shaft packing boxes are of interest, for, with a diameter of 16½in. at the quarter turns, the use of hemp is prohibited. A water-seal box has been used, operating automatically either at over pressure in the quarter turn or under vacuum. Discs on the shaft revolve in chambers connected to either circulating-water lines or drain-pipes from the draught tubes.

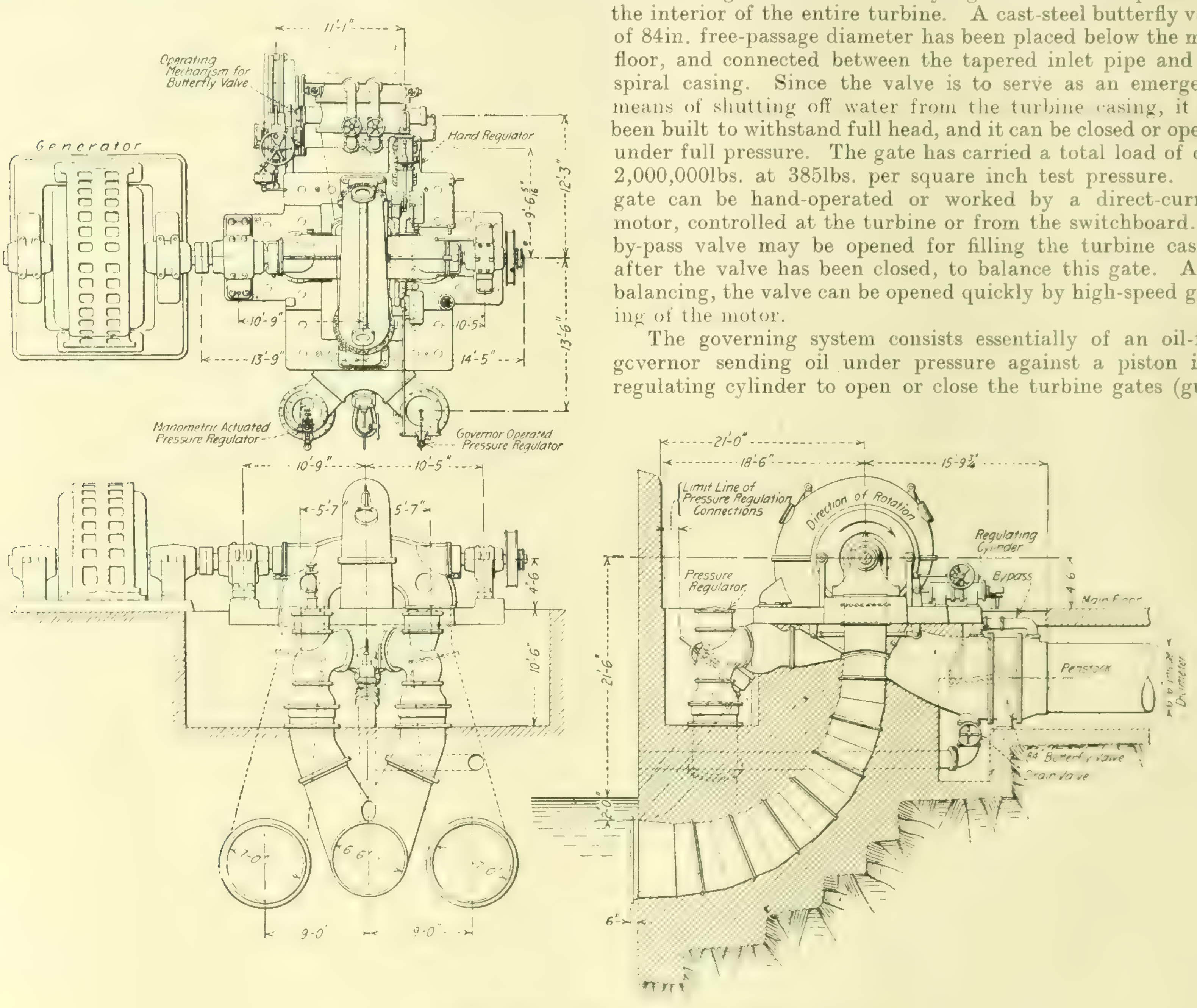


Fig. 2. Plan and Elevations of 18,000 h.p. Francis Turbine Installation

Balancing in normal operation is relatively easily accomplished here with double-discharge runners. The speed-gate covers also form pockets between the covers and the runner walls, so that the mechanical bearing has to support only the unbalanced pressure across the quarter turn opening in case one side of the discharge is blocked. The base plate of the turbine forms a top for the draught tube, which is bolted on and concreted into the foundation to form a tapered elbow of long curvature.

The turbine shaft carries a friction brake pulley, the hand operated grips for which are mounted on an extension of the foundation base plate. This brake is designed to bring the rotor from full speed to a dead stop in five minutes, with the speed-gates closed and the spiral casing under full pressure. The brake is water cooled.

Each turbine has its own independent pipe line, running from the forebay, where are located motor-operated gate valves, so that gate valves for each turbine are not needed in the power house. However, for a quick closing of the water supply in case of accident it was found desirable to have some means of shutting off water from the turbines quickly. For such a purpose a butterfly valve is satisfactory, provided it can be designed to be sufficiently tight to enable inspection of the interior of the entire turbine. A cast-steel butterfly valve of 84in. free-passage diameter has been placed below the main floor, and connected between the tapered inlet pipe and the spiral casing. Since the valve is to serve as an emergency means of shutting off water from the turbine casing, it has been built to withstand full head, and it can be closed or opened under full pressure. The gate has carried a total load of over 2,000,000lbs. at 385lbs. per square inch test pressure. The gate can be hand-operated or worked by a direct-current motor, controlled at the turbine or from the switchboard. A by-pass valve may be opened for filling the turbine casing, after the valve has been closed, to balance this gate. After balancing, the valve can be opened quickly by high-speed gearing of the motor.

The governing system consists essentially of an oil-feed governor sending oil under pressure against a piston in a regulating cylinder to open or close the turbine gates (guide vanes). It is of the type with the familiar fly-ball lift of a floating lever carrying the regulating valve stem compensating relay and a motor attachment for switchboard control. The governor regulating valve is double-acting and hydraulically balanced, so that practically no energy is required to raise or lower the valve stem. The fly balls are extremely sensitive, but still release considerable energy, so that the smallest speed variation will move the control valve. A speed variation of one-fifth of 1 per cent. is sufficient to cause a motion of the turbine gates. The regulating valve is returned to its middle position after each movement of the compensating relay acting on the other end of the floating lever. The desired maximum speed difference between friction load and full load can be set for any point between 0 and 4 per cent. The former, however, is not permissible with alternating current generators running in parallel with each other, as the lack of speed variation would cause a hunting of the load between the interconnected generators. To limit the maximum gate opening of turbines when regulated automatically, the governor

control-valve stem is prevented from dropping below a certain fixed but adjustable position.

The gate-regulating cylinder is mounted horizontally on the main base plate with a bracket under the cylinder and the other under the crosshead guide. The piston rod projects through front and rear heads, so that equal oil displacements are secured, which allows of a simple by-passing of the oil when the hand regulator is used. The piston-rod extension, through the rear (away from wheel) cover, carries a gate-opening indicator. The other extension goes to a crosshead in guides which receive the thrust of the connecting rod between crosshead and first gate lever at end positions. For inspection or repair of oil piston or governor without shutting down the whole unit, a hand screw is placed above the cylinder and connected with the first gate lever, so that it can be conveniently thrown in or out of connection.

To protect the pipe line and to assist the governor, serious surges in the water column must be prevented. Inertia in the water column has been overcome in three ways at this plant: (1) There is a compressed-air cushion in chambers outside the power-house connected to each penstock; (2) two 30in. relief valves are connected to each turbine casing, one of these being opened by the governor to by-pass water when the speed gates are closed, and closing thereafter gradually at a predetermined adjustable rate; (3) breaking plates which are provided to give way in case of failure of either of the other devices. Both relief valves consist of a main valve and an operating mechanism. The main valve is identical in both cases. A Y-pipe is connected to the bottom of the spiral casing below the generator floor, the branches of the Y leading to the relief valve. The neck of the Y is also connected to a hand-operated gate valve (normally open), which is closed at its lower end by the breaking plate between valve body and discharge pipe. The discharge from the two relief valves unite in a steel-plate elbow to economise space between draught tubes.

The body of each relief valve consists of an elbow which, at its lower joint, holds a circular bronze-bushed ring, against which is pressed a flared disc on a stem connected to a piston in a bronze-bushed cylinder above and extending through guides below. The shape of the disc valve and discharge ring is such that when the disc is lowered the discharge tends to spray, effectively reducing impact.

Water pressure on the disc tends to open the valve, but it is counteracted by pressure below the control piston. Adjustment of this pressure for motion of the disc is secured by a regulating valve which receives its operating water from the main pipe line through a pair of duplicate cylindrical screens. Main-line pressure can be directly thrown below the main piston, so that the relief valve may be held closed while the regulating valve is removed for repair or opened up for inspection.

The arrangement of these operating devices on the relief valves may be seen from Fig. 3. On the governor-actuated valve, a horizontal shaft is held in bearings cast integral with the cylinder cover. One end of this shaft carries a lever, which is connected to a reach rod from a gate-shifting bell crank. On the centre of the same shaft is a forked lever, carrying an oil dashpot on pivots. This dashpot contains a piston, the stem of which is connected to the outer end of a floating lever. The opposite end of this lever receives its motion directly from the disc valve, while the middle part of the lever is connected to the regulating-valve stem. The oil dashpot has an adjustable by-pass. When the turbine gates are closing slowly, due to a gradual reduction of the load, the dashpot cylinder is lifted slowly and the oil in the dashpot is merely by-passed; the floating lever is not moved. If, however, the gate motion of the turbine is quick, due to a sudden reduction of load, the oil is not by-passed quickly enough and the floating lever and the regulating valve are lifted. The pressure below the operating piston is thereby reduced and the relief opens. However, this movement of the disc has lowered the other end of the floating lever, so that the regulating valve is brought back toward its closed position and the relief disc is held balanced. Due to the slow by-passing of the oil in the dashpot, the piston therein moves slowly downward, closing the regulating valve and causing a corresponding closing of the relief. This closing time is determined by the amount of oil by-passed in the dashpot, and is adjusted individually for each unit, according to the condition in its pipe line; the main consideration in adjustment is not to close the relief valve so quickly that a secondary pressure rise is caused in the pipe line.

From the foregoing it is obvious that, if the by-pass is completely closed and if the relief valve has a discharge capacity equal to that of the turbine, the governor attachment allows this valve to serve as a water-wasting by-pass with which the velocity in the pipe line is held practically constant, no matter whether the turbine discharges its full amount of water or whether the speed gates are closed and the relief is wide open. Simple regulation of the amount of oil by-passed enables a change from water-wasting to water-saving operation, even during operation of the turbine, and this has been found valuable in plants where oscillations may be set up through wave interference, under severe pipe-line and load changes—troubles which are effectively subdued by a temporary wasting of water to maintain a constant velocity. With very long pipe lines or very high velocities, the pressure regulator must be operated as a water-wasting by-pass; but when the turbine speed gates are closed the disc valve will be wide open, and it may become dangerous to close the head gates: a hand wheel has been put on top of the dashpot-piston rod to allow a preliminary gradual closing of the relief valve. If the hand wheel is left at $\frac{1}{4}$, $\frac{1}{2}$, or $\frac{3}{4}$ full travel, then the by-pass will be closed at $\frac{3}{4}$, $\frac{1}{2}$, or $\frac{1}{4}$ opening of the turbine gate. This is desirable whenever the maximum load of the turbine expected for certain periods of service is less than full, and where it is desired not to waste the full amount of water.

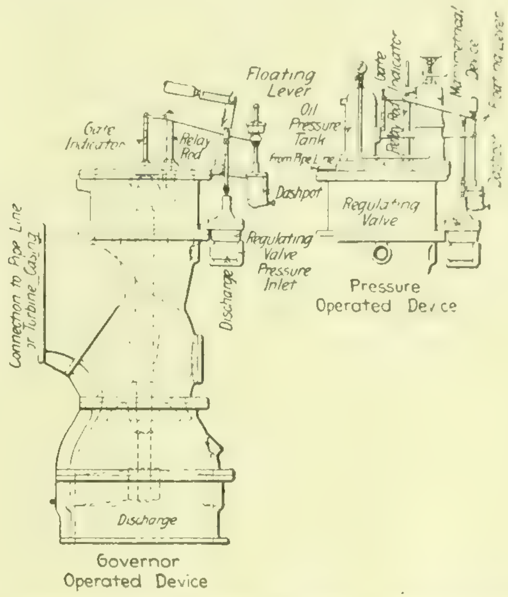


FIG. 3.—PRESSURE REGULATORS OF 18,000 H.P. FRANCIS TURBINE.

It is seen that the governor-operated relief valve controls pressure in accordance with the gate motion of the turbine to which it is connected, but any disturbance of pipe-line pressure, caused independently of speed-gate motion, is not controlled by this device, and such disturbances are taken care of in the second relief valve. Experience has shown, however, that the pressure-operated relief valve cannot function as correctly as the governor-actuated, and it is therefore advisable to set the former to open only under such pressure rise as might endanger the pipe line; and at any rate it must not close quickly to cause a secondary rise and re-opening. Incorrect operation of relief valves has often interfered with the governor action and even led to destruction of a whole plant.

The pressure-actuated control used here comprises a cylinder and piston under pipe-line pressure and balanced by compression of a strong spring. The piston rod goes to the centre of a floating lever, the outer end of which moves, through a dashpot, the regulating valve. The inner end is connected to the relief-disc stem. Pressure rise causes an upward motion of piston and regulating valve, which drops the relief disc. Motion of the latter restores the regulating valve to mid-position and holds the disc balanced. The dashpot between floating lever and control valve allows a gradual closing of the relief valve similar to the governor-actuated device described already. To prevent silt from interfering with the sensitive-

ness of this control, the water pressure is not directly admitted to the manometric cylinder, but it is carried into a pressure tank filled with oil, which is led against the control piston.

As this plant will take the principal load fluctuations of the company's whole power system, it is necessary to provide a larger supply of oil under pressure for the governors. Three rotary pumps have been installed, each with a normal capacity of 20 gallons per minute against a pressure of 400lbs. per square inch. Two are directly coupled to 65 h.p. induction motors, and the third is coupled to such a motor on one end and to a small impulse water wheel on the other. The pump is a two-stage gear type. Space was available in the power-house basement for pumps, pressure tanks, and receivers, and these are assembled in a compartment below the generator floor. All pipes to and from the governors and equalising pressure tanks are carried directly below the main floor, through basements, which are easily accessible. The three pumps are set with the driving shafts in line. The pumps in the centre are built symmetrical, and the auxiliary impulse wheel between them can be coupled to either of the two shafts, as needed.

There are two independent steel receiver tanks partly set in the basement floor, so that oil is received by gravity. The inflowing oil has liberal contact with air and discharges over a screen to clear and cool itself. The receivers are inter-connected, and each is of ample capacity, so that one is capable of carrying oil for the whole system, while the other is emptied for cleaning. On a concrete pier between the two receivers are two main pressure tanks of riveted steel plate, tested to 600lbs. per square inch; each has a capacity of about 250 galls. An adjustable safety valve is attached to each, and discharges directly into the receiver. This safety valve can be tripped from the outside, so that an operator can see if it is "free and sensitive."

The piping between the pressure and receiving tanks is arranged so that any combination of connections can be established to quickly cut out any part of the system. The pipes are of 4½in. annealed seamless steel tubing, with bends of at least 12in. radius. All connections are made with flanged joints. The ends of the oil-supply pipe carry two auxiliary pressure tanks to prevent serious drop of pressure due to the acceleration of the oil in the long line between pressure tank and governor. The two main and the two auxiliary pressure tanks are inter-connected by an air pipe and also connected to a small air compressor located in the basement.

Two exciter units have been provided. The wheels of each are of the impulse type with hand needle regulation and governor-operated deflecting hood. Each wheel is designed to develop 500 b.h.p. under 420ft. effective head, with a normal speed of 400 revs. per minute. A runaway speed of 800 revs. per minute has been designed to be withstood. Since close speed regulation is accomplished exclusively by the deflecting hood (operated by governor), and since economy of water was not essential with these small units as with the main unit, a simple hand adjustment of the needle was considered sufficient. The hood proper consists of a forked lever hinged below the nozzle and carrying a removable knife-edged blade. This blade cuts into the jet from underneath in such a manner that the entrance edge is parallel to the axis of the jet. By this arrangement the upper undeflected portion of the jet impinges on the buckets undisturbed, while the lower portion is deflected into the bottom of the wheel pit against a removable steel plate baffle lining. The shaft of the deflecting hood projects through the wheel housing above the floor, so that it can be directly connected to the governor.

The exciter governor is a self-contained oil type not connected to the central pressure system, but furnishing its own oil pressure. This scheme enables independent operation of the exciter unit, so that the field current can be held constant on the generators irrespective of the condition of the governors of the main units. The hydraulic equipment described above was furnished by the Allis-Chalmers Company, of Milwaukee. The first main unit and all exciters and apparatus were ready for commercial operation on October 31st last. The equipment was turned over to the operating staff on March 1st, and is now regulating the whole power system exclusively. Periodic load variations of about 3,500 kw. are taken care of by the governors. In order to keep the speed regulation within close limits the governors, of course, have to adjust more than the load fluctuations of the system and it will be noticed that these governors change the gate opening of the turbines between 0·3 and 0·4 of the full amount during such variations. The pressure regulators prevent any rise in penstock pressure exceeding 9lbs. above normal when full load is suddenly thrown off, and the air chambers now connected with the pipe lines furnish that amount of water which cannot quickly be received by acceleration when load is thrown on. The effect of these air chambers is extremely beneficial. The machines now carry a full-gate load of 15,500 kw. (20,800 h.p.) each under 440ft. effective head; and from a dead short-circuit to no load, which requires a full-gate motion by the governor from wide open to closed, the maximum speed does not exceed 395 revs. per minute, or about 10 per cent. above normal.

DYNAMOS FOR MOTOR ROAD VEHICLE LIGHTING.*

BY J. D. MORGAN.

Introduction. During the past few years serious attention has been directed to the development of electric lighting systems for motor road vehicles, as it is widely recognised that something superior to the ordinary methods of oil and acetylene lighting is urgently needed. The problem presented is a threefold one, being concerned with the form and arrangement of the optical parts of the lamp, the disposition of the filaments in the lamp bulbs, and the generation of current. In the present paper the object is to discuss briefly the subject of current generation, giving a short account of the most notable work which has recently been done, and of tests made by the author on machines of representative types. By common consent the use of a battery alone for providing current is unsuitable, and a dynamo is essential. The construction of a suitable dynamo presents peculiar difficulties, and the crux of the lighting problem is connected mainly with the dynamo. The principal conditions to be complied with are: (*a*) That the dynamo must be capable of maintaining a practically constant voltage over a wide range of speed variation and under different loads; and (*b*) if voltage variations are unavoidable, the amount of variation must not seriously affect

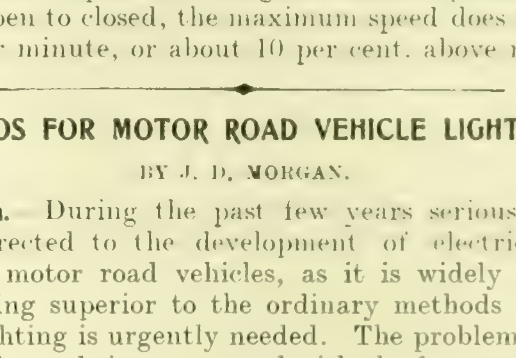


FIG. 1.

the brightness of the lamps. Regarding the first condition, it is usual to arrange for the dynamo to supply current at the normal voltage when the vehicle is moving at the rate of from 10 to 15 miles per hour, and to maintain the voltage constant, or as nearly constant as possible, at all superior speeds, which may reach 50 to 60 miles per hour. When the vehicle is at rest or travelling below 10 miles per hour the current is supplied entirely or for the greater part by a battery arranged in parallel with the dynamo circuit. Regarding the second condition, it is known that in metal filament lamps a small increase above the normal voltage is attended by a relatively large increase of brightness. An experiment on a 4-volt lamp showed that an increase of the voltage from four to five caused the candle-power to increase from 3·6 to 8. Variation of brightness with variation of voltage differs considerably in different lamps, but in all the samples tried the variation was found to be large. In an experiment by Mr. G. A. Shakespeare at the Birmingham University an increase of from 8 to 8·8 volts in an 8-volt lamp caused an increase of candle-power from 14½ to 26. Many proposals and attempts have been

* Abstract of paper read before the Institution of Electrical Engineers Birmingham Local Section, January [illegible], 1912.

made to construct dynamos complying with the above conditions, but in the present paper only a few leading representative types which have actually been reduced to practice are considered.

In passing it may be well briefly to anticipate a familiar criticism that there is little or nothing new in the problem of the dynamo for motor road vehicle lighting, as it is strictly analogous to that of the dynamo for train lighting, upon which a large amount of valuable work has been done, and that what is suitable for the one is also suitable for the other. To some extent this is so, but the task before the manufacturer of motor vehicle dynamos presents peculiar obstacles in that simplicity, compactness, and reliability must be obtained in a much higher degree than is essential for train lighting where skilled supervision is constantly exercised.

Electrically-regulated Dynamos. — A method of regulation which forms the basis of several known types of electrically-regulated machines consists in the use of a separate counter-exciting dynamo adapted to diminish the excitation of the principal machine in such a manner that the field of the principal machine varies inversely as the speed. This device is obviously objectionable on account of the duplication involved. Several attempts have been made to construct machines in which a series-compensating winding is used, the idea being to diminish the strength of the field progressively by the current in such winding after the normal voltage has been

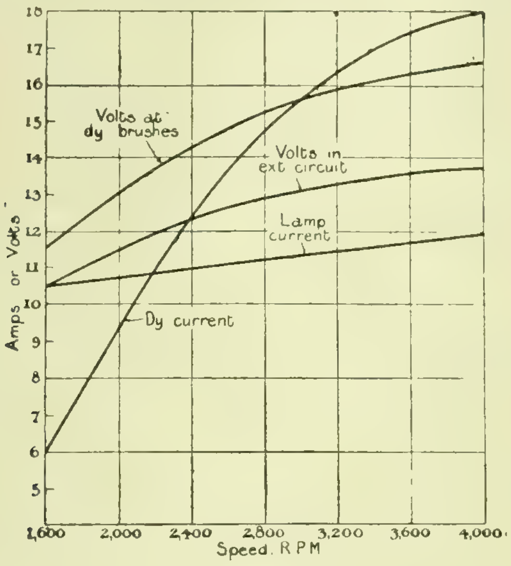


Fig. 2.

reached. Obviously a constant voltage cannot be obtained, but what is aimed at is to keep the voltage variation within practical limits over a given range of speed variation. A machine embodying this principle for road vehicle lighting is produced by Messrs. Bleriot, Ltd., and is illustrated diagrammatically in Fig. 1. The arrangement differs from the more familiar devices of this type in that the shunt winding *a* is connected across the external circuit, and the current leaving the armature passes through the series winding *b* before reaching the shunt winding. A centrifugal switch at *c* closes the external circuit when a certain speed is attained. Usually the arrangement is identical with that of an ordinary compound-wound dynamo, excepting that the series winding acts in opposition to the shunt winding. By the Bleriot method a much larger voltage variation can be produced at the brushes than is experienced in the external circuit, and the current through the shunt winding is subject to smaller fluctuations than it would be if connected across the brushes. Consequently a greater compensating effect can be obtained from the series winding than would otherwise be possible. A representative result, selected from a large number of tests made upon a Bleriot machine, is shown in Fig. 2. The machine was intended to supply lamps consuming about 12 amperes at 12 volts, but was designed to give out as much as 25 amperes. In the experiments the battery used was a set of six Fors cells of 50 ampere-hours capacity—a size commonly used in motor-car practice. The range of speed variation over which the machine appeared to be useful was not as large as might be desired. It will be observed that between the speeds of 1,600 to 4,000 revs. per minute the voltage rose from 10·5 to 13·75 and the current increased from 6 to 18. Over the same range of speed variation the voltage at the brushes rose from 11·5 to 16·75. The increasing difference between the two voltage curves illustrates clearly the usefulness of the arrangement of the windings in the Bleriot machine for regulation purposes. If the shunt winding had been connected across the brushes the two curves would probably have been nearly parallel, and a larger variation of voltage would have been experienced in the external circuit.

As a result of the test it may be urged that the performance of the Bleriot machine was not satisfactory. But it is possible that with a larger battery or a machine designed to give a smaller output at the same voltage better regulation

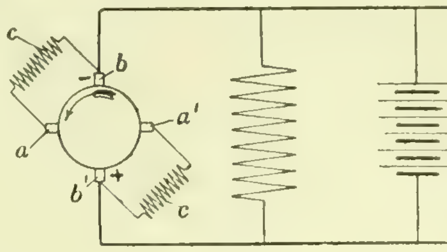


Fig. 3.

would have been obtained. When determining the output of machines of this type, makers generally appear to be faced by the difficulty that if the size of the machine is reduced there is a danger of excessive heating, whilst if liberal proportions are adopted the regulation is impaired.

A further result of the test was a demonstration of the fact that the regulation of the machine is dependent on the condition of the battery. At the higher speeds the current given out is much larger than that consumed by the lamps, and in consequence a heavy surplus is directed into the battery. With the battery run down superior regulation to that shown in the diagram was experienced, but when the battery approached the fully-charged condition the voltage in the external circuit increased without increase of speed. Thus, in one experiment the voltage in the external circuit increased from 15 to 20 without any alteration of speed, this being due apparently to change in the condition of the battery. Obviously, to get the best results the current given out should approximate more closely to that required by the lamps, and this observation applies generally to all types of machines. It is sometimes urged as an advantage that certain machines are capable of

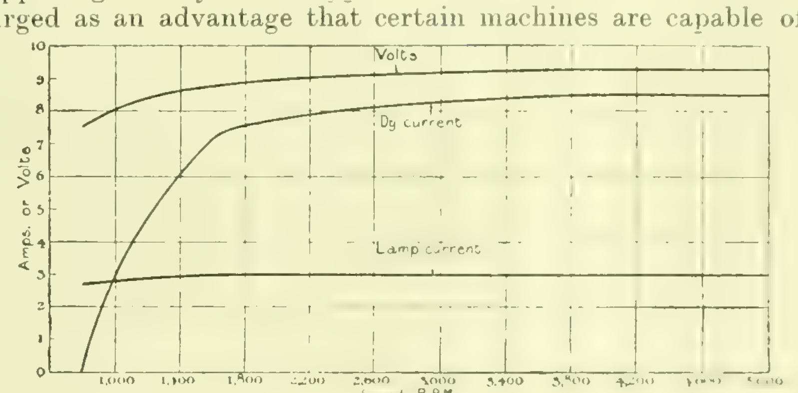


Fig. 4

giving current largely in excess of requirements. Apparently this is fallacious; it is a disadvantage rather than an advantage. The best results as regards steadiness of voltage are obtained when the maximum output does not exceed the consumption by more than about 2 or 3 amperes. With some batteries this figure may be increased, but in all cases a heavy charging current should be avoided.

From the foregoing account of the Bleriot machine it might be inferred that superior regulation could be obtained by separately exciting the field windings from a battery or other source of constant potential, or by using permanent magnets. The author believes that machines constructed with permanent magnets and a regulating series winding have been placed on the market for motor-car lighting, but he has not been able to obtain one. It would be rather surprising to find that they were serviceable, for the winding must exercise a demagnetising effect and in time render the magnets useless. Regarding the use of a separate exciting battery, this would obviously be objectionable on account of the extra battery required, and the additional attention necessary for keeping the battery in proper condition.

An exceedingly good and interesting machine of the inter-brush type is that of Messrs. Trier & Martin, which is illustrated diagrammatically in Fig. 3. The machine is of 2-pole shunt-wound construction, and is provided with a pair of intermediate brushes *a a'* placed midway between the ordinary main brushes *b b'*. The main and inter-brushes are connected together through resistances *c*. It will be observed that the arrangement differs from the more familiar Leitner arrangement in that the inter-brushes are connected to the main brushes instead of to the field windings. The makers describe the action of the machine in their patent specification as follows: "As *b* is the negative and b^1 the positive brush, the current in the resistance connecting the main brush b^1 with the auxiliary brush a^1 will, when the machine is running on open circuit, flow from b^1 to a^1 and, in the resistance connecting the other pair of brushes, will flow from *a* to *b*. The affect of these currents, which, of course, also flow in the armature coils between b^1 and a^1, and *a* and *b*, is to strengthen the main field. As the load increases an armature reaction is set up which displaces the axis of the field forward, and by so doing reduces the current in the resistances *c*, and consequently the magnetic field is also reduced. When the axis of the magnetic field is displaced by 45°, there will be no current at all between the main and auxiliary brushes, as they will then be at equal potentials. A further displacement of the magnetic field due to increasing load and speed will cause a current to flow again between the main and auxiliary brushes, but such current will now be in the reverse direction, and its effect will be to weaken the main field instead of to strengthen it. Thus the output of the dynamo becomes self-regulating."

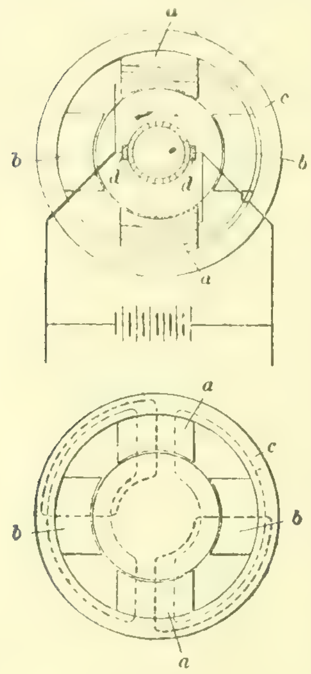


FIG. 5.

Regarding the performance of the machine, this is illustrated in Fig. 4. In the tests an 8-volt battery was used. The output rapidly rises until a speed of about 1,600 revs. per minute is reached. Above this speed the output rises very slowly and keeps within a practical limit. As with other self-regulating machines, a battery is essential, and the maximum voltage and current obtained depends to some extent on the condition of the battery. The variations with changes in lamp load are insignificant. In the experiment recorded, cutting out all the lamps caused an increase of the maximum voltage of ½ volt and a diminution of current of less than ½ ampere. With lamps consuming 4½ amperes the maximum current given by the machine was 8 amperes.

Another interesting machine is the Midgley-Vandervell, or C.A.V. machine. This is of the type with which electrical engineers have been familiarised by the Rosenburg machine, depending for its self-regulating property upon the short-circuiting of certain armature windings. The principle of the C.A.V. machine is illustrated in Fig. 5, where the upper view shows the connections and the lower one the magnetic system alone. Two opposite pairs of poles *a* and *b* are united by the body *c*. The poles *a* are provided with shunt windings, whilst the poles *b* are left unwound. Current is supplied to the external circuit by the armature windings under the poles *b* through brushes *d*, and the armature is wound in such a manner that the brushes also short-circuit armature coils lying in the neighbourhood of the leaving edges of the poles. The initial path of the magnetic flux is indicated diagrammatically by the thin dotted lines in the lower figure. When the current in the short-circuited coils reaches a certain value, the magnetism associated with them appears to break down the principal flux at the parts adjacent to those coils, and causes the flux to swing into opposite quadrants as indicated by the thick dotted lines in the figure. At this stage the machine becomes self-regulating, as the cross-magnetisation due to the armature coils under the poles *b* counteracts the principal flux, and so progressively weakens the field as the speed increases. This action proceeds to a limit beyond which under a given load the voltage and current are constant at all speeds.

The above explanation is based upon information contained in the inventors' patent specification, but whilst apparently satisfactory as a general guide to the action of the machine, it does not appear to be complete, for long before a marked change occurs in the disposition of the flux, current is supplied to the external circuit, which suggests that the two dispositions of flux shown in the figure exist concurrently at all speeds.

The behaviour of a machine in practice is shown by the diagram in Fig. 6, which is representative of a large number of tests with the machine coupled to a battery and lamps as in service conditions. It will be observed that when the maximum voltage is reached it remains remarkably steady. A drop is shown in current at the higher speeds. This is probably due to defective brush contacts. It will be observed that the maximum current directed into the battery was 1·2 amperes. With such a small charging current a practically uniform condition is maintained in the battery, and the latter is therefore not so likely to interfere with the regulation of the machine as when a machine is used the output of which is largely in excess of the demand. The lamps used in the test were two 12-volt headlights in parallel and three 4-volt side and tail lights in series. Using the headlights only the maximum volts increased from 13 to 13·5, and using the side and tail lights only, the maximum volts rose to 14.

When a battery is used such an increase of voltage is attended by a proportionately larger increase of current passing through and from the machine, and in consequence self-regulation can be obtained. This fact is of great importance, inasmuch as it makes the battery an indispensable part of the equipment.

Another interesting self-regulating system is that of Grob, shown in Fig. 7. The machine *a* is separately excited by a battery *b*, and the field windings *c* are connected between the positive poles of the battery and machine respectively. With increase of voltage across the brushes the difference of potential at the ends of the windings diminishes, and in consequence the strength of the field diminishes. This action rapidly proceeds to a limit above which the voltage and output of the machine under a given load remains fairly constant at all speeds. The system appears to be capable of giving good results, but it possesses the serious disadvantage that a battery of twice the normal size must be carried in order that one-half may be charged whilst the other half is in service. Further, the permanent or residual magnetism of the machine seems to prevent a perfectly steady voltage from being obtained.

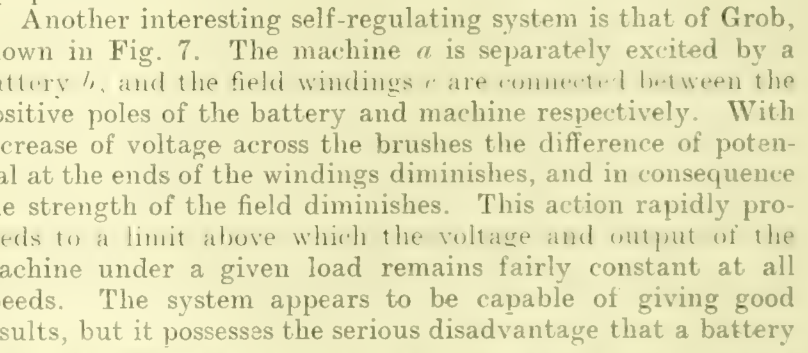


FIG. 6.

Mechanically Regulated Dynamos.—Mechanically regulated dynamos depend for their action upon some moving part. A number of different methods of mechanical regulation are known. Whilst only one or two are of any practical value for road vehicle service, a few of the more familiar methods are here mentioned as objects of interest. In one machine the armature is moved axially by a governor, so that the number of lines cut out by the armature winding varies practically inversely as the speed. In another machine the air

gap is widened or contracted, either by the use of governor-controlled hinged pole pieces, or by a conically-shaped armature which moves axially under the action of a governor between conically-shaped pole pieces. Sliding masses of iron for varying the flux through the pole pieces have also been proposed. The idea of shifting the brushes automatically seems to have been popular with inventors, and a machine embodying the equivalent idea of swinging the machine relatively to fixed brushes has been notified in the Press, if not actually put on the market. A very common method of regulation consists in the use of a field regulator actuated by a governor. This is undoubtedly a simple and practical procedure, having one or two possible advantages in its favour,

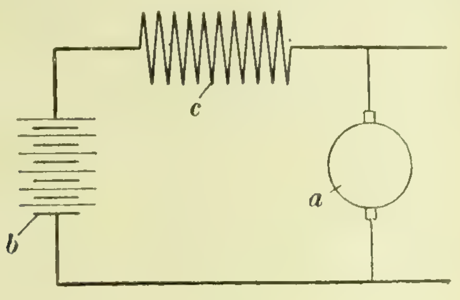


FIG. 7.

but the difficulty appears to reside in the production of a sufficiently simple regulator capable of withstanding the conditions experienced on the roads. Inventors working in this direction usually favour a combination of a governor and a switch arm, but obviously this is too complicated and not so good as other devices in which a governor is used for performing a different function. For example, the combination of a governor and a slipping clutch gives excellent results and is very simple. If a field regulator is to be successful, it must show advantages over the slipping clutch, and in consequence some means other than a governor appears to be required for its operation. For this purpose a fixed and moving coil system might be used in conjunction with an arrangement of windings whereby a change of current causes the switch arm to take up a new position. The difficulty lies in making such a device sufficiently sensitive without sacrificing durability and immunity from road shocks and vibrations. The electrical condition which a field regulator must comply with is very simple if the dynamo is worked well in the region of magnetic saturation, and is one which can readily be followed in an automatic regulator.

The most important of mechanical devices hitherto produced for regulation purposes are those depending upon a slipping drive. These are divisible into two classes, which are characterised respectively by constant torque and constant speed. Engineers have long been familiar with a notable instance of constant torque in the Stone machines, which employ a slipping belt. In view of the extensive use and excellent service of these for railway train lighting, it is natural to consider whether they are equally applicable to motor-car lighting. Apparently they are not. In the first place, it is generally expected that as soon as electric lighting on motor vehicles becomes extensively adopted, provision will be made by builders for direct connection of the dynamo to the engine, as for the magneto. This would at once make the use of a belt inconvenient, if not impracticable. In the second place, a constant torque device is wrong in principle for motor-car lighting. No doubt tolerably good results could be obtained, but development could never reach perfection on account of the inherent unsuitability of the device for this particular service. The problem before the designer is to keep the voltage at the lamps as constant as possible. Assuming that a constant torque mechanism is adjusted to slip under full load at a given speed, then if the load be reduced considerably the speed of the dynamo will at once increase, and this will result in increase of voltage, which, although it may be prevented by a suitably proportioned battery from becoming excessive, can never be avoided. In motor-car practice it is common to arrange the side and tail lights in series under the control of one switch, and the head lights—if two are used—in parallel under the control of another switch. To cut out either set of lamps causes a big difference in the lamp load, and is, in consequence, attended by an increase of speed in the dynamo and of brightness in the remaining lamps. It may be urged that variations at the lamps can be kept within practical limits, especially when a battery is used, but the point which it is here desired to emphasize is that the constant torque device must always be imperfect for motor-car service.

As regards constant speed devices, these usually consist of a governor-controlled clutch. An exceedingly good form is one constructed by Messrs. Joseph Lucas, Ltd. Fig. 8 shows a section of the clutch. A driving pulley *a* is arranged to run freely on the armature shaft *b*, and is shaped at one end to contain a number of free governor balls *c*. The latter are supported in slots in a plate *d* keyed to the armature shaft, and are arranged to bear against the inner surface of a clutch element *e*, which, whilst secured to the shaft, can slide thereon. The inner periphery of the pulley is shaped to correspond with the outer coned periphery of the part *e*, and between the two surfaces is inserted a thin ring of vulcanised fibre. Springs *f* serve to keep the clutch in action. At and below a certain speed the mechanism revolves as one piece, but above that speed the balls by their centrifugal action relieve the pressure due to the springs between the clutch surfaces and enable slipping to occur. There is no appreciable separation of the clutch surfaces when in action, but simply a variation of pressure. It will be observed that the balls are connected to the driven part and not the driving part of the mechanism.

As might be expected, a jerkiness of action is a common fault in slipping clutches at the critical speed owing to the difference between static and kinetic friction, and a drop in speed is often experienced at the instant when slipping begins; or, in other words, the clutch can continue to accelerate the speed of the armature beyond the maximum speed for which the clutch is adjusted, but as soon as slipping sets in the speed drops and remains tolerably constant at all superior speeds of the driving pulley. Messrs. Lucas have avoided this defect by arranging for ample lubrication of the clutch surfaces, so that they are always separated by a thin film of oil. By this provision the instant at which slipping occurs becomes practically imperceptible, and an extremely smooth action is obtained. Fig. 9 illustrates the results of a series of tests made on a Lucas dynamo fitted with a clutch of the type above described. It will be observed that the maximum output remained perfectly steady. With variation of load an increase of the maximum dynamo speed was obtained and a consequent increase of voltage. When supplying current—3·8 amperes—to two 12-volt head lights and three 4-volt side and tail lights the maximum voltage was 13. On cutting out

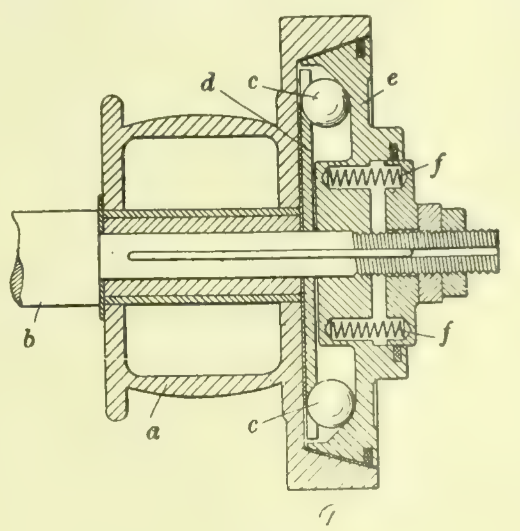


FIG. 8.

the side and tail lights the voltage increased to 13·6, whilst on cutting out the head lights—leaving the others in service—the voltage rose to 14. The variation is not serious, but it serves to show that in some degree the governor-controlled clutch possesses the same characteristic as the constant torque clutch. This difference must be observed, however, viz., that by increasing the sensitiveness the speed variation under varying loads can be made much smaller in the governor-controlled clutch than in the constant torque clutch. It is doubtful, however, whether anything is to be gained by

developing the mechanism beyond a certain point, seeing that, even with a perfect mechanism, it is practically impossible completely to avoid variations of voltage with variations of load, owing to conditions existing in the dynamo and battery. Such results as those obtained in the tests referred to are sufficiently good for practical purposes. As with other machines, the Lucas dynamo is arranged to work in conjunction with a battery, supplying into the latter about 2 amperes when the maximum output is reached. When the clutch is adjusted to suit the particular lamps and battery which it is required to supply, the cutting out of the battery involves a large—though restricted—increase of voltage in the lamp circuits. This is, however, not so serious as in the electrically-

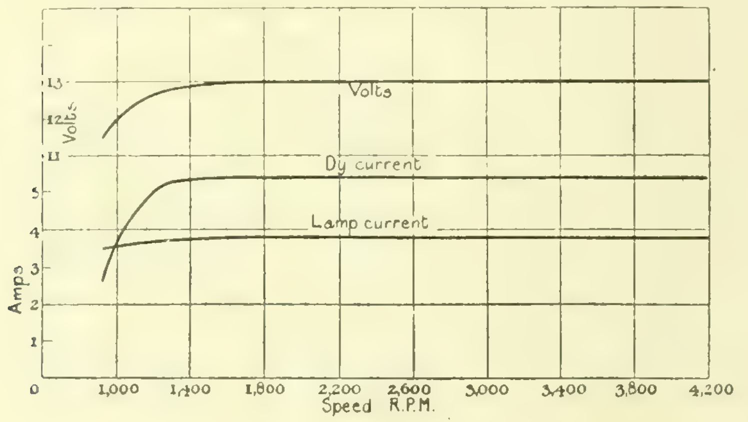


FIG. 9.

regulated systems described, and would not render it impossible to use the lights in the event of a mishap to the battery.

Much controversy is centred at present on the relative merits of the mechanically and the electrically regulated machines which are capable of complying with service conditions, and this is likely to increase, not because the machines of either system are predominantly superior to those of the other, but because the advantages of each are fairly evenly balanced. It is a significant fact, however, that in spite of the enormous amount of work which has been done in the development of electrical systems of regulation for train lighting, the mechanical systems of regulation appear to be the most extensively used.

CORRESPONDENCE.

The "Titanic" Disaster and Internal-combustion Engines.

To the Editor of "The Mechanical Engineer."

Sir,—The recent appalling disaster to the "Titanic" must impress everyone with the great difficulties under which those in charge of a ship work when passengers have to be transferred to the boats, and it is obvious that this difficulty is enormously increased if this transfer has to be made in darkness. In the case of the "Titanic" the special construction of the ship, with boilers in small groups in separate compartments, appears to have enabled the engines driving the dynamos to have continued at work long after the collision. In most ships such a collision would have almost immediately allowed water to rush into the boiler rooms and put out the fires, thus shutting down the engines and throwing the ship into darkness, which, undoubtedly, would have increased the loss of life. The White Star Company evidently realised this possibility when designing the "Titanic," but a further development by the same company in the same direction will perhaps interest your readers. We refer to an installation which a little while ago we installed on the new White Star liner "Megantic," on behalf of the White Star Company and Messrs Harland & Wolff, having for its object the continuance of the Marconi apparatus, and of a considerable portion of the lights, even after the whole of the steam machinery below has been stopped by an accident such as that mentioned above. In this scheme a 15 b.h.p. Mirrlees-Diesel oil engine, made by us and directly connected to a dynamo, is installed on an upper deck, and from the dynamo a separate circuit is taken round the ship and connected with lights fixed in the main passages, companion ways, saloons, &c. This circuit is also arranged to provide lights in the neighbourhood of the boats, in addition to being connected with the Marconi apparatus. From the above description it will be seen that in case of a serious disaster such as that on the "Titanic," a supply of electricity would be continued on board the ship and give light for the free movement of people about the ship, also for the launching of the boats, as well as giving current for the wireless telegraphy, right up to the last moment when the upper deck sinks below the sea. The installation on the "Megantic" is set to work daily as darkness approaches and continues until daylight, quite irrespective of the fact that the steam-driven electrical dynamos are working. This is done so as to avoid any rush or hurry to start up the plant in case of anything happening in the night. Of course, an independent plant of this kind could be driven by other forms of engines than the Diesel, but with steam or gas engines the space occupied would be greater and the handling of coal on an upper deck would cause considerable nuisance. Petrol or paraffin engines might be suitable for the work, but the oils they use would be quite unsafe on board a large ship, and in fact are prohibited by Board of Trade regulations. The oil used on our engine is cheap residual petroleum, *i.e.*, the heavy residue left from crude petroleum after all the light oils have been distilled off. We believe that the arrangement described is a life-saving appliance of the greatest value, as with ample light boats can be much more quickly and safely launched than in darkness or semi-darkness. Also the extended time during which the wireless telegraphy apparatus can be worked gives a greater chance of help being obtained. The fact that the White Star Line has been the first to try this scheme proves their desire to do everything possible to secure the safety of their passengers.—Yours faithfully,

MIRRLEES, BICKERTON, & DAY, LTD.,
(Chas. Day, Managing Director.)

April 26th, 1912.

INDUSTRIAL AND TRADE NOTES.

Floating Workshop for the Admiralty.—Messrs. Scott, Greenock, launched on Monday last for the British Admiralty the depot ship "Maidstone," the first vessel specially designed as a floating workshop for use with the submarine fleet in deep water. The vessel has appliances that will lift submarines out of the water, and is fitted with emergency gear and workshop tools for the speedy execution of repairs.

Capital Invested in German Industrial Enterprises.—According to the "Frankfurter Zeitung," the amount of fresh capital invested in industrial enterprises in Germany during the first quarter of 1912 amounted to 21½ millions sterling, as compared with nearly 16¾ millions in the corresponding period of 1911. The approximate amount invested in engineering was £3,200,000; electricity and gas undertakings, £2,175,000; and mining, foundries, &c., £1,925,000.

Barrow Steel Plate Mill Restarted.—After standing idle for a few years, the plate mill at Barrow Steel Works was re-started on Monday last. The department has been modernised, and will be capable of dealing with much larger ship-boiler plates than hitherto. The local demand for shipbuilding material was never so brisk, but all plates for some time have been obtained from outside the district—Scotland, South Wales, East Coast, &c. There is every prospect of a busy time in the iron and steel trades.

Geared Turbine Steamer.—The Isle of Man Steam Packet Company have just placed an order with Messrs. Cammell, Laird and Co., Birkenhead, for a turbine steamer, to be delivered by May 1st of next year. The vessel, which is intended for the mail and passenger service between the Isle of Man and the mainland, is to be about 300ft. in length by 43ft. in breadth, with a draught of 12ft. aft and 11ft. 6in. forward. Her guaranteed speed is to be 21 knots. The propelling machinery will consist of geared Parsons turbines.

Clyde Shipbuilding.—The Clyde shipbuilding returns for April show that 28 vessels of 56,115 tons were launched, as compared with 20 vessels of 52,205 tons in March, an increase of eight vessels and 3,910 tons. For the four months of the year the number of vessels floated is 81, of 191,455 tons. For the first four months of last year the tonnage put into the river totalled 163,51[illegible]. Though a fair amount of new work was booked in

March, it falls considerably short of the contracts reported in some recent months. The yards will be busy for a long time ahead, however, in fulfilment of contracts on hand.

Steelworkers and an Eight Hours Day.—For some time past an agitation has been in progress amongst the millmen at Consett in favour of eight-hour shifts. At a mass meeting of the men at the Consett works recently held, a resolution was carried to the effect that the present was an opportune time to arrange for an eight-hours working day amongst the iron and steel workers in the North of England. It is expected that similar gatherings will take place in other industrial centres in support of the movement.

Wages of Cleveland Ironstone Miners.— A meeting of Cleveland ironstone mineowners and the miners' representatives was held at Middlesbrough on Monday last, Sir Hugh Bell, Bart., presiding, to consider the wages to be paid for the ensuing three months. The men's representatives asked that an advance of 1¼ per cent. to be conceded. The owners said they could not entertain the request. There were legislative enactments shortly coming into force which would place additional heavy burdens on the cost of getting the ironstone, and, having regard to all the circumstances, the mineowners could not offer a fraction more than 1 per cent. Eventually it was agreed that the advance should be 1 per cent.

Oil-engined Coasting Vessels.—The first vessel of the fleet of oil-engined coasters which are being built for the Coasting Motor Shipping Company, of Glasgow, was launched on the 24th ult. at Kirkintilloch by Messrs. Peter M'Gregor & Sons. The fleet of boats when complete will consist of 18. The vessels, which will have oil engines of various types, are intended for the general cargo trade. The vessel launched is 67ft. in length, 18ft. 3in. in breadth, and 9ft. in depth, and has a cargo carrying capacity of 140 tons. The engine will be of the Bolinder type, and will be supplied by Messrs. Douglas Primrose & Co., Glasgow. The engine is designed to give a speed of 8 knots, and Scottish crude oil will be used as fuel.

American Motor-car Industry. — The exports of motor-cars from the United States in 1911 were valued at £4,327,332, as against £2,800,000 in 1910, whilst the imports of these articles into the United States show a tendency to decline, being of a value of £480,000 in 1911. The cars in use, both pleasure cars and motor wagons, are being more and more supplied by native industry. Imports from all foreign countries are decreasing, France having sent £200,000 worth and the United Kingdom, Germany and Italy about £60,000 each, in 1911, as against France, £600,000, Germany, £75,000, the United Kingdom, £65,000, and Italy, £57,000, in the fiscal year ended June 30th, 1906. Most of the cars exported go to British territories, Canada last year taking nearly £1,500,000 worth, or one-third of the entire export. The United Kingdom took £740,000 worth, and Australasia about £450,000 worth.

The Sending of Wireless Messages from Post-offices.— An important announcement was made in the House of Commons on Monday last by the Postmaster-General, in reply to a question asking whether the Post Office was prepared to arrange for the public use of the Marconi wireless system between this country and America. Mr. Samuel said: "On an application from the Marconi Company, I have made arrangements to accept from the public on and from May 1st, at all telegraph offices in the United Kingdom, telegrams addressed to places in Canada and the United States for transmission by the company's wireless Transatlantic service. The company have notified that the full rate for telegrams sent by their route to New York or to Montreal will be 8d. a word, the rate for cablegrams being 1s. a word, and that there will be a similar reduction in the full rates for telegrams for other parts of America. For deferred telegrams in plain language the rate to New York will be 4d. a word, the cablegram rate being 6d., with corresponding reductions for other places."

Effect of Minimum Wage on the Iron and Steel Trade.— At the annual meeting of the South Staffordshire Iron and Steel Institute, held on Saturday last at Dudley, Mr. William Simons, of the Shelton Ironworks, North Staffordshire, said that in regard to the iron and steel trades, manufacturers were in the happy position of having plenty to do for the next five or six months; in fact, he thought it was difficult to recall a previous period in recent years in which the demands were so large. But for the coal strike this year would have been a good one for those engaged in the iron and steel trades. The strike had interfered with manufacturers in their efforts to meet the competition of other countries, and he thought a permanent loss had been sustained by the concessions made to the miners' leaders. As the result of the minimum wage coal would be permanently dearer by anything from 6d. to 1s. per ton. At the modest figure of 6d. this would mean a loss to the rolling mills of the country of £150,000 per year, and the Insurance Bill would place upon manufacturers a further burden of about £25,000.

Large Stern Frames for the "Aquitania."—The large steel stern frames and rudder brackets, which have been cast at the Darlington Forge for the new Cunarder "Aquitania," were removed to Middlesbrough on the 28th ult. by special train, for shipment to Messrs. John Brown & Co.'s shipyard, Clydebank. These castings are understood to be the largest ever constructed in the annals of shipbuilding. The aggregate weight of the rudder, stern frame, and brackets closely approximate 220 tons. The stern frame and rudder alone in completed condition weighs 130 tons, whilst the main stern post (which was cast in one piece) weighs 50 tons, the after brackets 33 tons, the forward brackets 35 tons, and the rudder 70 tons. Although the stern frame was loaded upon a specially designed 51 ton trolley wagon, its dimensions were of such exceptional size as to largely exceed the British railway loading gauge, the "wing" of the frame overlapping the wagon side by 10ft. 10in., whilst the overhang on the abutment side was 5ft. 6in., the overhang being balanced by heavy steel ingots. The distance from the rail level to the top of the load was no less than 13ft. 6in. It was found quite impracticable to transport the castings by railway from Darlington to Glasgow, the only alternative being to convey the articles to Middlesbrough, to be there shipped by special steamer to Clydebank.

British Railways in 1911.—Some interesting figures relating to the railways of the United Kingdom are given in a Government return just issued. According to this, the total length of line open for traffic last year was 23,396, whilst the authorised capital of the various companies reached a total of £1,401,185,000, as compared with £1,399,313,480 in the previous year. Paid up capital amounted to £1,324,003,000, as compared with £1,318,515,417. Exclusive of season ticket-holders, the number of passengers conveyed in 1911 reached a total of 1,326,246,000, compared with 1,306,728,583 in the previous year. There was a total of 780,000 season ticket-holders, the number in 1910 being 752,663. The various railways conveyed a total quantity of minerals and general merchandise amounting to 523,556,000 tons, compared with 514,428,806 tons in 1910; whilst the number of miles travelled by trains reached a total of 428,581,000, compared with 423,221,538 in the previous year. The gross receipts from passenger traffic amounted to £53,933,000, the corresponding figures for 1910 being £52,758,489. There was received from goods traffic £63,273,000, compared with £61,478,643 in 1910, whilst the receipts accruing from steam boats, canals, harbours, docks, &c., reached a total of £10,010,000. The total gross receipts under all heads amounted to £127,216,000, as compared with £123,925,565 in the previous year. Working expenditure on all the railways is given at £78,566,000, leaving net receipts of £48,650,000, the corresponding figures for 1910 being £76,569,676 and £47,355,889.

Mineral Oil Industry of the Caucasus.— A report by his Majesty's Consul at Batoum states that the mineral oil industry still ranks first in magnitude amongst the industries of the Caucasus, and although the output of oil in the Baku district is far from showing signs of actual exhaustion, the quantity of oil now produced by the wells of that territory has much decreased. The deficiency in 1911, as compared with the production of 1910, is estimated at 239,400,000 gallons, a decrease of 11 per cent. Under the effects of the following conditions, viz., an ever-growing demand for mineral oil products for home consumption, short production, and the high level of prices for oil in Russia, a prevailing low tendency in prices abroad, a variety of combinations entered into between the leading petroleum dealers of Europe and the United Kingdom, combined with the operations of the two or three powerful groups which control the oil industry and trade of America and the Far and Near Easts, and the competition of Roumania, the Russian oil trade in 1911 ceased to exercise the great influence it at one time had on the markets of the world. Moreover, the State monopoly of transport, although the arrangements are of the best, seriously handicapped the trade owing to the costliness of the system. Consequently only a small proportion, viz., 179,830,559 gallons, of the petroleum products manufactured at Baku found their way to Batoum for oversea trade. Prices of mineral oil in the Caucasus were well maintained throughout 1911 at an average rate of about 6½d. per 36lbs. In fact, prices during the year were so high that in the districts along the Volga where crude oil has been for years used for fuel, owners of factories, in many cases, have reverted to coal for fuel purposes. Despite the improved situation as to prices, producers exhibited little inclination to engage in drilling new wells. The petroleum pipe line between Baku and Batoum was in use without interruption during the year; but, owing to the small quantities of kerosene that had to be conveyed to Batoum, was not worked to its full capacity. Only 132,750,000 gallons of kerosene were pumped through the line in 1911.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

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Machines for drilling and boring metals. Joshua Buckton & Co., and James. 5422.
Wheels and axles. Adamson. 8443.
Slide valve mechanism for multi cylinder internal combustion engines. De Jong. 8510.
Manufacture of hollow-rolled metal rods and bars. Bedford. 8551.
Steam generators. Robinson. 8559.
Moulding machines. Soc. Non. des Etablissements Ph. Bonvillain and E. Ronceray, Ronceray, & Bonvillain. 8818.
Safety suspending grip for mine cages. Longridge. 8833.
Carburetters for use with internal combustion engines. Johnson, Glaser, & Lloyd. 8926.
Grinding machine with automatic vertical adjustment of the table Kundig. 8939.
Fluid pressure motors. Oschatz. 9028.
Two-stroke cycle internal combustion engines. Sangster & Evans. 9056.
Internal-combustion engines. Barnett. 9074.
Rotary valves. Marks. 9106.
Axle boxes for railway and tramway rolling stock. Biernacki. 9140.
Mounting of patterns for moulding. Rix & Moore. 9862.
Variable gearing for motor-cars. Lamplough & Buckingham. 10347.
Fuel admission valves for internal combustion engines. Breuer. 10365.
Variable speed gearing. Horstmann. 10381.
Control of elastic fluid compressing plants. Kubler, Woollatt, and Fraser, and Chalmers, Ltd. 10940.
Couplings for railway vehicles. Thorn. 11136.
Lathes. Hulse & Co. 12137.
Heating or temperature regulating systems for buildings. Benham & Sons, Ltd., and Allensby. 12778.
Spanners. Eggleton. 12825.
Means for removing dust in coal mines. Rollin. 12902.
Machines for milling surfaces. Shanks. 13174.
Automatic safety grip for pit cages and lifts. Adams. 13427.
Rock drilling machines. Ferguson & Rule. 15152.
Condenser. Berg & Drake. 15428.
Striking gear for power transmitting belts. Boutall. 15460.
Steam generators. George Fletcher & Co., and Rudder. 15522.
Propeller. Habig. 15896.
Carburetters as used upon internal combustion engines. Downs. 15923.
Blade with successive outlet surfaces in different planes for screw fans. Turlur. 16146.
Apparatus for bending metal bars or rods. Anthony. 16455.
Pneumatic percussive tools. Pokorny and Wittekind Maschinenbau Akt.-Ges. 16909.
Fluid pressure clutches. Pauilhac. 18963.
Furnace grates. Johansen. 19383.
Production of high grade steel and slag rich in soluble phosphates Deutsch Luxemburgische Bergwerksund Hutten Akt. Ges. and Vogler. 19640.
Valves for steam engines. Bloxam. 20147.
Speed recording devices. Schulze. 21428.
Process and apparatus for regulating continuous air brakes. Dandy. 21893.
Valve mechanism for pneumatic apparatus. Dornenburg. 22940
Steam superheaters. English & Mills. 23236.
Epicyclic toothed gearing. Barker. 24140.
Rock drilling apparatus. Kubat. 24553.
Regenerative coke ovens. Gohmann. 25960.
Carburetting apparatus. Schmidt. 25998
Metal moulds for casting metals. Cothias. 27548
Means for consuming smoke in boiler furnaces Ogden 27763
Rotary internal combustion engines. Curtin & Stanfield. 28190
Superheaters. Schmidt'sche Heissdampf Ges 28607
Machines for cutting metal by smooth discs rotating at high speed Mars Werke Akt Ges. & Heynau 28972

1912.

Ore concentrators Mower & Williams 1739
Variable speed pulleys R Bourbeauz and H Devaux 5320
Mining machines. Jensen 6285.

ELECTRICAL, 1911.

Thermo electric gravity motors. Rouse. 7386.
Electrical time switches. Chiger. 8585.
Brushes for dynamos. Engisch. 8656.
Electrically-controlled grab-hoist gear. Brull. 8798.
Wireless telegraphy. Lodge & Robinson. 8806.
Electrical measuring instruments. Lake. 9000.
Arc lamps. Hecht & Dowdell. 9072.
Constant speed devices for driving dynamos. Van Celst. 11738.
Soldering of electric conductors. Egner. 11841.
Automatic regulators for dynamos. Hirst & Angold. 13477.
Regulation of electric generators driven at varying speeds. British Thomson Houston Company, and Young. 13650.
Automatic regulating mechanism applicable to electric generators. Grillet & Truchetet. 17419.
Inductive wireless telephone and telegraphic installations. Von Kramer. 17634.
Electric switches. Crabb, Perl, & Hutchinson. 18667.
Manufacture of electrical coils. Lake. 19116.
System of electric propulsion for vehicles. Lister. 19747.
Automatic electric circuit-breakers. Cuculic. 20161.
Electro magnetic reciprocating motors. Lake. 21806.
Electrically heated soldering irons. Evershed & Vignoles, Ltd., Evershed & Clark. 24933.
Electric ignition apparatus for internal combustion engines. Kettering. 28539.

1912.

Intercommunication telephone systems. Corwin. 3098.

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" Scotch	59/10½ "
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Mica (in original cases), small	6d. to 2/- per lb.
" " " medium	2/6 to 4/- "
" " " large	4/6 to 8/6 "
Quicksilver	£8/5/- per bottle.
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Tin plates	14/6 "
Zinc sheets (Silesian)	£29/-/- "
" (Stettin; Vieille Montagne)	£29/7/6 "

The Institute of Metals.— The third May lecture of the Institute of Metals will be delivered at the Institution of Mechanical Engineers, on May 10th, by Sir J. Alfred Ewing, K.C.B., F.R.S., the subject being "The Inner Structure of Simple Metals." The chair will be taken by Prof. W. Gowland, F.R.S. Those desirous of being present should apply for tickets to Mr. G. Shaw Scott, M.Sc., Secretary, Institute of Metals, Caxton House, Westminster, S.W.

Mine Shaft Signalling.—Considerable attention is now being paid to the question of shaft signalling, and improved methods are being introduced with a view to avoiding accidents. The subject came up for consideration at the meeting of the Notts and Derbyshire branch of the Association of Mining Electrical Engineers, held at Nottingham on Saturday last, when Mr. F. Turner gave a demonstration of a luminous mine shaft signalling apparatus, which has been designed to provide a safe and ready means of communication of orders from the different levels of the mine to the engine-house by the addition of visual indications of the orders to the bell signals usually employed. It is claimed that this apparatus provides the only electrical system which gives confirmatory visual signals and at the same time complies fully with the Home Office regulations.

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Alloys Research.

PRESSURE on our space has prevented us till now from expressing to the Institution of Mechanical Engineers the appreciation which we think will be felt by all thoughtful members of the profession of the tenth report to the Alloys Research Committee prepared by Messrs. Rosenham and Archbutt on the alloys of aluminium and zinc, which was recently presented and a summary of which has already appeared in our columns. Complaints are heard from time to time that investigations undertaken by the institution are characterised by unreasonable slowness, but we fear that many of those who utter these have a very imperfect conception of the amount of labour involved in research work when results have to be put forward authoritatively and with a due sense of responsibility. Some idea of what it means is afforded by the report just issued. The properties of no alloy can be deduced from a simple knowledge of the physical characteristics of its ingredients, and the variations in proportions even of a simple binary alloy necessary for thorough research furnish at the outset innumerable samples for investigation, and when it is considered that each of these must be submitted to a wide variety of tests to determine its physical properties, such as tensile strength, compressive strength, its ability to resist torsion, alternate stress, or impact, the extent to which material may be hot worked, or cold worked, and the effect of such treatment, the resistance of the alloy to corrosion, its liability to "ageing," &c., it is evident that enormous labour and considerable time is needed to arrive at reliable results, which after this must be passed under careful review before those of practical value can be gleaned. The outstanding feature of the present investigation, viz., the important effect produced upon aluminium-zinc alloys by hot work, is not one that could have been foreseen or anticipated. The same may also be said of another fact brought to light, viz., that two atoms of aluminium and three of zinc (Al_2Zn_3) form a definite compound whose exist

ence had not previously been established. The influence of hot treatment and temperature generally on the physical properties of these alloys is probably the feature of greatest interest to engineers. For instance, the alloy containing 25 per cent. of zinc (20 per cent. is given as the proportion most generally useful), which gave a tensile strength at ordinary temperature of 27·5 tons per square inch, falls off to 18·5 tons at the temperature of boiling water. Another curious feature is that while exceedingly brittle to shock and incapable of being forged much above 400° C. (752° Fah.), the alloy nevertheless exhibits an exceptional amount of ductility in the testing machine and makes it possible to roll into bars alloys which are brittle in the cast state, though accurate control of the rolling temperature is essential. The highest ultimate tenacity was found with this alloy, and oddly, with bars of one diameter, viz., 1¼in. Alloys richer in zinc present the unusual property that cold drawing from 1¼in. to $\frac{15}{16}$in. raises both yield point and elastic limit, while at the same time lowering elongation and actually reducing ultimate stress. We mention these as showing the unexpected facts brought to light in the course of the research and which nothing but painstaking examination of wide ranges of tests could possibly reveal. Torsion tests also displayed results somewhat at variance with those with which the engineer is familiar in the simple metals. The strength, for example, while it increased considerably with the increase of the zinc content, yet did not increase as rapidly as the tensile strength. Another interesting behaviour of these alloys worth noting, from a structural point of view, is, after 15 per cent. of zinc the resistance to alternate bending impact tests is strictly proportional to the zinc content, a result somewhat at variance with the commonly accepted belief that these alloys are weak under shock. Not the least important of their properties is the facility with which all containing from 10 per cent. to 30 per cent. of zinc can be worked by machine tools, a contrast in this respect to pure aluminium, which is often very troublesome, while the alloys named possess the further quality that machined surfaces retain their brightness for months without protection of any kind. The report just given is but a preliminary to a further investigation which is being undertaken by the same authors into the ternary alloys of copper, aluminium, and zinc. This introduction of another element makes, of course, the field of investigation wider still, and before the results of this enquiry can be revealed a considerable interval, it will be evident to all who realise its nature, must elapse. Attention, however, is drawn in this report to one particular specimen of ternary alloy, consisting of 72 per cent. of aluminium, 25 per cent. of zinc, and 3 per cent. of copper, which may be useful in many directions on account of its lightness and tenacity. It is stated that this alloy gives an ultimate stress of no less than 34 tons per square inch, while its resistance to repeated bending impact is over 4,500 blows, as compared with 3,400 with the best of the binary alloys. The strength of this new alloy, it will be seen, compares with the best steel, and its discovery serves also as an indication of the unexpected possibilities which such researches may reveal. They are of a kind which no single individual could possibly undertake and for which every engineer must feel grateful.

Elasticity in Boiler Connections.

WHILE the importance of providing some degree of elasticity in boiler steam pipe connections to allow for the inevitable expansions and contractions arising from variations in temperature is generally recognised, failures from inadequate provision are not infrequent, and even when actual failures do not occur a good deal of unnecessary trouble is often incurred at the various joints from inadequate allowance on this score, and is the less excusable, as it could so easily be avoided. It is not in steam pipes alone, however, that the importance of elasticity and freedom to move, either on account of alterations in temperature or settlement in foundations, should be recognised. Feed pipes and blow out pipes are just as important, but as they are out of sight, they often receive scant attention until some scalding accident or fatality awakens in those responsible a sense of their importance. We are reminded of this by a fatality in a recent Board of Trade Report, No. 2,111, arising from the sudden fracture in the blow-out pipe of an economiser, due to the stresses to which it was exposed when the tap was opened, as a result of one end of a long waste pipe being bound fast in a wall through which it passed to the drain. This is a common defect, and has been responsible for many serious accidents, and we call attention to the present one in the hope it may lead all boiler attendants and engineers-in-charge to carefully inspect such arrangements. The provision for expansion provided in the hearth-pit, where there are a group of boilers, is not always sufficient. A waste pipe, although only used occasionally, may easily become a trap if it is not free to move throughout its entire length, whether it be long or short. In the latter case it is very common for it to be built fast in a wall, and, although the question of expansion or contraction is not then so important, a slight movement in the boiler foundations may easily cause fracture, and many blow-out elbow pipes have been broken in this way.

Bursting of a Mould.—Four men were engaged in ladling molten metal in the Bessemer department of Messrs. Samuel Fox & Co., Stocksbridge, when the mould which they were filling burst, and the contents flew in all directions. Two of the men were severely burned about the legs, and were removed to the infirmary. The other two men, whose injuries were not so serious, were taken home.

Gasolene-electric Car for the Canadian Northern Railway.—The Canadian Northern Railway Company are experimenting with a gasolene-electric car of United States manufacture, propelled by power generated by a 200 h.p. gas engine carried above the front truck, with a view to the adoption of this type of car on their local lines. The engine is started by compressed air, and drives a generator which provides electric power for two motors working on the front trucks. The gasolene tanks have a capacity of 100 galls., which is sufficient for a run of about 200 miles. The car seats about 75 passengers, and is equipped with electric light and a plant for compressing air for the starter and brakes; it is about 60ft. long and about the same weight as an ordinary railway coach.

Fatal Explosion of a Steaming Vessel at a Paper Mill.—We have on many occasions directed attention to the disastrous results which can attend the bursting of boiling or steaming vessels even when worked at low pressure and the desirability of insuring them, as is the general practice with ordinary steam boilers. Accounts are to hand of another explosion from a vessel of this description, which occurred at the East Lancashire Paper Mill, Radcliffe, on Tuesday, April 30th, and which resulted in the death of one man and serious injury to another, in addition to extensive damage to property. In this case there were two revolving vessels, arranged close together on trunnions, each measuring 9ft. in length by 7ft. in diameter, used for boiling and beating purposes and furnished with steam through 1in. pipes at a pressure of 25lbs., supplied through reducing valves from boilers working at 130lbs. on the inch. It appears that only one of the vessels burst. This was displaced and the end blown out, which then came into violent contact with the other vessel, dislodging it and forcing one end of it through a wall into the yard. We cannot state definitely the actual cause of the explosion, but we understand it was due to overpressure.

MARINE BOILER FAILURES.

At a recent meeting of the Liverpool Engineering Society a paper, entitled "Further Notes on Marine Boiler Failures," was read by Mr. J. Reney Smith. He said that in a paper read before the society in 1904 an endeavour was made to show that the great source of boiler troubles, apart from the failures due to neglect, was the distortion and alteration in form of the various parts of the boiler caused by unequal expansion and contraction. The result of longitudinal expansion was that as the front and back plates prevented an increase in the length, the furnace was compressed and the corrugations were closed, the effect being greater on the upper than on the lower part of the tube. Simultaneously there was an increase in the vertical direction with a combined result that the furnace was flattened, the flattening being greatest at the combustion chamber end where the corrugations were exposed to the greatest heat, and where, in fact, the furnace usually failed. The effect was most marked in a double-ended boiler with a combustion chamber common to two furnaces. Here the furnaces and chamber might be considered as a beam securely held at each furnace mouth. The effect of expansion in this case was distortion of the furnaces, together with a sagging effect and consequent failure of the back tube plates and saddle corners, due to the comparatively weak forms of these plates below the lower stay tubes. The inevitable bill for repairs could be materially cheapened by adopting a method of attachment for the furnace backs which would permit a renewal of a furnace at a comparatively low cost. The back of the furnace was contracted in area, the corrugation tapering off in a bottle-neck shape and being flanged outwards to join the saddle piece, which was secured to the tube plate and combustion chamber.

Many serious troubles were due entirely to the great differences of temperature between the lower third of a boiler and the upper two-thirds. In the investigation carried out by Mr. C. E. Stromeyer it was found that this difference could amount to as much as 270° Fah., which meant that in a double-ended boiler 18ft. long the variation in length would amount to nearly ½in. Worked out, this gave an equivalent of 13 tons per square inch as an extra stress to which the lower third of the boiler was subjected. The large percentage of cracked lower seams and leaky joints in this part of the boiler was undoubtedly due to this cause, and occurred more frequently in double-ended boilers.

When cracks were discovered in a comparatively new boiler, cutting out and renewing seemed in most cases to be the only alternative to patching, which was a most unsatisfactory method of covering a crack, especially in places where uniformity of section was essential for the proper transmission of heat. A new system was that of welding the cracks, or rather filling the cracks with new metal brought to a welding heat by the oxy-hydrogen or oxy-acetylene method. But some difficulties were experienced in using this system, and consequently electric arc welding had made a rapid advance in favour, and was the system now generally adopted for this class of repair. In the Bernados system an ordinary electric light carbon was connected to the positive main from the generator, the metal to be heated being joined to the negative main. In manipulating the tool the carbon was touched against the metal near the part to be welded and drawn a short distance away, when the electric arc was struck and the metal quickly heated. The arc was about 4in. to 4½in. in length. In about 12 seconds the required temperature was produced, the arc was removed, and the weld hammered in the ordinary way. There was an objection, however, to the use of carbon, as it was found that a certain proportion combined with the welding metal, the result being that a material was produced similar to cast iron, and therefore unsuitable for boiler work. Pommee, of Hamburg, recognising the disadvantages of carbon, experimented with the system developed by Messrs. Albrecht & Dantz. The principal feature in this method was that the iron welding pencil itself formed one pole, whilst the part of the boiler where the work was being done formed the other. An advantage was the avoidance of great heat in confined spaces, as the enormous temperature of the electric arc rapidly brought the small point on the surface being dealt with to a welding heat, the point of the iron pencil simultaneously rising to the same temperature, when a drop was deposited upon the work and combined with the metal heated to receive it. The drops followed one another in quick succession until the fracture was filled and the work completed. The objections to heating the plates over a large area were thus avoided, for although the temperature was high (about 3,500° C.), it was rapidly produced and the work was finished before the heat was transmitted to any extent to the surrounding metal. The method of dealing with local wasting of the plates was simply building up to original thickness the plate where wasted. It was necessary to remove the oxide or dirt by first chipping to bare metal and then drop by drop to add to the thickness until something over the original scantling was reached.

MARITIME WIRELESS TELEGRAPHY.

A matter of the utmost importance to the shipping interests is the transfer of the ship and shore stations formerly owned or worked by the United Wireless Company to Marconi's Wireless Telegraph Company, of America, in accordance with the judgment of the United States Court. It is well within the recollection of our readers that the Marconi Company succeeded in their action against the United Wireless Company for infringement of their American patent, corresponding to the well-known English patent No. 7,777 of 1900, and the defending company not only acknowledged the validity and scope of the patent and admitted their infringement, but submitted to judgment and a permanent injunction in favour of the Marconi Company. The result of this is that 500 ship stations and about 70 land stations which had been erected and worked by the United Wireless Company passed into the hands of the Marconi Company. It is not difficult to conceive the great advantage of this arrangement, whereby the points for inter-communication between ship and ship have been so considerably increased, and many additional land stations thrown open for traffic with vessels off the American coasts. To give anything like a list of the ships fitted with wireless which have come into the hands of the Marconi Company would occupy too much space, but some indication of the magnitude and importance of the arrangement may be gauged by the mere mention of the important lines affected by the arrangement.

The classes of vessels which are now added to the Marconi organisation comprise passenger, cargo, collier, barges, and other craft, and the vessels are owned by such well-known and important shipping companies as the Mallory Line, the Quebec Steamship Company, the Red D Line, the New York and Porto Rico Steamship Company, the Savannah Line, the Panama Railroad Company, the Old Dominion Line, the Standard Oil Company, the Merchants' and Miners' Transportation Company, the Royal Mail Steam Packet Company, the United Fruit Company, the Wilson Line, the Nelson Line, Lamport, Holt, & Co., the Lloyd-Brazileiro Steamship Company, the Clyde Line, the Ward Line, the Bank Line (Messrs. Andrew Weir & Co., Ltd.), the Pacific Mail Steamship Company, the Grand Trunk Pacific Coast Steamship Company, the Canadian Pacific Steamship Company, and the Pacific Coast Steamship Company. From the names of the shipping companies which we have extracted from the list, it will be seen that the vessels are owned by most of the leading lines plying between New York and Boston and other ports on the Atlantic and Pacific coasts of America. A good many of the ships are employed in the Great Lake service.

The British Acetylene Association.—This association have arranged with the Northern Polytechnic, Holloway, to hold instruction classes in oxy-acetylene welding at that institute. These classes are intended for men who propose taking up oxy-acetylene welding as a trade. The course will extend over a period of one month. Working hours, 9 till 5 daily. Workmen desirous of joining these classes should apply to Dr. Clay, Northern Polytechnic, Holloway Road, N., or to the Secretary of the Association, 103, Cheapside, E.C. A nominal fee of one guinea (£1. 1s.) is charged for the month's course. This fee is reduced to ten shillings and sixpence (10s. 6d.) if the workman is in the employ of a member of the association.

SOME ASPECTS OF DIESEL ENGINE DESIGN.*

BY D. M. SHANNON.

(*Continued from page 511.*)

Valve-gear Diagrams.—The noise caused by some cam and roller gears is due principally to two causes, the first and greatest being the speed with which the cam strikes the roller, and the second the valve striking the seat. If the first can be eliminated, the second will naturally vanish, or at least cause no inconvenience, since it occurs inside the cylinder, and is consequently of a muffled nature. For noiseless running the flat part of the cam profile should slide under the roller at a tangent, and should grip the roller with no velocity. If this is done the valve can then be pushed open as rapidly as desired. The same remarks apply to the closing of the valve.

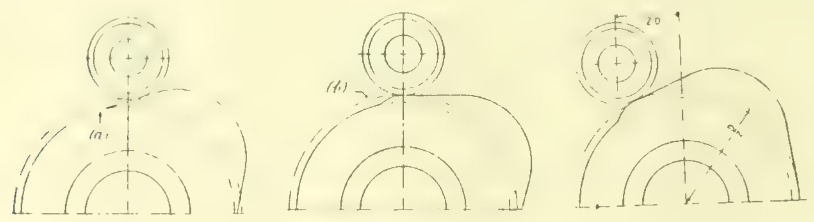


FIG. 13. FIG. 14. FIG. 15.
CAM AND ROLLER GEAR.

The general method of making cams is to let the flat part of the cam profile run tangent to the cam circle as at (*a*), Fig. 13. Owing to the high surface speed of the cam, this gives rise to a violent knock when the flat face engages the roller. To overcome this the flat part of the cam should run tangent to the clearance circle (*b*), as shown by Fig. 14, and should then fillet into the cam circle.

Diagrams and actual measurements for the opening sides of a cam like Fig. 13 are shown on Fig. 16. The abrupt start of the speed and acceleration curves is very marked, and forms a contrast to the curves given by Fig. 17, which also gives the curves for the closing side. These curves are for a cam of a form similar to Fig. 14. The effect on the acceleration curve of putting a piece on to the cam profile as indicated by the dotted line is shown on Fig. 19. This concave curvature cannot be carried out on high-speed cams because the acceleration is so great as to practically amount to a blow. Since force = mass × acceleration, it follows that the acceleration curve is simply a force curve to a suitable scale. The equivalent mass of the valve gear parts at the valve centre must be calculated and the curve calibrated to suit. Fig. 18 shows the acceleration curve of Fig. 19 converted and the spring-load curve plotted above it. The spring-load curve should always be considerably in excess of the acceleration curve so as to make certain that the roller will not fly off the cam when the valve is opening and closing. The friction at the lever pivots and valve stem helps the spring on opening, but retards it on closing, and has consequently to be allowed for. This amount can only be obtained from practice, since it is largely a question of lubrication and workmanship. On examination of a large number of cases I find that the strength of the spring should be from 2 to 2·5 times the accelerating force for high-speed engines.

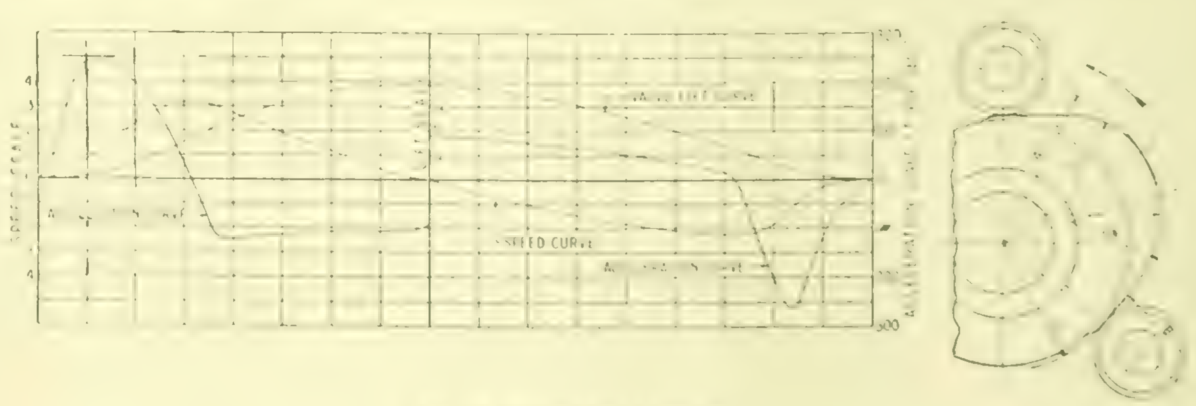


FIG. 17.—VALVE GEAR CURVES.

Similar curves may be drawn for eccentric gear or a combination of eccentric and cam gear, and an example of this latter, giving a variable opening to the valve, is shown in Fig. 20. It is not necessary to draw the complete acceleration curve, because when the speed curve has been drawn it will be seen that the maximum acceleration occurs at the point where the speed curve is steepest, and this can readily be calculated. The speed of the valve at closure is also easily determined from the valve-lift curve. These points are indicated on the curves which are self-explanatory, although they are rather more difficult to construct than those for cam and roller gear.

Cams like Fig. 13 are nearly noiseless in operation if the roller be held in contact with the cam by means of a light spring and not given clearance as shown. Unfortunately the roller is then running under load all the time and the wear on the pins is heavy. Push rods should be avoided, since these introduce more joints between the cam and its work, and there is always noise and vibration by the cam taking up the slack every time the valve is opened.

Offsetting the roller, as in Fig. 15, gives a slightly quicker opening of the valve, and allows it to seat a little quieter, but these effects are small. This practice, however, should not be followed on account of the lateral thrust and heavy wear thrown on the valve gear. Reducing the size of the roller in proportion to the valve lift is beneficial, but this cannot be carried far, as the pins become too small. Increasing the diameter of the cam in proportion to the valve lift has much the same effect, and for high-speed work the cam diameter should be from 6 to 7 times the valve lift. For the same class of work the diameter of the roller should be at least 2·5 times the valve lift.

As a rule eccentric gear with rolling links is very much quieter in working than cam gear, on account of the low speeds of the contact surfaces. Although theoretically cam gear should be as noiseless as eccentric gear in practice, this has not been found to be the case for reasons which are principally constructional, and as time goes on more engines will be fitted with eccentric gear on account of its superior running qualities and the quicker and variable openings it can give to the valves.

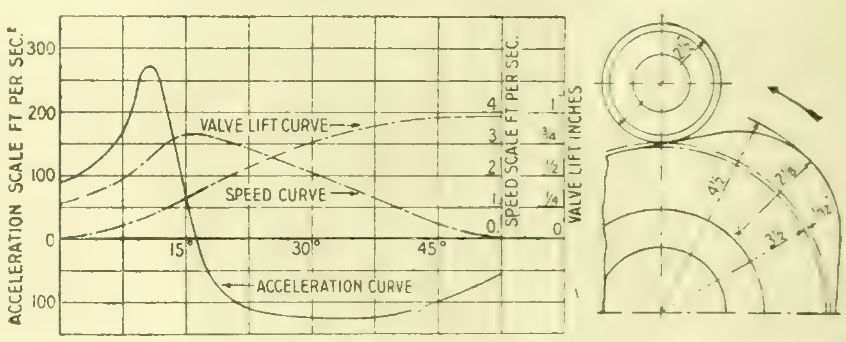


FIG. 16.—VALVE GEAR CURVES.

In calculating the strengths of push rods and valve levers, the loads are best arrived at by graphical construction. Fig. 21 shows curves for an exhaust valve, and Fig. 22 those for an induction valve. In the former the principal load is, of course, that due to the gas pressure on the valve at the point of opening and this amounts to about 40lbs. per square inch of valve area. The resultant will have to be increased by an amount already given to allow for frictional resistances, and the push rod or lever designed to suit this total. For the induction valve the gas pressures are so low that they have been neglected altogether.

The effect of varying the cam profile on the gas speeds through the valves is very important, since this greatly affects the efficiency and power of the motor. The power depends upon the volumetric efficiency of the working cylinder, and how best to increase this can be studied by diagrams like Figs. 23 and 24. It is also desirable to get rid of the exhaust

* Paper read before the Institution of Engineers and Shipbuilders in Scotland, [illegible]

gases as quickly as possible by providing free passages and good valve openings. Considering the exhaust cam shown on Fig. 17, the effect of putting on the dotted piece is indicated on Figs. 23 and 24, the former showing the gas speeds for the full line cam, and the latter those for the dotted line.

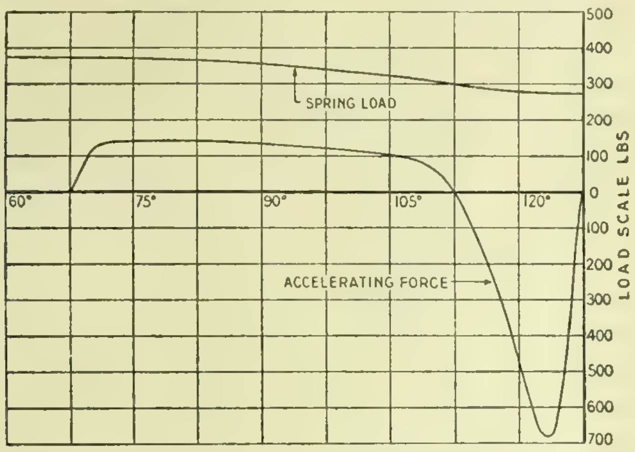


FIG. 18.—VALVE GEAR CURVES.

This has the advantage of bringing the gas speed down from 630 feet per second to 420 feet per second. The final effect of this can only be obtained by actual trial, but without drawing such diagrams any attempts at varying the shapes of the cams must be largely a matter of guesswork.

AIR COMPRESSORS AND SCAVENGING AIR. GENERAL FORMULÆ.

Let x = number of stages in compressor.

k = number of any particular stage.

D_k = diameter of cylinder for k stage in inches.

D_1 = diameter of 1st stage cylinder.

S = stroke of piston in inches.

P = atmospheric pressure = 14·7lbs. per square inch.

P_k = absolute pressure at end of any stage k.

a = ratio of compression.

$$= \frac{\text{final gauge pressure} \times 14\cdot7\text{lbs.}}{14\cdot7\text{lbs.}}$$

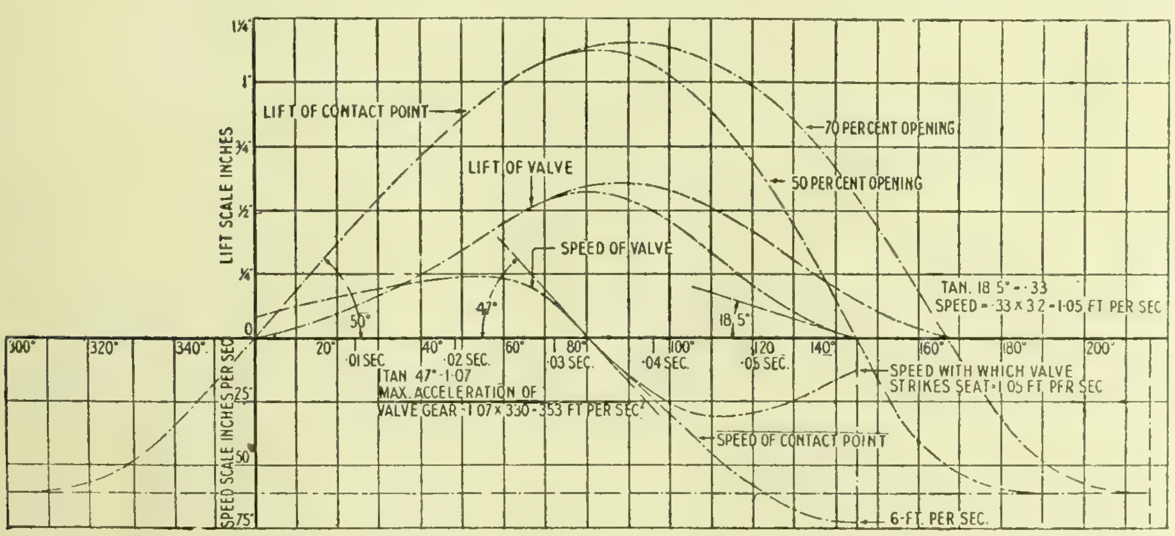
t = absolute temperature of air at the beginning of 1st stage compression.

approximately atmospheric temperature + 460°.

t_k = absolute temperature at end of any stage.

c_1 = clearance in 1st stage cylinder expressed as a fraction of the piston stroke.

n = exponent to the compression curve = 1·35 for high-speed Diesel engines.



· FIG. 20.—ECCENTRIC VALVE GEAR CURVES.

V = volume of free air delivered per stroke in cubic inches.

Then

$$D_1 = 2\sqrt{\frac{V}{\pi S \left\{ 1 + c_1 \left(1 - a\right)^{\frac{1}{xn}} \right\}}}$$

$$D_k = D_1 \left(\frac{1}{a}\right)^{\frac{k-1}{2x}}$$

Taking cylindrical clearance into account

$$D_k = D_1 \left(\frac{1}{a}\right)^{\frac{k-1}{2x}} \sqrt{\frac{1 + c_1 - c_1 (a)^{\frac{1}{xn}}}{1 + c_k - c_k (a)^{\frac{1}{xn}}}}$$

$$P_k = P (a)^{\frac{k-1}{x}}$$

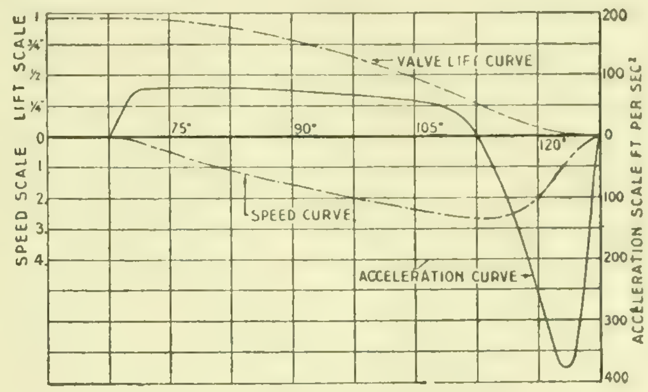


FIG. 19.—VALVE GEAR CURVES.

Volumetric efficiency $= 1 + c_1 \left(1 - a^{\frac{1}{xn}}\right)$

Work done per stroke of compressor.

$$= \frac{\cdot 962\, D_1^2 S}{\frac{n-1}{xn}} \left\{ (a)^{\frac{n-1}{xn}} - 1 \right\} \left\{ 1 + c_1 \left(1 - a^{\frac{1}{xn}} \right) \right\}$$

Work done per cubic foot of free air delivered

$$= \frac{2116}{\frac{n-1}{xn}} \left\{ (a)^{\frac{n-1}{xn}} - 1 \right\} \left\{ 1 + c_1 \left(1 - a^{\frac{1}{xn}} \right) \right\}$$

Assuming that the air is always cooled back to atmospheric temperature after each stage.

$$t_k = t\,(a)^{\frac{n-1}{xn}}$$

These rules are deduced from the fact that for the most economical compression the intermediate pressures are in geometrical progression, and in the form given they are suitable for a compressor having any number of stages. For tandem compressors the equivalent diameters must, of course, be found, and in all cases the stroke of the pistons for the several stages have been assumed to be the same. If these vary in any way allowance must be made when finding the various diameters. The value of the exponent to the compression curve varies from point to point of the curve, on account of the variable rate of heat transmission to the jacket water, and the value given is only an average one calculated from a number of actual indicator cards. In order to get rid of the suction valves, the practice of allowing the piston to overrun the ports is sometimes resorted to. This is very often done in the first stage of small compressors, and the induction pipe is tuned up to such a length that, when the piston overruns the ports, oscillations are set up, and it has been found possible to start compressing with a pressure of about 19lbs. per square inch absolute, instead of at atmospheric pressure. In this way a reduction can be made in the cylinder diameter. The effect is the same as if the compressor was working in a denser atmosphere, and P in the formula will have the value of 14·7 + super-pressure. The practice is not defended except for the express purpose of simplifying the compressor; for although much of the energy lost during the suction stroke is recovered in the form of super-pressure, a good deal is lost due to heating up the air as it rushes through the inlet ports.

Table III. gives a complete set of formulæ for air compressor design, extended to include compression in one, two, three, and four stages.

TABLE III.—Symbols.

D_1, D_2, D_3, D_4 = diameter of 1st, 2nd, 3rd, and 4th stage cylinders.

P_1, P_2, P_3 = absolute pressures at end of 1st, 2nd, and 3rd stages.

TABLE III.—*Air Compressor Formulae*

No. of Stages	Cylinder Diameters			Cylinder Diameters taking Clearance into Account.			Intermediate Pressures		
	D_2	D_3	D_4	D_2	D_3	D_4	P_1	P_2	P_3
2.	$D_1(\frac{1}{a})^{\frac{1}{4}}$			$D_1(\frac{1}{a})^{\frac{1}{4}}\sqrt{\frac{1+C_1-C_1(a)^{\frac{1}{2n}}}{1+C_2-C_2(a)^{\frac{1}{2n}}}}$			$P(a)^{\frac{1}{2}}$		
3.	$D_1(\frac{1}{a})^{\frac{1}{6}}$	$D_1(\frac{1}{a})^{\frac{1}{3}}$		$D_1(\frac{1}{a})^{\frac{1}{6}}\sqrt{\frac{1+C_1-C_1(a)^{\frac{1}{3n}}}{1+C_2-C_2(a)^{\frac{1}{3n}}}}$	$D_1(\frac{1}{a})^{\frac{1}{3}}\sqrt{\frac{1+C_1-C_1(a)^{\frac{1}{3n}}}{1+C_3-C_3(a)^{\frac{1}{3n}}}}$		$P(a)^{\frac{1}{3}}$	$P(a)^{\frac{2}{3}}$	
4.	$D_1(\frac{1}{a})^{\frac{1}{8}}$	$D_1(\frac{1}{a})^{\frac{1}{4}}$	$D_1(\frac{1}{a})^{\frac{3}{8}}$	$D_1(\frac{1}{a})^{\frac{1}{8}}\sqrt{\frac{1+C_1-C_1(a)^{\frac{1}{4n}}}{1+C_2-C_2(a)^{\frac{1}{4n}}}}$	$D_1(\frac{1}{a})^{\frac{1}{4}}\sqrt{\frac{1+C_1-C_1(a)^{\frac{1}{4n}}}{1+C_3-C_3(a)^{\frac{1}{4n}}}}$	$D_1(\frac{1}{a})^{\frac{3}{8}}\sqrt{\frac{1+C_1-C_1(a)^{\frac{1}{4n}}}{1+C_4-C_4(a)^{\frac{1}{4n}}}}$	$P(a)^{\frac{1}{4}}$	$P(a)^{\frac{1}{2}}$	$P(a)^{\frac{3}{4}}$

No. of Stages	Intermediate Temperature t_k	Volumetric Efficiency	Work in Foot-lbs Required per Stroke of Compressor	Work in Foot-lbs. Required per Cubic Foot of Piston Displacement.
1.	$t(a)^{\frac{n-1}{n}}$	$1+C_1(1-a^{\frac{1}{n}})$	$\frac{.962 D_1^2 S}{\frac{n-1}{n}}\left\{(a)^{\frac{n-1}{n}}-1\right\}\left\{1+C_1(1-a^{\frac{1}{n}})\right\}$	$\frac{2116}{\frac{n-1}{n}}\left\{(a)^{\frac{n-1}{n}}-1\right\}\left\{1+C_1(1-a^{\frac{1}{n}})\right\}$
2	$t(a)^{\frac{n-1}{2n}}$	$1+C_1(1-a^{\frac{1}{2n}})$	$\frac{.962 D_1^2 S}{\frac{n-1}{2n}}\left\{(a)^{\frac{n-1}{2n}}-1\right\}\left\{1+C_1(1-a^{\frac{1}{2n}})\right\}$	$\frac{2116}{\frac{n-1}{2n}}\left\{(a)^{\frac{n-1}{2n}}-1\right\}\left\{1+C_1(1-a^{\frac{1}{2n}})\right\}$
3.	$t(a)^{\frac{n-1}{3n}}$	$1+C_1(1-a^{\frac{1}{3n}})$	$\frac{.962 D_1^2 S}{\frac{n-1}{3n}}\left\{(a)^{\frac{n-1}{3n}}-1\right\}\left\{1+C_1(1-a^{\frac{1}{3n}})\right\}$	$\frac{2116}{\frac{n-1}{3n}}\left\{(a)^{\frac{n-1}{3n}}-1\right\}\left\{1+C_1(1-a^{\frac{1}{3n}})\right\}$
4	$t(a)^{\frac{n-1}{4n}}$	$1+C_1(1-a^{\frac{1}{4n}})$	$\frac{.962 D_1^2 S}{\frac{n-1}{4n}}\left\{(a)^{\frac{n-1}{4n}}-1\right\}\left\{1+C_1(1-a^{\frac{1}{4n}})\right\}$	$\frac{2116}{\frac{n-1}{4n}}\left\{(a)^{\frac{n-1}{4n}}-1\right\}\left\{1+C_1(1-a^{\frac{1}{4n}})\right\}$

P = atmospheric pressure = 14·7lbs. per square inch.

C_1, C_2, C_3, C_4 = clearances of 1st, 2nd, 3rd, and 4th stage cylinders expressed as fractions of the piston stroke.

t^k = absolute temperature at end of any stage k.

t = absolute atmospheric temperature = 460° + 60° = 520° Fah.

a = ratio of compression = $\frac{\text{gauge pressure} + 14 \cdot 7\text{lbs}}{14 \cdot 7\text{lbs.}}$

n = exponent to the compression curve.

= 1·35 for high-speed Diesel engines.

s = stroke of compressor in inches.

For the scavenging air the compression line is straight, because of the low compression pressure required, and consequent small heat losses to the cylinder walls. The calculation of the power required by scavenging pumps is, therefore, a simple matter, and requires no particular formulæ.

General.—The following notes and suggestions on marine requirements may not be without interest. They refer principally to 2-cycle engines. The use of the stepped piston engine is not advisable for marine work, chiefly on account of the amount of gear that has to be dismantled before a piston can be examined. In all designs this means the removal of a

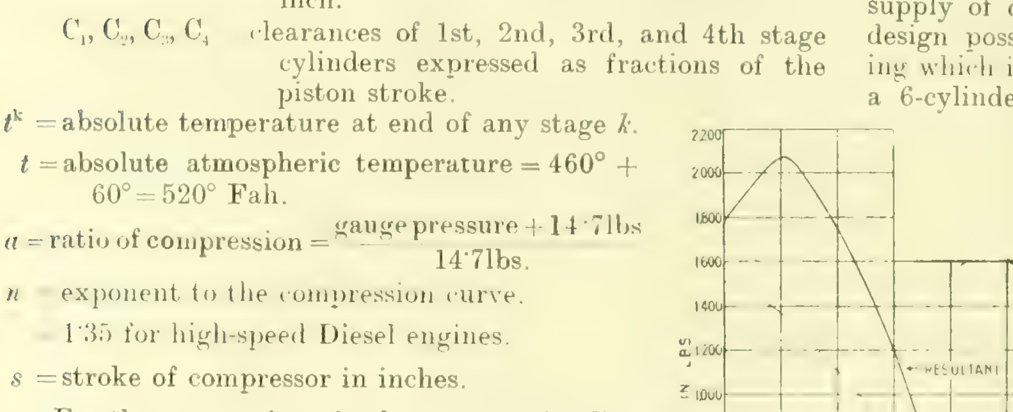


FIG. 22.—LOADS ON VALVE LEVER OR PUSH ROD INLET VALVE.

cylinder, and in some, the cam shaft and gear extending over two cylinders, in addition. The advantages claimed for the design are that balancing is much easier and better, and that if the scavenging part for one cylinder breaks down it only affects the working of that cylinder. The latter reason is quite sound, but with regard to balancing, any addition of weight to the reciprocating masses is bad, and aggravates any unbalanced forces and couples there may be in the engine. In some engines, such as the 4-cylinder type with cranks at 90°, it is desirable to have an additional crank, since this can be arranged to give a good balance without disturbing the equal phase difference of the working cranks. It also makes a cheaper engine to have a separate scavenging crank, although the cylinders do not all receive the same measured quantity of air.

Some of the stepped piston engines have only one fuel oil pump for supplying all the cylinders, and if it breaks down or gets choked up, which is by no means uncommon, the whole engine stops working. The better method is to have a separate pump for each cylinder, so designed that it can be overhauled without stopping the engine. Higher powers have been obtained from engines so arranged, because the supply of oil to the cylinders is better under control. This design possesses advantages from the standpoint of governing which is a most important feature in marine engines. In a 6-cylinder engine with one oil pump, one stroke of the

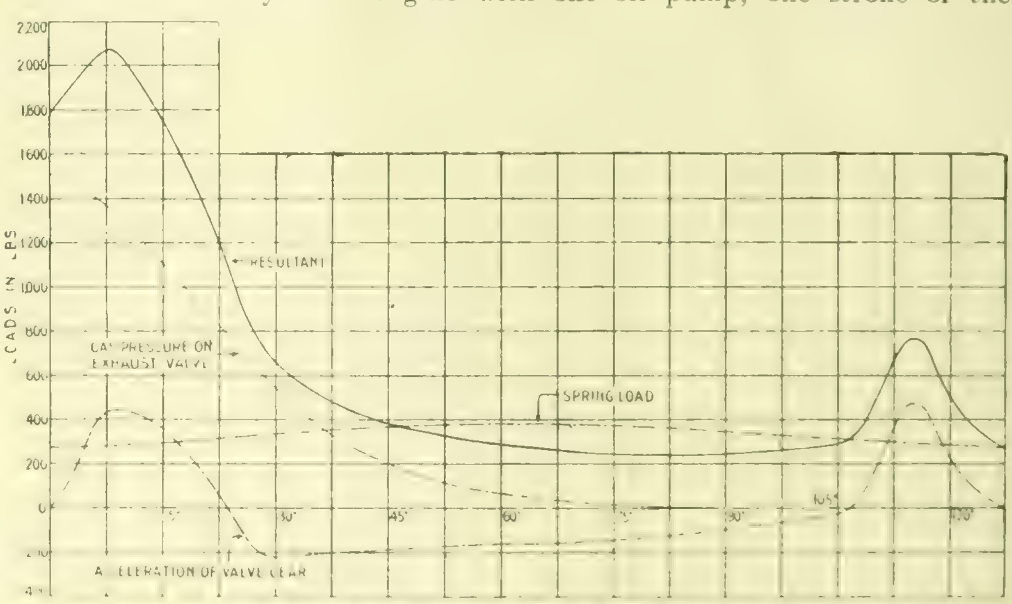


FIG. 21.—LOADS ON VALVE LEVER OR PUSH ROD EXHAUST VALVE.

pump delivers six charges of oil. Now, supposing that the governor was required to act immediately after the pump had made a delivery, it cannot affect the six charges which have gone beyond its control, and must go through the cylinders, even although the propeller may be out of the water. With six separate oil pumps delivering at intervals to suit the crank arrangement, it would have been able to act upon five of the charges, and would, consequently, be much more sensitive in its action. The oil should be withheld from the Diesel valve until it is just about to open, so that the governor has a chance to act upon it right up to the point at which it is required in the cylinder. With oil engines there is not the slightest fear of racing taking place on account of the propeller lifting out of the water, for it is possible to throw the whole load instantly off the engine, and there is no perceptible variation in speed. The usual method of starting up these

engines is to admit air to all the working cylinders, and when a certain speed has been reached, to cut the air off from half the number, and turn the oil on. When this half has commenced firing, the air is shut off from the other cylinders and oil turned on, when the whole engine will be running on oil. Instead of this method all the pumps may be dropped into gear at the same instant that the starting air is turned on, and as soon as firing has commenced the starting air should be shut off all the cylinders. By this method, as soon as the

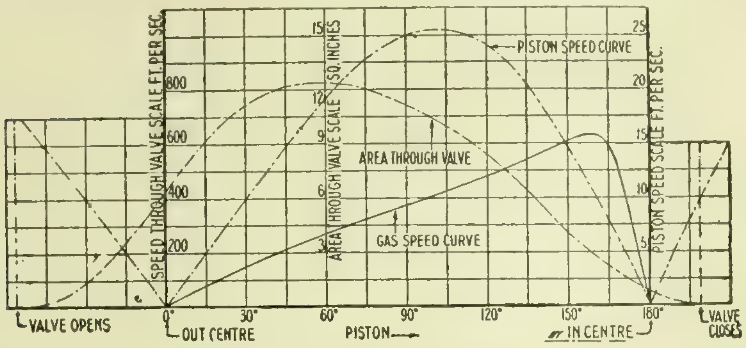


FIG. 24.—GAS SPEED CURVES.

engine begins to move, the oil pumps begin delivering, which results in quicker starting, and effects a saving in starting air.

If the ship is fitted with an auxiliary set of engines, provision should be made for sending the hot water discharged from it through the cylinders of the main engine. This preliminary warming up would prevent the engine being subjected to sudden variations in temperature.

In twin-screw vessels, the gear on each cylinder need not be handed, because each cylinder is a complete unit, and there are no great structural changes such as exist in steam jobs. It is rather a convenience for a man to turn from one engine to the other and find it exactly the same. It also means less first cost, and only half the number of spare parts are necessary.

In order to increase the power for purposes of overload, or in cases of emergency, it is only necessary to create a denser atmosphere in the engine-room, by the usual forced-draught appliances, the engines having first been designed to suit the increased compression pressure. With 4-cycle engines this is all that is required, but with 2-cycle engines the case is different, on account of the cylinders being open to the outside atmosphere during charging. The back pressure in the exhaust would require to be increased, which can be done by

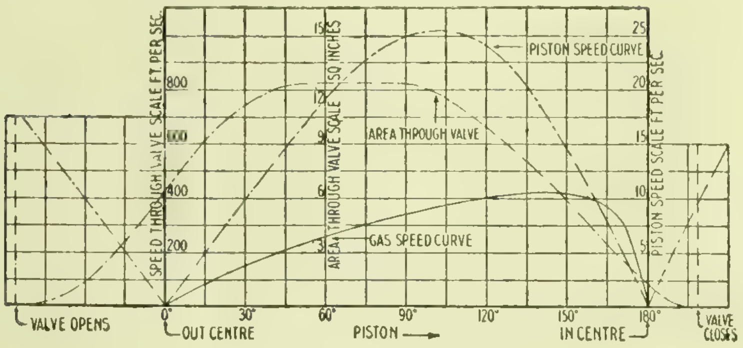


FIG. 23.—GAS SPEED CURVES.

means of a water seal, an arrangement that permits any desired back pressure to be used. If scavenging pumps are separately driven it is not necessary to increase the atmospheric pressure in the engine-room. The speed of the pumps would be increased instead, thereby increasing the scavenging air pressure, and at the same time the back pressure on the engine would be artificially increased.

Wireless Telegraphy.—Sir Oliver Lodge recently delivered at the Birmingham University the first of a series of technical lectures on wireless telegraphy. His first subject was "The Emission of Waves." He said the whole world had recently had its attention called to the subject of wireless telegraphy by one of those catastrophes which occurred from time to time—in this case eclipsing all the others. Without wireless telegraphy we should have known very little, perhaps nothing, about the loss of the "Titanic." It would have been one of those cases where a ship disappeared on the high seas, was heard of no more, and concerning the manner of whose loss there would be merely speculation.

WELDING UP OF BLOWHOLES AND CAVITIES IN STEEL INGOTS.

BY J. E. STEAD, D.MET., F.R.S.

IN the previous note, †experimental data, obtained by heating and forging steel bars in which cavities had been made by drilling, showed that if the walls of the cavities were clean and bright perfect welding was easily obtained. No actual trials had at that time been made to determine whether the real blowholes in crucible steel ingots could be as perfectly welded up. Experiments have therefore been made to determine this question, and also whether cavities with oxidised walls can be welded up. It is to describe these further trials that this second note has been written.

Honeycombed Crucible Steel Ingots.—Experiments with a honeycombed ingot of 0·5 per cent. carbon crucible steel were made at the works of Messrs. J. H. Andrew & Co., Ltd., with the assistance of the manager, Mr. J. L. Potts, and his melter, Mr. Duckenfield. Two steel ingots from the same mixture were melted in such a way that one was honeycombed and the other sound. The sections of these are shown in Figs. 1 and 2. The honeycombed steel rose to nearly 10 per cent. of its length after teeming, whilst the sound ingot did not rise, but contracted down its central axis.

We may assume that about 9 per cent. of the volume of the honeycombed ingot was occupied by blowhole cavities. The ingots were forged to a smaller size after heating to a

FIG. 1. SECTION OF HONEYCOMBED CRUCIBLE STEEL INGOT.

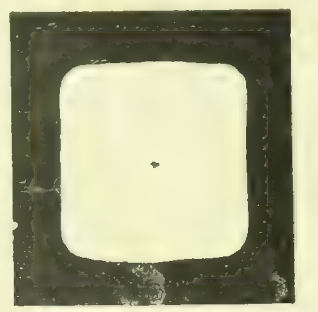


FIG. 2. SECTION OF SOUND CRUCIBLE STEEL INGOT.

wash-welding temperature, estimated at not less than about 1,100° C., sufficient to melt the scale on the surface, and were divided into two parts. Half of each set of bars were reheated to 1,100° C. for one hour, and were then rolled to bars 1in. diam. The remaining halves were heated in the usual way without "soaking," and were also forged to 1in. round bars. All the bars were "reeled" after forging. Portions of each of them were turned down to prisms of $\frac{7}{8}$in., $\frac{5}{8}$in., $\frac{3}{4}$in., and $\frac{1}{2}$in., and through each a hole was drilled, so as to make a series of cylinders with walls $\frac{3}{16}$in. in thickness. A similar hole was drilled through portions of the bars which had not been reduced in diameter by turning. The cylinders thus prepared were cut up into a series of rings about $\frac{1}{4}$in. in depth.

The object of making these rings was to determine the degree to which they could be expanded before breaking, and to see if at their outer polished surfaces they would open out into seams on being slightly strained. The outer parts of the rings were brightly polished, and the rings were expanded by driving into them a hard taper steel drift.

The results need not be given in detail. It is sufficient to state that in no single ring after slight expansion was any unwelded steel detected, and in every case when fracture was effected the steel on each side of the parting showed evidence of contraction or plastic flow. We may conclude, therefore, that the surfaces of the rings were as sound in the steel from the bars of the honeycombed as they were in the steel from the sound ingot, and as there was no difference between the bars with and without soaking, we may be certain that soaking after wash welding, in this case at least, was of no advantage, because the forging in the first instance produced as perfect welding as was possible, and no soaking afterwards could improve what was perfection. Although the welding up of the blowholes was apparently good, there was, however, a great difference in the physical properties of the rings from the respective ingots.

* Paper read before the Iron and Steel Institute, May 9th, 1912.
† See "The Mechanical Engineer," May 12th, 1911, p. 591, Vol. XXVII.

The rings from the sound ingot expanded on the average about 50 per cent. more before breaking than those from the honeycombed ingot, a peculiarity suggesting at first sight imperfect welding of the blowhole walls. A careful examination of the fractures revealed the presence of dull lines of microscopic fineness in the rings from the honeycombed ingot, while nothing of the kind could be detected in the steel from the sound ingot.

Further, on bending the broken rings from the honeycombed ingot, it was found that some portions of them could be bent to a greater extent without breaking than others, whilst there was not such variation in the steel from the sound ingot. In the cases where fracture occurred on slight bending these dull lines could almost always be detected on the broken surfaces, but none were present in the portions of the same rings which could be bent to a much greater degree before fracturing. Obviously these dull lines and reduced ability of the steel to extend were co-related.


FIG. 3.

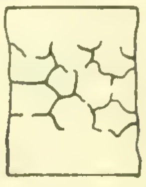


FIG. 4.


FIG. 5.

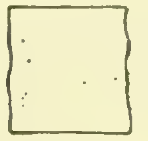


FIG. 6.

FIG. 3. Section through closed-up oxydised cavity. Black part represents cinder; white part metal. FIG. 4 Same as Fig 3 after heating for 3 hours at 950 C. Dark parts are actual spaces and unreduced slag inclusions. FIG. 5.—Same as Fig. 4 after heating for 1 hour at 1,100 C. Dark parts are actual spaces and unreduced slag inclusions. FIG. 6. Same as Fig. 5 after heating to 1,100 C and forging down to smaller size. Dark parts are slag inclusions.

As the steel contained only 0·02 and 0·03 per cent. of sulphur respectively, it seemed improbable with such a small amount of sulphur that there could be any material segregation of manganese sulphide in the blowholes. To determine whether there was or not, cross-sections of the inch bars from the sound and honeycombed steels were cut and polished, and auto-sulphur prints were obtained on bromide paper. The results showed that the sulphur was distributed evenly in the bar from the sound ingot, but was segregated in the places where there had been honeycombs in the unsound ingot. Sulphur prints taken from a cut section of the honeycombed ingot itself also proved that the cavities contained sulphides. We may, I think, be satisfied in concluding that the dull lines are co-related in some way with the sulphide segregation. Finally, sulphur prints of the fractures proved that the dull lines were rich in sulphides.

That clean faces of cavities in crucible steel can be perfectly welded together under treatment identical to that to which the honeycombed ingot was subjected has been fully proved; we are therefore satisfied that the inferior ductility in cross-sections of the bars made from the honeycombed ingot was due to the presence of sulphide of manganese threads which prevented the metallic faces from completely coming into contact.

Blowholes with Oxidised Walls.—During the latter part of the year 1911 a series of trials was made, with the assistance of Mr. Parkin, to determine whether or not artificially formed cavities with oxidised walls could be welded up. It was taken for granted that if no carbon were present in the steel, oxidised blowholes could not be perfectly welded. In the first experiment with a 2in. square steel bar about 8in. in length containing 1·2 per cent. carbon, a small hole was drilled nearly to the bottom, along the central axis. The bar was then heated to redness and oxygen gas was blown down the hole, so as to oxidise the walls of the cavity. After heating to about 900° C. it was hammered, so as to bring the sides of the cavity into juxtaposition. The bar was then heated to and maintained at a temperature of about 1,100° C. for one hour, and was at once forged down to a smaller size. When cold it was nicked at intervals and broken at the nicks, and the fractures examined. They indicated imperfect welding near to what was originally the open end of the bar, but below this for two thirds of the length the welding appeared to be perfect.

On microscopic examination of the polished cross-sections of the parts where welding appeared to be good it was found that the seam, originally consisting of oxide of iron, had been practically reduced to the metallic state, with the exception of minute globular dust like inclusions, probably of iron or manganese silicate—the residue of the oxidised steel which was incapable of being reduced by the carbon. But for these excessively minute inclusions the welding was perfect. On bending a polished and etched section to open the joint, the metal at this point being lower in carbon than the surrounding mass extended and then broke, showing a perfectly crystalline fracture, a proof that good welding had been effected.

In a second experiment with the same steel a bar was prepared as above described, with the exception that after the cavity was oxidised and closed the bar was heated to 950° C. for three hours. It was then cut in half; one half was retained for examination, the other was reheated at 1,100° C. for one hour, and without forging, it was allowed to cool. It was again cut into two portions, one of which was heated to 1,100° C. and then forged down to a smaller size. The other part was reserved for examination. Each of the three specimens was sectioned, polished, and examined microscopically without etching.

Figs. 3 and 4, representing magnifications of 330 diameters, show that by heating at 950° C. the carbon of the steel reduced the iron scale to metallic iron, which remained in separate grains, surrounded either by some slight amount of unreduced oxide, or gaseous spaces, or by both. On attempting to bend the specimens, the grains at once separated; there was no cohesion, they had not completely crystallised together—a result not surprising, for the volume of metallic iron is less than that of its oxide.

Fig. 5 represents the same bar as the last after heating to 1,100° C. for one hour. The drawing shows that the greater mass of the reduced iron grains had crystallised together and pressed to one side the intervening gases, and compelled them to segregate into relatively large bubbles at a considerable distance from each other. The microstructure of the joint in the third portion, which had been reheated to and forged from 1,100° C., was identical with that in the bar of the first experiment, which had been heated to 1,100° C. for one hour and then forged to a smaller size, and is represented in Fig. 6. The welding was perfect, with the exception of the minute globular inclusions previously referred to.

In a third experiment the steel bar was treated exactly as in the first, but the bar itself contained only 0·50 per cent. carbon. The welding was found to be complete, but the joint previously occupied by the scale now consisted of carbonless ferrite, and the adjacent steel contained less carbon than the mass of the steel itself. These results show, as was anticipated, that if the walls of the cavities are not too thickly scaled and a sufficient quantity of carbon is in the steel, the scale itself can be reduced practically entirely to the metallic state, and this can be welded up to the sides of what was originally the cavity.

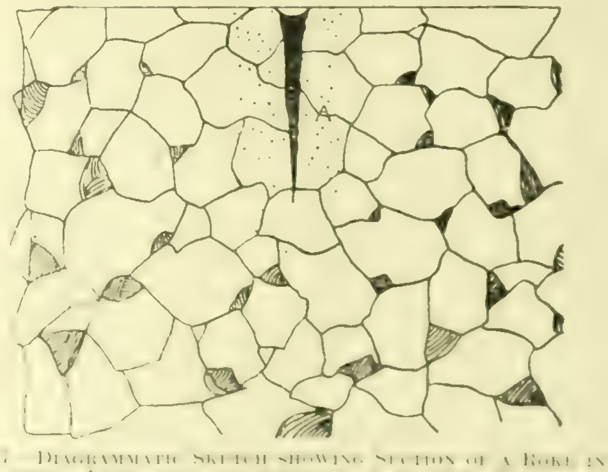


FIG. 7.—DIAGRAMMATIC SKETCH SHOWING SECTION OF A ROKE IN A STEEL AXLE, WITH SURROUNDING OF REDUCED SCALE.

It is generally assumed that blowholes, which terminate on one side through the outer skin of the envelope of steel ingots, having access to oxidising gases, do get so severely oxidised on their walls that no welding of the cell walls occurs, and that in rolling out they are simply extended and appear at the surface of the rolled sections as rokes, which penetrate to the full depth of the extended blowholes.

The presence of the microscopic dark inclusions observed in the welded joints (Fig. 6) led to the examination of many sections of steel which had evidently been rolled from honeycombed ingots. It was believed that if any of the oxide

initially filling the blowholes had been reduced to the metallic state and welded to the surrounding steel, similar inclusions would be discovered. The results of these examinations proved beyond doubt that in a very large number of cases in steel containing between 0·25 per cent. and 0·5 per cent. carbon, these microscopic inclusions were present, and were located in the surrounding layer of ferrite immediately below the lower part of the surface rokes. It is only necessary to describe a single instance. This was a railway axle, on the surface of which there was ample evidence of pre-existing cutaneous blowholes in the ingot, for at intervals there were longitudinal lines or fine grooves an inch or more in length. A cross-section vertical to the surface, after polishing, was sufficient to reveal the position and depth of these rokes. The depth varied from one-hundredth to one-fifth of an inch. The outer envelope was completely decarburised, as is usual in low and medium carbon steels which have been reheated in an oxidising atmosphere previous to forging or rolling.

There was a complete absence of the minute inclusions in this envelope; the steel contained no carbon, but the ferrite immediately in contact with the scale, and for a little distance beyond, contained minute globular inclusions, whilst at a greater distance the crystals of iron contained none.

The crystals of one zone penetrated into the other and were common to each—in other words, one part of the crystals at the border-line contained inclusions, whilst the other contained none.

FIG. 8.—ACTUAL PHOTOGRAPH NEAR REGION A IN FIG. 7.

The diagrammatic sketch (Fig. 7) explains better than words the appearance under the microscope. The photograph (Fig. 8), taken at the point corresponding to A in the sketch, clearly shows the globular inclusions.

There can be little doubt that the ferrite containing the inclusions surrounding the remaining unreduced oxide was at one time oxide or scale in a blowhole, that this was reduced practically entirely to the metallic state by the carbon in the adjacent steel, and that the particles of reduced iron had crystallised together and to the steel itself, producing a practically perfect weld—indeed, on straining, so as to bend the steel, there was no opening out at the junction of the two zones. The minute inclusions are the residual portion of the scale which could not be reduced by carbon or carbon monoxide at the temperature at which the steel had been heated and rolled.

In conclusion, it seems reasonable to believe that under the ordinary treatment to which honeycombed ingots of steel are heated and rolled, internal small cavities or blowholes do become perfectly welded up, provided there is an absence of sulphide segregations, and that even when these segregations are present, as they are not in continuous lines but occur only at intervals, the clean metallic faces between them come into contact and weld together.

It seems also justifiable to conclude that surface blowholes which become oxidised on their walls during the heating and rolling of the ingot, do become more or less completely welded. The conditions favourable to this welding must be a sufficiently high temperature, and maintenance of the steel at that temperature for a long enough period after the cavities have been closed, to admit of the carbon in the adjacent steel being afforded the opportunity to reduce the oxide scale.

It must be pointed out that much more work is still required and trials made with other classes of steel and similar steels which have had treatment varying from what has been described in this note, as it is certain under some conditions that blowholes may not be welded up.

The methods described and the observations made will, it is hoped, facilitate the work of others who take up this branch of research. Finally, I must acknowledge the assistance of the gentlemen mentioned in the text of this report.

THE COAL RESOURCES OF GREAT BRITAIN.*

BY DR. G. T. BEILBY, F.R.S.

THE final report of the Royal Commission on Coal Supplies was issued so recently that it appears to the present writer that he will best serve the ends which the Committee on the Conservation of Energy has in view if this report is devoted, first, to a brief summary of the work of the Royal Commission, second, to some discussion of the conclusion of the Commission, and, third, to some suggestions as to ways in which the British Science Guild might help to keep this important subject before the legislature and the public.

The Work of the Royal Commission.—The Commission was appointed by Royal Warrant, dated December 28th, 1901. Forty-seven meetings were held for the taking of evidence and 126 witnesses were examined. The scope of the enquiry was subdivided for the purpose of the final report as follows: (1) The resources of our coal fields. (2) Their probable duration. (3) Possible economies. (4) The effect of export of coal on the British consumer and the Royal Navy. (5) Maintenance under the existing conditions of the competitive power of our coal mining industry with the coalfields of other countries.

That portion of the final report which deals with the general conclusions under these heads was issued on January 7th, 1905, or three years after the appointment of the Commission.

(1) **The Resources of our Coalfields.**—"It is estimated that the available quantity of coal in the Proved Coal Fields of the United Kingdom is, in round numbers, 100,000 million tons."

(2) **Probable Duration of our Coal Resources.**—"This question turns chiefly upon the maintenance or the variation of the annual output. The calculations of the last Coal Commission as to the future exports and of Mr. Jevons as to the future annual consumption make us hesitate to prophesy how long our coal resources are likely to last. The present annual output is in round numbers 230 million tons and the calculated available resources in the proved coalfields are in round numbers 100,000 million tons, exclusive of the 40,000 million tons in the unproved coalfields, which we have thought best to regard only as probable or speculative. For the last 30 years the average increase in the output has been 2½ per cent. per annum—and that of the exports (including bunkers) 4½ per cent. per annum. It is the general opinion of the District Commissioners that owing to physical considerations it is highly improbable that the present rate of increase of the output of coal can long continue indeed they think that some districts have already attained their maximum output; but that on the other hand the developments in the newer coalfields will possibly increase the total output for some years. In view of this opinion and of the exhaustion of the shallower collieries we look forward to a time, not far distant, when the rate of increase of output will be slower, to be followed by a period of stationary output, and then a gradual decline."

(3) **Possible Economies.**—The use of coal cutting machines, of improved explosives, and of electricity and compressed air are discussed. More careful sorting, sizing, and washing of coal are recommended. It is pointed out that only 10 per cent. of our total output of coke was obtained from recovery ovens in 1902. In beehive ovens there is a loss of 10 per cent by weight of the coke in addition to the complete loss of the volatile products, gas, tars, and ammonia. The recovery of the waste small coal of the mines, by washing, coking, or briquetting, is recommended. Economies in transport are briefly referred to, also the transmission of power instead of coal by the extension of central power stations.

"68. Very few statistics are obtainable as to the consumption of coal in the various industries of the country, but we have collected information from many sources, and we

* Report presented to the British Science Guild on "Natural Sources of Energy."

think that the following estimate for 1903 may be regarded as approximately correct: —

Coal Consumption.	Tons.
Railways (all purposes)	13,000,000
Coasting steamers (bunkers)	2,000,000
Factories	53,000,000
Mines	18,000,000
Iron and steel industries	28,000,000
Other metals and minerals	1,000,000
Brick works, potteries	
Glass works	5,000,000
Chemical works	
Gas works	15,000,000
Domestic	32,000,000
Total	167,000,000

"69. In considering these figures from the point of view of possible economies, we would draw attention to Mr. Beilby's interesting calculation that out of an annual consumption of from 113 to 168 million tons of coal in this country there is a possible saving of from 40 to 60 million tons. Other witnesses have confirmed Mr. Beilby on special points. How these economies may be effected, and the difficulties standing in the way of their extensive adoption, may be indicated under several heads."

Under these heads there is a useful summary of the evidence which had been led to show the economies in power production and in heat production which might be effected by the use of the most approved methods and apparatus. Gas production, steam boiler improvements, the gas engine and the steam turbine, were all very fully discussed by experts. The use of waste gases from blastfurnaces and coke ovens was also dealt with at considerable length.

The effects of the coal tax are discussed at considerable length, and the following very important statement on the subject is made: "In view of the extent of the estimated coal resources of the country, and if our anticipation is correct, viz., that the present rate of increase in the output will soon be checked by natural causes, there seems no present necessity to restrict artificially the export of coal in order to conserve it for our home supply."

Discussion of the Conclusions Arrived at by the Royal Commission in the Light of Recent Experience. It is now known with reasonable certainty that the nation has at its disposal about 100,000 million tons of coal which, it is believed, can be mined and brought to the surface at a cost not greatly exceeding that of the coal which is at present being raised. A certain proportion of this gross amount must of necessity be used up in mining and bringing the coal to the surface and in preparing it for the market. A further proportion must be used in carrying it to the consuming centres. There are good reasons for believing that under each of these heads there is room for economy. In 1903 from 14 to 18 million tons was consumed at the collieries. It was stated by one witness that if the whole of the collieries in the kingdom were fitted with modern plant of the best description the consumption of coal would be one half of what it is to-day. Taking the consumption at the mines at the average figure of 7 per cent. of the gross total, or 7,000 million tons, the reduction to even 4 per cent. would set free 3,000 million tons, or about 12 years' output at the present rate.

Though no estimate is given of the savings to be effected by the use of more perfect methods of mining and preparing the coal for the market by washing, sorting, coking, and briquetting of inferior seams, it is clear that relatively larger savings are possible in these directions.

The Commission dealt at considerable length with the most important subject of "Economies in Use." In paragraphs 68 and 69, which have been quoted above, reference is made to the writer's calculation of the possible economies under this head. As this table is buried in the large volume of "Minutes of Evidence" it may be permissible to reproduce it here, as it gives in a compact form the writer's conclusion seven years ago, and therefore forms a convenient starting point for a brief review of recent developments.

The table shows that there is a greater proportion of coal used for power production than any other item of consumption. In round numbers 70 million tons is consumed under the first four heads. On these items it was estimated that 30 to 40 million tons might be saved if wasteful and inefficient steam engines were replaced by engines of proved efficiency. It was pointed out in evidence that under the conditions of the time the average consumption of coal per horse-power-hour was not less than 5lbs., while by the most efficient steam engines the consumption need not exceed 1½lbs. to 2lbs., and by gas engines only 1lb. to 1¼lbs. Seven to eight years have elapsed since these figures were laid before the Commission, and it will be interesting, therefore, to make a brief review of what has been happening during this period.

	Consumption in Millions of Tons	Saving in Millions of Tons.	Means of Economy.
Railways	12 - 14	5 7	Gas Generator and Engine. Electric Motor and Traction.
Steamers	6 - 8		
Factories	40 45	20 30	
Mines	10 12	5 7	Gas Engine and Recovery Ovens.
Blasting Furnaces	16 18	2 3	
Iron and Steel ...	10 12	2 3	
Other Metals ...	1— 2		Gas Generator and Coke.
Brickworks, Potteries, Glass and Chemical Works	4 6	1 2	
Gas Works	14 15		Gas Cooking and Heating. Briquettes and Coke.
Domestic Purposes	30 36	5 8	
	143 168	40 60	

At the time when the Commission was taking evidence the two most important developments in modern power production, the steam turbine and the large gas engine, were still to some extent on their trial.

For various reasons the large gas engine had been more in evidence than the steam turbine, partly, no doubt, because the rapid adoption of the latter for marine purposes had overshadowed its use for land purposes. In the minutes of evidence much more was said and thought about the development of power gas and gas engines than about the steam turbine. The hopes and expectations of the writer and of others who gave evidence on this subject were not quite realised in the way they predicted. In spite of its admitted superiority as a means for the development of energy from coal, the combination of gas producer and gas engine has made comparatively slow progress, while the other combination of steam boiler and steam turbine has made unexpectedly rapid progress. The more mature experience of to-day enables us to account for this in an entirely satisfactory way. Though inferior as a heat engine, the steam turbine has up till recently been able to prove itself superior as a machine, especially when it can be used in large units of 5,000 h.p. to 10,000 h.p. The gas engine is not only a superior heat engine, but it is also an excellent machine in units of any size up to 1,000 h.p. The most recent experience shows that units of 2,000 h.p., or even 4,000 h.p. are being satisfactorily made and worked, but this experience came to hand too late in the period under review to affect the actual result. The large steam turbine lent itself so admirably to the purposes of the Central Station engineer that its adoption for the production of electricity in bulk has almost led to a revolution in this branch of electrical engineering. The large power station of the Newcastle-on-Tyne Electric Supply Company at Walisend has now for a number of years been equipped with large turbo-generators of a total capacity of 40,000 engine horse-power. But this is only one of the Company's stations, for through their own operations and through those of their associated companies, the whole of the north east of England from the Tees to the Tyne has been linked up into one great system for the supply of electrical power in bulk to the railways, industries, and Corporations of the thickly populated districts between Middlesbrough and Newcastle. On the Tyne alone, power is being supplied to shipyards, engineering works, and railways which employ on the aggregate over 40,000 men. On this linked-up system there are not only great central stations similar to the Wallsend Station, in which the electric current is generated by coal fired boilers and turbo generators, but there are also a number of smaller stations set down beside coke ovens in different parts of Durham, where the waste gases from the ovens are burned under steam boilers for the production of current by turbo-generators. These "heat stations" are enabled to work continuously on full load, and therefore with the maximum economy, for they are linked up with the central stations in which the great

reserves of generating power can be used to maintain a perfectly steady supply under any fluctuation of demand. This important development in the north-east of England thus supplies a useful object-lesson on a scale so large that it cannot be ignored. It amply justifies many of the conclusions of the Royal Commission and of the witnesses who appeared before it, as to the economy of fuel which would result from the production and distribution of power in the form of current. It shows that engineers and other large users of power can be made to realise that it is worth their while to replace their less perfect methods of power production by electric motors driven by current obtained at reasonable prices from a great central system. It further shows that fuel economy by the use of waste gases from coke ovens and blastfurnaces is not only practicable but profitable, for the sub-company which owns and works these stations has made substantial profits from the outset. The lessons to be learned from this development have not been without their effect in other quarters, and it is to be hoped that ere long the other great industrial centres of the country will possess an equally satisfactory organisation for the supply of power in bulk.

Though there have been disappointments in connection with the development of the large gas engine, working either on specially prepared power gas, or on blastfurnace gas, it also has been making real and satisfactory progress, and to-day it is possible to lay down gas engine installations on a scale of thousands of horse-power at a first cost which is very similar to that of a modern steam installation on the same scale, and with machinery of a thoroughly trustworthy description which can be reckoned upon to produce a constant and steady output at a cost which compares favourably with that of steam installations on the largest scale.

It can be confidently predicted that the next seven years will see the gas engine taking a larger and more important place in the total power production. It appears also to be equally certain that the steam turbine will continue to be a large factor in the economy of fuel both by sea and land.

The use of engines working with suction gas producers, as well as of oil engines of the Diesel type, is rapidly spreading and will lead to the further displacement of wasteful and inefficient steam engines.

Closely associated with this reform is the replacement of small engines in works by electric motors driven by current obtained from central stations. The important object-lesson in this kind of reform in the north-east of England has already been referred to; but in every large town the same reform is going on, if on a smaller scale. The convenience of small motors is leading to their general adoption in the industries of even the smaller towns and cities, while in all the large industrial centres the organisers of electric supply on the one hand, and the makers of electric motors on the other, are united in their efforts to extend the use of electrically distributed power.

Similarly, the replacement of steam engines of small power by gas engines is being fostered and encouraged by the gas corporations. The importance of swelling the day load of the gas works in this way is being realised more and more, and the healthy rivalry between the electricity and gas departments is doing much to popularise the more scientific methods of power production. In economies in the use of coal for the production of heat for industrial purposes the progress during the past seven years has not been so obvious, but here also there are hopeful signs. In the coking of coal, beehive ovens are being gradually replaced by recovery ovens. The increasing annual production of sulphate of ammonia from coke oven works is a fair indication of the rate at which the replacement is proceeding. These figures, extracted from the 44th, 45th, and 46th reports of the chief inspector under the Alkali Works Regulation Act, are as follows:—

	Tons of Sulphate of Ammonia.
1903	17,438
1904	20,848
1905	30,732
1906	43,677
1907	53,572
1908	64,227
1909	82,886

If the yield of sulphate of ammonia be taken at 15lbs. to 16lbs. per ton of coal, or, say, 0·7 per cent., we arrive at a figure of 5,870,000 tons as the amount of coal which was coked during the year 1909 in recovery ovens. If the present increasing rate of conversion is continued, it seems not unreasonable to predict that within the next few years this important reform will have spread to the whole of the coking industry, and the greater part of the 16 to 18 million tons will be turned into coke in this way, and the saving of 2 to 3 million tons of fuel will be an accomplished fact. The writer has not, as yet, been able to collect any recent statistics of the replacement of raw coal by gas in metallurgical, chemical, and other works, but there is sufficient evidence of a general nature to show that real progress is being made. One indication of this is found in the sulphate of ammonia returns already referred to. In 1903 the output from gas producers was given as 10,265 tons. In 1909 it was 24,705 tons. These figures only apply to washed gas of the Mond type, and therefore to installations for the gasification of not less than 50 tons of coal per day. But it is probable that many more installations, both large and small, for the use of unwashed gas have been erected.

The item of consumption which is next in importance to that of "power production" is that of "domestic fires." This is now probably not less than 40 million tons per annum, or practically one ton per head of the whole population of the British Isles. The most hopeful sign of a coming reform in this direction is found in the general awakening of the civic conscience on the subject of smoke prevention. It is earnestly to be desired that this awakening may be really permanent, and that the partially successful, or even the entirely unsuccessful, efforts in the direction of reform may not be interpreted by the public in any hopeless spirit. The reform will not be effected by the adoption of one universal panacea, it must come from many sides and by the adoption of many methods each adapted to meet a particular type of case. Central heating, improved grates, smokeless solid fuel, cheap gas fires, cheap electric radiators, all these must take their due place in the reform if it is to be permanent and far-reaching.

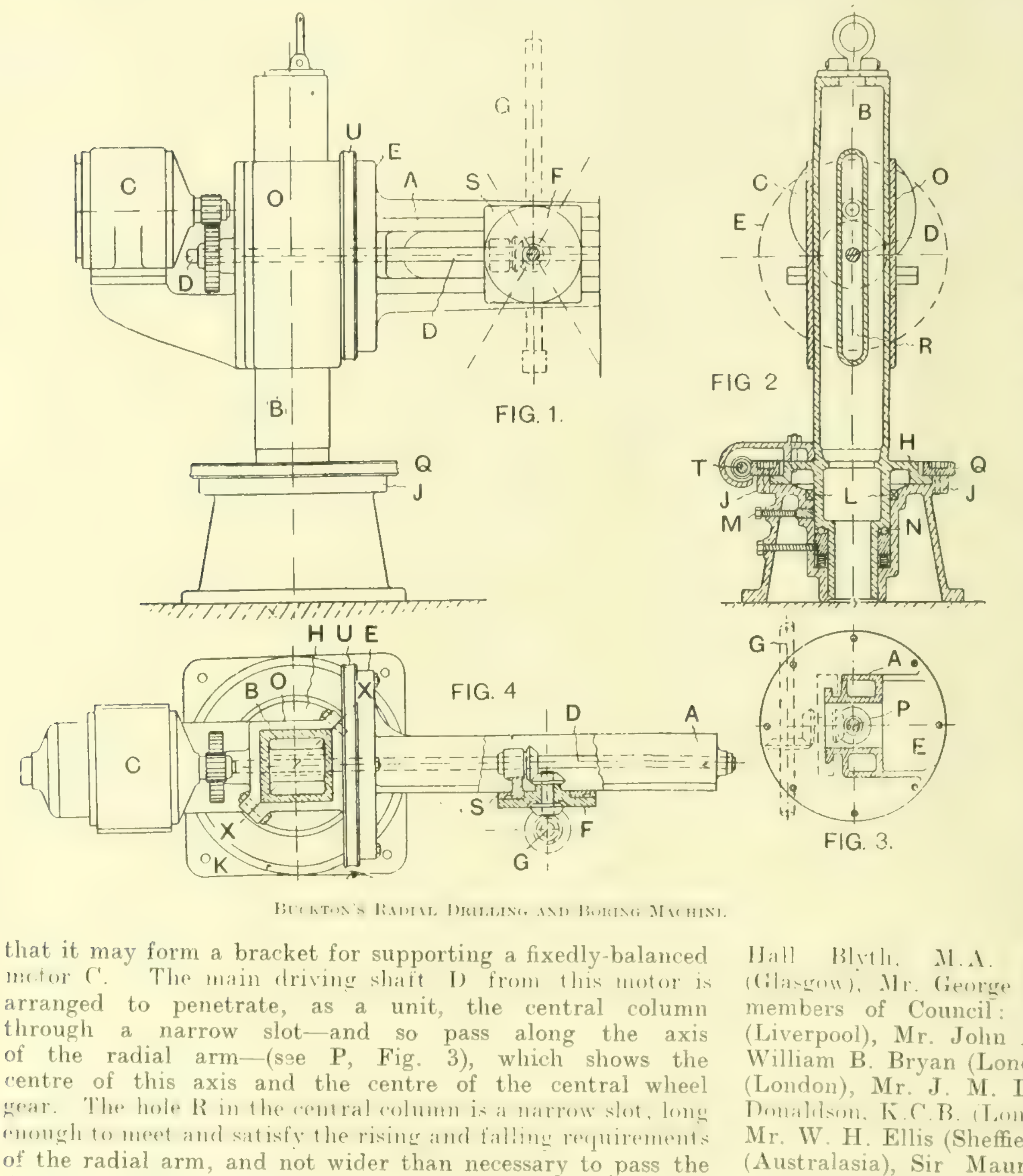
Suggestions as to Ways in which the British Science Guild might Help the Work of Reform.—Before the Royal Commission came to the end of its labours there was a strong feeling in certain quarters that something ought to be done to preserve the continuity of the enquiry in some permanent way. During the course of the enquiry new sources of information had been opened up, and the interest of many intelligent workers had been aroused in the question from a national as well as from a purely industrial point of view. It seemed unbusinesslike as well as unscientific that the useful organisation which had grown up in this way should be disbanded or allowed to fall to pieces through the lack of some permanent head whose duty it should be to keep certain of the more important statistics up to date and to report from time to time on progress in economy and reform. It appears to the writer that it is not yet too late for some steps to be taken with a view to the realisation of this idea. It also appears to him that this is a work which might wisely be undertaken by the British Science Guild either through a permanent committee of its own, supported by voluntary contributions, or by exerting its influence on the Government.

It appears also worth considering whether the guild could co-operate in some active way with the Smoke Abatement Guild in its missionary efforts and in its attempts to secure more satisfactory legislation on the subject of smoke prevention.

Launch of the Cruiser "Dublin."—This vessel, one of the new "Town" class of light armoured cruisers, was launched from the yard of Messrs. Wm. Beardmore & Co., Dalmuir, on the 30th ult. She measures 430ft. in length and has a tonnage of 5,400. She will be fitted with Parsons turbines of 25,000 h.p., driving four screws, and her designed speed is 25½ knots. Steam will be supplied by 12 boilers of the Yarrow type, fitted for burning liquid fuel as well as coal. The "Dublin" mounts eight 6in. guns and eight smaller weapons, has a capacity for 1,000 tons of coal, and, besides having protective deck, has armoured protection on the sides. The estimated cost of the vessel is £334,058. The keel of the "Dublin" was laid on April 6th, 1911. The average time taken for the construction of ships of this class is about 20 months, so that the "Dublin" should be commissioned about November.

BUCKTON'S RADIAL DRILLING AND BORING MACHINE.

THE accompanying illustrations show a design of radial arm drilling and boring machine, the invention of Joshua Buckton & Co., Ltd., Well House Foundry, Leeds, and C. W. James. Referring to the illustrations, the radial arm A, which at the centre of the machine takes the form of a vertical sliding piece O, for the purpose of embracing the central column B, is continued beyond the central portion in order that it may form a bracket for supporting a fixedly-balanced motor C. The main driving shaft D from this motor is arranged to penetrate, as a unit, the central column through a narrow slot—and so pass along the axis of the radial arm—(see P, Fig. 3), which shows the centre of this axis and the centre of the central wheel gear. The hole R in the central column is a narrow slot, long enough to meet and satisfy the rising and falling requirements of the radial arm, and not wider than necessary to pass the driving shaft through it, the slot being boxed up solid with the main casting. As close as possible to the face of the vertical sliding piece O is mounted a vertically-arranged swivelling connection E, for allowing the radial arm to swivel or rotate about its axis, which axis in this case is the centre of the shaft D through the whole of the 360°. On the flat saddle S of the radial arm there is mounted another swivelling joint F, in order that the drill head, whose centre lines are shown, may be slanted to any desired angle. It will be seen that there is no revolving sleeve encircling the central column, or any substitute therefor, above the base of the machine.



BUCKTON'S RADIAL DRILLING AND BORING MACHINE.

An arrangement—entirely circular—which allows the foot of the pierced central column B to be turned round, horizontally, to any position in the whole 360°, is shown arranged in the machine base, thus. At a convenient position below the lowest range of the vertical sliding piece is arranged a truly circular horizontal swivelling connection H (Fig. 2) of as large a diameter as the size of the machine demands. The outermost portion of this flange, of this circular swivelling piece H, forms part of the central column B, and by mounting it on and in a circular bed J, formed in the base of the machine, the fixed worm wheel Q assisting in holding the flange down, the central column can be held up tightly, but movably, in a truly vertical position. Below this swivel the column is continued downwards in a circular form, and is made to fit in the bored-out portion of the base. Rollers L are introduced to take side thrusts all round, and a set screw M arranged for locking the column at any selected position when at work.

When the size of the machine makes the superimposed weight considerable, and so renders the swivelling movements difficult to carry out, the column is arranged to run on a ball race at N, which is mounted on springs. These springs support a fixed annular ring on which the balls N roll. Again, when the size makes it desirable, the swivelling movements of the column B and the arm A (as well as the swivelling piece at E) is fitted with a worm and worm wheel, as follows: At Q (see Fig. 2) is the fixed horizontal worm wheel, and at T is the worm, which latter is mounted in a "housing" attached to and thrown out from the central column B. Another worm wheel is shown at U (Fig. 1), by which the radial arm may be moved round.

The vertical sliding piece O is formed with a loose side, or other adjustable piece, for taking up wear, as shown in Fig. 4, where the joint is arranged diagonally along the line X X.

INSTITUTION OF CIVIL ENGINEERS.

AT the annual general meeting of the Institution of Civil Engineers, held on Tuesday evening, April 30th, the result of the ballot for the election of officers was declared as follows: President: Mr. Robert Elliott-Cooper (London); vice-presidents: Mr. Anthony George Lyster, M.Eng. (Liverpool), Mr. Benjamin Hall Blyth, M.A. (Edinburgh), Mr. John Strain (Glasgow), Mr. George Robert Jebb (Birmingham); other members of Council: Mr. John A. F. Aspinall, M.Eng. (Liverpool), Mr. John A. Brodie, M.Eng. (Liverpool), Mr. William B. Bryan (London), Col. R. E. B. Crompton, C.B. (London), Mr. J. M. Dobson (London), Sir Frederick H. Donaldson, K.C.B. (London), Mr. E. B. Ellington (London), Mr. W. H. Ellis (Sheffield), Mr. W. Ferguson, M.A., B.A.I. (Australasia), Sir Maurice Fitzmaurice, C.M.G. (London), Sir John Purser Griffith (Ireland), Mr. C. A. Harrison, D.Sc. (Newcastle-on-Tyne), Mr. Walter Hunter (London), Mr. Harry E. Jones (London), Mr. E. H. Keating (Canada), Sir Thomas Matthews (London), Mr. W. H. Maw, LL.D. (London), Mr. C. L. Morgan (London), Mr. Basil Mott (London), Hon. Sir Charles Parsons, K.C.B. (Wylam-on-Tyne), Mr. F. E. Robertson, C.I.E. (London), Mr. Alexander Ross (London), Hon. Sir Francis J. E. Spring, K.C.I.E. (India), Mr. A. M. Tippett (S. Africa), Sir Philip Watts, K.C.B. (London), Mr. W. B. Worthington (Derby). This Council will take office on the first Tuesday in November, 1912.

The Council of the Institution have made the following awards for papers read during the session 1911-1912: Telford Gold Medals to Messrs. Ernest and Walter Mansergh (London); a George Stephenson Gold Medal to Mr. Roger T. Smith (London); a Watt Gold Medal to Mr. A. H. Roberts (Leith); Telford Premiums to Messrs. John Goodman (Leeds), A. B. McDonald (Glasgow), G. Midgley Taylor (London), D. C. Leitch (London), W. C. Easton (Glasgow), and D. H. Morton (Glasgow), and the Manby Premium to Mr. S. H. Ellis (Liverpool). The award for papers published in the proceedings without discussion and for students' papers will be announced later.

THE DIRECTOGRAPH PITOMETER.

A DEVICE which has been introduced recently for measuring and recording the flow of liquids in pipes, and which has the special feature of showing and recording its results on a direct-reading chart, is known as the directograph pitometer. It is used for recording the rate of flow as measured by pitot tubes, venturi meters, or other devices in which the desired result is obtained by the measurement of the difference between two pressures. As described in this article and shown in the accompanying cuts, for which we are indebted to "Engineering News," it is designed for use in connection with a pitot tube for measuring the rate of flow in water mains.

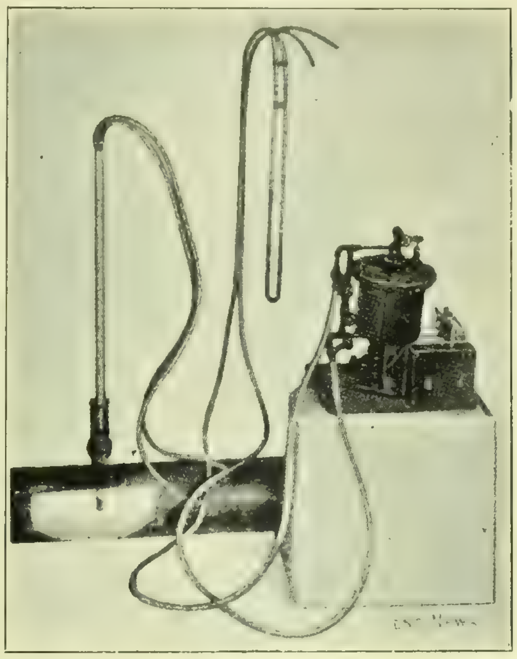


FIG. 1.—THE DIRECTOGRAPH PITOMETER, WITH PITOT TUBE AND CONNECTIONS TO RECORDING DEVICE.

The instrument and its connections to the main are shown in Fig. 1. The pitot tube is of a standard form, having two orifices or pressure openings, and connected with pressure tubes passing through a metal casing of such form and length as will permit its insertion into a water main through a 1in. opening, and will allow it to be set at any point across the diameter of the pipe. These two pressure tubes are connected by means of rubber tubes or pipes to a glass U-tube containing a liquid slightly heavier than water. Thus they form a good serviceable indicating flow meter for use in cases where a short test measurement is desired on any pipe line. When it is desired to obtain a continuous record of the rate of flow, from which the total output of any line (as, for example, a pumping-station discharge) can be computed, the recording device is connected in parallel arrangement with the U-tube, as shown in Fig. 1. This method of connection allows the instrument to be used either for indicating or recording the rate of flow, and furnishes means for checking the adjustment of the recorder.

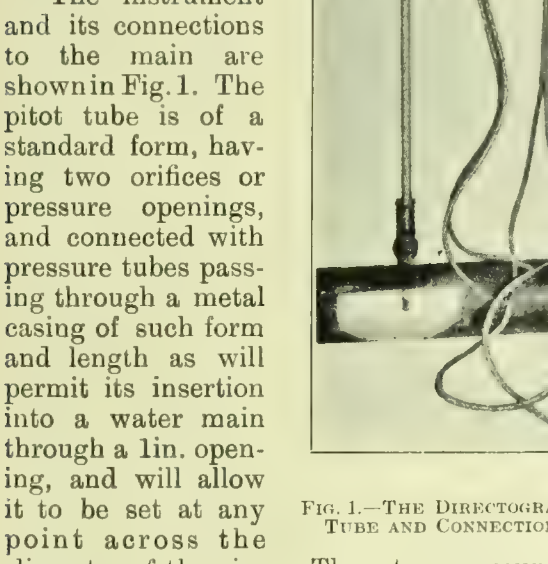


FIG. 2.—SECTIONAL ELEVATION OF THE RECORDING APPARATUS OF THE DIRECTOGRAPH PITOMETER.

The recorder is shown by the sectional drawing, Fig. 2. It consists of a collapsible metal box or bellows A, built up of flat and corrugated diaphragms. This contains a helical spring B, made of phosphor-bronze wire, and is enclosed in a cylindical brass case C in such a manner as to form two separate pressure chambers. The upper chamber or interior of the collapsible box A is connected to the upstream or impact orifice of the pitot tube by the tube D, and the lower or outer chamber is connected to the down-stream or trailing orifice by the tube E.

If there is no flow in the main, the collapsible box will stand at a normal position of rest, as the pressure in both chambers will be equal. But if the water in the main is in motion, the pressure in the upper chamber is greater than in the lower chamber and the bellows is extended or expanded a distance which is dependent upon the amount of difference between the pressure in the two chambers and the resistance of the helical spring. This thrust is transformed by means of rollers and cam F into a rotary motion, and is transmitted through a frictionless packing gland to a pen arm G. This arm carries a pen H, which marks on a continuous paper chart, and this is counterbalanced by the weight J.

The chart (Fig. 3) is made in the form of a continuous sheet or ribbon, and has parallel lines indicating feet and fractional feet of velocity per second. A sample of a chart with record is shown in Fig. 3, and it will be noted that the transverse lines or hour-divisions are curved to agree with the radial movement of the marking pen. The mechanism is so constructed that the distance travelled by the pen is directly proportional to the increase in velocity, thus permitting the use of a polar planimeter to obtain the average rate of flow for any period of time. This form of chart is especially desirable, since average rates, and therefore total amounts, for given periods can be obtained from it with a minimum of office work. In fact, where the flow is fairly steady, as at many pumping-station outlets, the average rate can be obtained by inspection without the use of the planimeter.

The portability and convenience of installation combined with the direct-reading chart are claimed to make this meter specially adapted for the use of the water-works engineer, as by its use he can determine (1) the distribution of supply along the lines of the various feeder mains in the system, (2) the velocities under which these feeder mains are working, (3) the amount of water used in any particular section of the distribution system, and (4) the actual output of the pumps and consequently the efficiency of same.

In making field surveys, the ease with which the instrument is installed and the small expense involved enable the operator to proceed much more rapidly and to carry on the investigation to include much smaller limits of territory than he would be able to do by the use of meters which require cutting into the main and the resultant permanent installation of the meters or expensive bypass connections. Further,

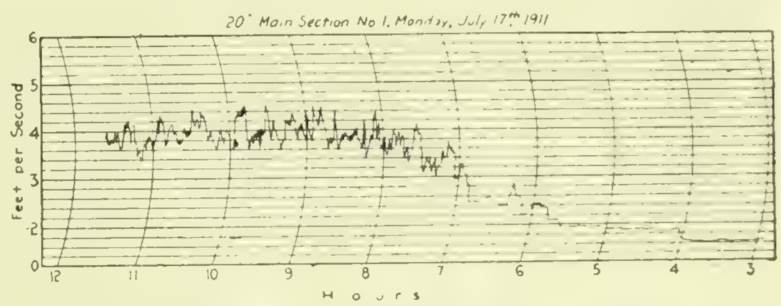


FIG 3.—SECTION OF CHART MADE BY THE DIRECTOGRAPH PITOMETER.

the number of meters required to carry on a survey is limited to the number of points at which simultaneous readings are desired, regardless of the size of main, since the same instrument can be used on any main, from a 4in. to the largest size in the system.

When used as a master meter to determine the output from a pump or other source of supply, it offers the same advantages as to convenience and cheapness of installation. When used on a pump it can be equipped with a special scale attached to the U-tube so calibrated as to read in terms of revolutions per minute, thus making a convenient indicating instrument with which to check slip of the pump by a very simple comparison of readings on the scale with readings of the revolution counter. The care of this instrument is much the same as that required by any recording gauge, and therefore it can be operated at a station by the engineer or his assistant who has charge of the other various gauges about the plant without additional expense of expert trained service.

This device was designed by W. R. Brown, of Chicago, and was tried by him with satisfactory results on both pumping-station and field-survey tests at Milwaukee, Wis., during the past summer. Fig. 3 is a reproduction of one of the charts obtained during these tests. Patents on this invention were obtained by the Water Works Specialty Company, 35, South Dearborn Street, Chicago, and it is now being manufactured by that company.

AERIAL FLIGHT.*

BY HENRY REGINALD ARNULPH MALLOCK, F.R.S.

(*Concluded from page 551.*)

TURNING again to Fig. 4, which shows the discontinuous flow of a perfect fluid past a plane, and comparing it with Fig. 9, the actual flow of water or air in the same circumstances, we see, at anyrate, some of the reasons for the difference between the forces calculated and found. On the up-stream side of the plane friction does little to modify the conditions except in the neighbourhood of the edges; but down-stream we find, instead of a pond of still fluid, a complex wake consisting of a central current moving forwards towards the plane, bordered by a series of eddies whose origin is of the same nature as those just

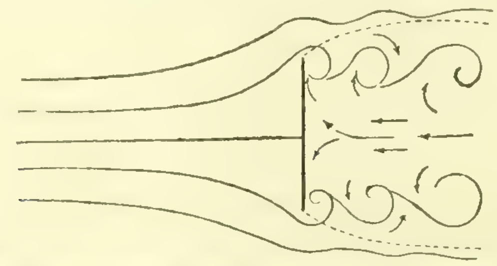


FIG. 9. FRICTIONAL FLOW: STREAM NORMAL TO PLATE.

referred to in the expanding channel, namely, to degradation of the streams passing round the edges of the plane which, having insufficient velocity to follow the stream-line path of Fig. 4, are deflected inwards and become involved with the reversed central stream, about half the fluid in each eddy being supplied from up-stream and half from the wake.

The eddies are formed periodically, growing to a certain size, and then, breaking away from their place of birth, they form part of the train which borders the wake current. The wake current itself is due to the constant removal of fluid in this way from the back of the plane; and the fact that the outflow from the back has its maximum velocity close to the edge, where the composite eddy is being formed, shows that the pressure on the back of the plane is lower at the edges than in the centre. Hence it could be stated with certainty, even without any experiment, that the total resistance of a plane must be greater than $\rho\, v^2 \dfrac{\pi \sin \alpha}{4 + \pi \sin \alpha}$, which assumes that the pressure over the rear surface is uniform, and equal to the general pressure at a distance.

Experiment, however, is required to determine the actual resistance, and when the plane is broadside to the stream this is found to be about half as much again as the head resistance alone, or about 20 or 25 per cent. greater than the dynamic head × the area of the plane.

When the angle α is small, as it always is in flight, the character of the wake takes the form shown in Fig. 10. Here the wake stream is only recognisable as a reversed current quite close to the plane, and the small eddies as fast as they are formed are so rapidly degraded that after travelling a short distance they are merely recognisable as slight variations in the direction of the general current. The abstraction of wake water by eddy-making continues, however, even for very small values of α, and has the effect of deflecting the upper boundary

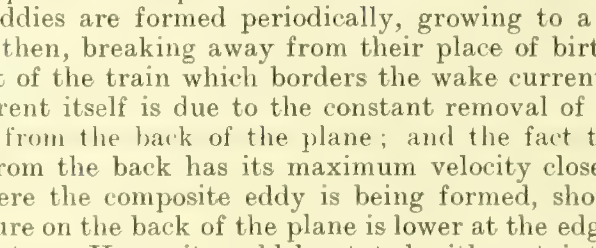


FIG. 10.—FRICTIONAL FLOW: STREAM OBLIQUE TO PLATE.

of the wake as shown. The deflection may be considered from another point of view as the outcome of the defective pressure on the down-stream surface of the plane.

This short account gives a general explanation of the observed difference between results calculated for the discontinuous flow of a perfect fluid and those actually found by experiments in air and water, and if the nature of the flow over the back surface were accurately known, the value of α for the maximum of L/R could be predicted. Even in the absence of this knowledge, the assumption that surface friction varies as v^2, and acts only on the up-stream side, leads to a value of α that is not far removed from truth.

Let A B, Fig. 11, be the plane making a small angle α with the stream, and let L and R be the lateral force and resistance which would be experienced if there were no friction. If L′ and R′ are the same quantities, taking friction into account, and putting $F\,v^2$ as the frictional force parallel to A B, we have $L' = L - F\,\alpha$, and $R' = R + F\,v^2$, and since $L = R_n\,\alpha$, and $R = R_n\,\alpha^2$, R_n being the normal resistance $A\,v^2$:

$L' = L - F\,\alpha = \alpha\,v^2\,(A_n - F)$, and $R' = R + F\,v^2 = v^2\,(A\,\alpha^2 + F)$; hence $L'/R' = \alpha\,(A - F)/(\alpha^2\,A + F)$ and this is a maximum when $\alpha = \sqrt{F/R}$.

Lanchester's experiments make $F/R = 0{\cdot}0075$,
Zahn's ,, ,, $F/R = 0{\cdot}0037$,

which correspond to α 6·5 or 3·5 respectively.

The actual value found from direct experiments on L and R lies between these two, and although 6·5° is nearer the truth than 3·5°, this does not imply that 0·0075 is the more nearly correct value of F/R, for the complete theory must take into consideration the action of the streams on both sides of the plane.

I may add that the work done in eddy-making, and therefore the total resistance, varies with the stage of growth of the eddy, and that the resistance of a plane in a real fluid is not a constant, but a fluctuating quantity, the period of fluctuation being the time occupied in the formation of each eddy. The whole subject of eddy production—real eddies, it must be remembered, are very different from the closed-circuit vortices of mathematics—presents a wide field for useful investigation, in which very little has as yet been done.

The curves in Figs. 5 and 6 refer to the properties of plane surfaces. In flying machines the wing surfaces, as is well known, are slightly curved. The typical reactions of such a curved surface are shown in Fig. 12. In this particular diagram the surface exposed to the stream is one-eighth of the circumference of a circular cylinder. Here, if the inclination to the stream (the angle α) is measured from the chord, α is negative when the lifting force vanishes, and the resistance is

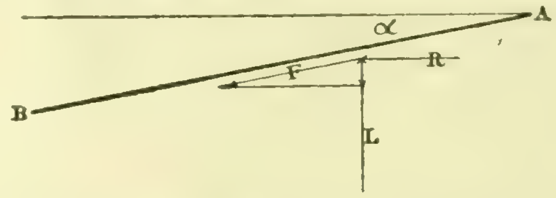


FIG. 11.

not a minimum in this position. The curve showing the ratio of lateral force to resistance is of the same type as shown in Fig. 6, but with rather a flatter top, so that the region of best efficiency is not confined within such narrow limits as it is in the case of a plane.

In Fig. 13 the curves relate to a body whose back surface is part of a cylinder, but with a plane front. Here again the L/R curve shows a flattened top as compared with a plane, although not in such a marked way as when the front is concave; but by making the section of the body a meniscus as good results can be obtained as from a single concave surface. Many more or less fanciful benefits have been claimed for sections in which the bounding curves are not parts of circles, but apart from considerations of this kind, the increase in the range of efficiency given by any reasonable form of curve and the facilities offered by the meniscus section for the introduction of stiffening girders in the substance of the wings are sufficient reasons for the adoption of the forms actually in use.

From the curves just given it may be calculated that with such a fluid as air, allowing 1/7 as a possible gliding angle, it would require 3 h.p. and a speed of 27 miles per hour to support a weight of 150lbs. on 150 sq. ft. of wing surface, so that even if the wings and framework of a flying machine were weightless, it would require something like 30 times the power of a man to make such a machine fly. It is clear, therefore, that human beings will never be able to fly by their own muscular exertion, and it was not until the internal-combustion engines had been developed in connection with motor cars that sufficient proportion of power to weight was available for ascents in still air. If ascending currents can

* James Forrest lecture delivered at the Institution of Civil Engineers, April 19th, 1912.

be found or if use can be made of differences of speed in the wind at different levels, there is no reason why engineless flight should not succeed, but the opportunities are rather limited.

The heaviest birds which can fly (great bustards, turkeys, and some of the vultures, eagles, and pelicans) weigh between 20lbs. and 30lbs. Of these, bustards and turkeys are short-winged and the load is over 2lbs. to the square foot of wing. But their flights are short and their wing movements rapid, and the power expended while rising from the ground must be very great in proportion to their size. The large birds which make long flights have wing areas giving a load of less than 2lbs. per square foot, and are all adepts at making use of ascending air currents, so that for the most part of their time in the air they have but little work to do.

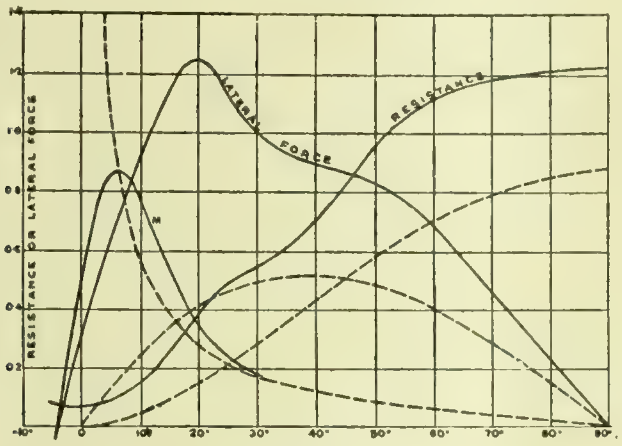


FIG. 12.—VALUES FOR A SURFACE FORMING 45° OF A LONG CIRCULAR CYLINDER.

Much controversy has arisen on the question of the sufficiency of upward currents or upward components of currents of air to account for such flights, but the more the circumstances are examined the more clearly it appears that soaring is in most cases effected in this way, although the origins of the ascending currents are very various. Sometimes they are caused by natural obstructions in the path of the wind, such as cliffs, hills, the sides or sails of a ship, or the slope of waves, but on a larger scale they are chiefly the result of air ascending after having been warmed by contact, direct or indirect, with the ground. At low levels such vertical movements are very small, and at the surface of the ground any motion must, of course, be parallel to the surface, but at considerable height, especially in sunny countries; these convection currents must always exist even when the weather is calm, except in the rare events of large tracts of sea or country having the same temperature as the air in contact with them. It was by experiments on gliding in a wind blowing up a hillside that the Brothers Wright got sufficient experience to control the wings of their machine and maintain its balance in the air, and, this accomplished, true flying followed almost as a matter of course when a suitable engine was added.

I do not propose to devote much time to the relative merits of the various types of flying machines which have been introduced since the first success of the Wrights. Practically the monoplane and biplane are the only candidates in the field at present, and each has advantages for special purposes; but, given the necessary engine power, together with a supporting surface appropriate to the intensity of the load, it is merely a question of skill on the part of the pilot to be able to fly whatever the disposition of the surfaces may be; the degree of skill, however, required, and the chances of accident, are much greater with some forms than others.

With monoplanes and biplanes now in use, it appears to be not much more troublesome to learn to fly in still air or a uniform wind than to manage a bicycle, in spite of the extra degrees of freedom introduced by the absence of any fixed support, but in gusts and eddies the difficulties of balancing are formidable and of many kinds. To anyone flying at a height the sense of true vertical which we have, and by which we adjust our balance when standing or moving on the ground, is replaced by the direction of the resultant force of gravitation and any acceleration which the machine may be subject to. In still air or in a uniform wind acceleration can only be the result of an alteration of level or of the engine speed, and the effects due to the latter cause cannot be very large or rapid. When, however, the machine passes quickly from a region of still air into a wind, or vice versâ, which is what happens practically in gusts, the sensation of vertical direction is lost, and although the speed and direction of travel of the machine only change gradually, the resultant of the forces acting on it does so instantaneously, not only in direction, but in magnitude.

The three diagrams in Fig. 14 show the direction in which a short pendulum at the centre of gravity of the machine would point (*a*) when the flight is in uniformly moving air, (*b*) when in an overtaking gust, (*c*) in an opposing gust. The connection between the angle (θ) which the pendulum makes with the true vertical being

$$\tan \theta = \frac{\text{Propulsive force} - \text{Resistance}}{\text{Lifting force}}.$$

It is hardly to be wondered at that such changes in the apparent vertical should be confusing to the pilot, and that accidents which are often fatal should happen while experience is being acquired. Side gusts may produce still more embarrassing effects, the character of which depend on the class of machine and the disposition of the wings to a greater degree than is the case with gusts in or against the direction of motion. Nevertheless, when there is sufficient distance between the machine and the ground, and provided the airman can keep his head and his seat, it ought to be possible to correct any upset due to these causes if the various parts will stand the stress of the necessary manœuvres.

These stresses may be very large compared to the ordinary flying stresses, as, for instance, when a machine plunges and has to be brought rapidly into a horizontal path in order to avoid striking the ground. At the present time the wings and framework of all machines are made as rigid as possible by wire stays, &c., with the result that the breakage of any one part is likely to wreck the whole; and it is probable that as time goes on more attention will be paid to increasing their pliability, so as to allow a reasonable amount of distortion without crippling the structure. The problem of determining the greatest possible flexibility which can be given to a structure of a definite shape, size, and weight, which is also to have a definite initial stiffness, is theoretically capable of solution in terms of the strength, density, and dynamic worth of the materials (by dynamic worth is meant the worth which can be stored elastically in the unit volume), and although I am not aware that any case has been worked out, the subject is worthy of investigation.

The most important questions which can be raised about flying machines relate to their stability in flight and the ease or difficulty of starting or stopping them, and on each of these questions I will say a few words. First, as to the theories of stability which have been given from time to time.

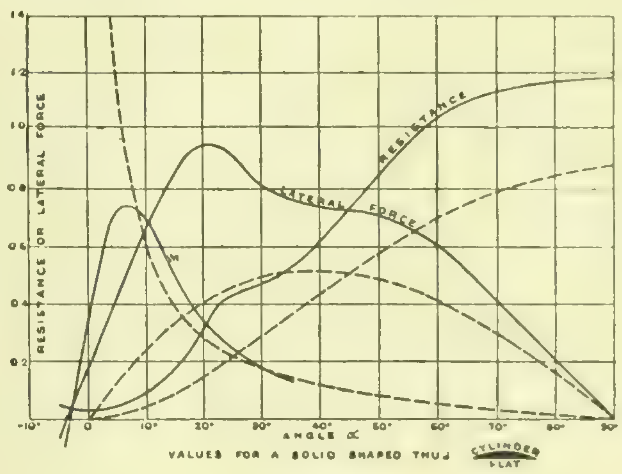


FIG. 13

Some of these I believe to be correct as far as they go, but none of them are anything like complete, since they are all based on the pressures and variations of pressure acting on the up-stream surfaces of wings, and omit the variations due to the eddy formation which goes on on the down stream side.

Before proceeding further it will be as well to define what I mean by stability in connection with flight. A flying body is stable if, when acted on by a propulsive force and the

reactions of the air (but not steered), any small angular velocity imposed about a horizontal axis tends to die out, and any small displacement about a vertical axis to reach a constant value. Or, in other words, any accidental motion of the nature of pitching or rolling must tend to disappear, while an arbitrary twist to the right or left must put the machine on a new but straight course.

Technically, stability is compatible with the presence of forces which produce increasing oscillations as the result of disturbance, but for the present purpose not only must the average force so called into play be a restituent force, but the disturbing motions must also tend to die out. The oscillations, in fact, must be damped, and not maintained. The variation of pressure caused by the periodic formation of eddies, however, is frequently of a kind which will maintain or increase a disturbed motion until some other cause puts a limit to its magnitude.

An example of this may be seen in the spinning-plates which are sometimes used for advertisements. Here a long rectangular plate is mounted on an axis parallel to the long side and passing through its centre of gravity, and is therefore in neutral equilibrium if gravity is the only force which acts on it. In a wind, however, the plate spins, and spins in either direction indifferently, and if started gently accelerates until the linear speed of the edge bears a certain proportion to the speed of the wind.

This would not happen if the only forces in action were those on the windward surface, and the rotation is produced by the distribution eddies at the back, which change in a remarkable way in the course of each revolution. This can be

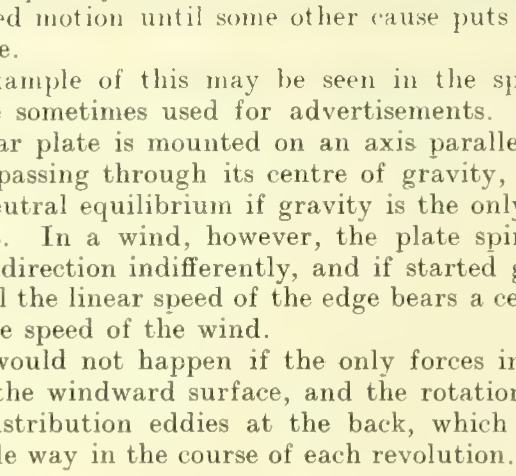


FIG. 14.

well observed if a stream of smoke is allowed to flow past the revolving plate, and is intermittently illuminated at a rate slightly different from the half period of revolution.

From observations of this kind, which I made about 20 years ago, Fig. 15 has been prepared, showing the eddies during the various stages of their growth. Many other cases might be adduced where, for similar reasons, a perfectly symmetrical body symmetrically supported will spin in either direction in a current, but the example given above is sufficient to show the importance of the back pressure in the theory of stability.

None of the flying machines at present in use are stable in the sense in which the word is here used, but in the ordinary conditions of flight the eddies formed behind the wings are small and their period of formation so rapid that the change in the attitude of the wings (that is, in the angle at which they can produce in one period is inconsiderable, and the stability or instability depends chiefly on the distribution of pressure on the up stream surfaces; but the case is very different when the machine is passing through variable currents, and the angle at which the air meets the wings is liable to large and rapid changes. The alterations in the arrangement of the pressures on the back surfaces are then much greater and take longer to go through their phases—long enough, in fact, to make the process of correction exceedingly baffling.

That flying machines should be unstable in ordinary circumstances is really of very little consequence. The same objection applies to walking. No conscious effort, however, is required to keep upright on terra-firma, but on the deck of a small vessel in a seaway we all known that sea-legs are only got by practice, often involving many falls. The flying machine, in gusty weather, is much in the same condition, but the falls have more serious consequences.

I think it very unlikely that any type of flying machine will be evolved which, without guidance, will be safe in bad weather; but it is quite possible that the necessary corrections should be applied by an automatic device, and if flight is to be anything but a fair-weather pastime something of the kind will probably be found necessary. What is required is an apparatus which will so trim the wings as to keep the machine related in a definite manner, firstly, to the true vertical, and, secondly, to the direction of the resultant force at the time. The various ways in which this could be done might furnish subjects for several lectures, and I will only say here that the many proposals which have been made to use pendulums or gyroscopes to act directly on the correcting mechanism are certainly bound to fail.

It is essential to the success of any automatic control that the forces called into play to make the corrections of trim should not react on the director of those forces, whether this is a pendulum or gyroscope, or any other equivalent device. The only instance in which this condition has been fulfilled is the "steady platform" of the late Mr. Beauchamp Tower. In this Mr. Tower caused a gyroscope (which in effect was a pendulum with a very long period) to direct an axial jet of water on a group of openings connected by pipes to a series of rams, in such a way that if the openings did not face the jet symmetrically, water flowed into one or other of the pipes, and so altered the position of the openings until symmetry was restored, the restituent force having no tendency to alter the direction of the axial jet. There may be other methods of attaining the same object in the case of wing-trimming or control for flying machines, but any device in which the correcting force tends to alter the position of the corrector is more likely to do harm than good.

The question of stability also becomes important when the flying machine is coming to the ground. In alighting, the machine either has to touch the ground at full speed and trust to retardation supplied chiefly by the ground for coming to rest, or it must alter the wing attitude with reference to the path so as to experience a greater resistance for a given lift. This latter method is adopted by birds when pitching on the ground, and in their case at the last moment is generally supplemented by flapping the wings, when the velocity is so much reduced that the greatest lift the wing area is good for will not sustain their weight. Birds, when pitching on any elevated perch, such as a bough of a tree or a rock, nearly always finish their flight in an upward direction, but neither this nor wing-flapping is at present open to flying machines on account of the mechanical difficulties of construction.

Alteration of the trim of the wings, however, presents no great constructional difficulty, but when the angle between the wings and the path is large the effect of accidental variations of pressure due to eddy formation is more serious, and the instability is greater than when the angle in question is the gliding angle; and here, therefore, automatic correction would be very important. If this could be used successfully, a machine whose flying speed was 40 miles an hour, and which had a gliding angle of 1/7, could, as may be found from the resistance diagrams, reduce its velocity by alteration of the trim of the wings to 25 miles per hour before the weight ceased to be air borne. Further, since for the whole time the resistance would average about one-fourth of the whole weight, the time taken in effecting the reduction of speed would be

four times that required for gravity to generate the difference between 40 and 25, being 15 miles per hour. During this time—2·7 seconds—the average speed would be 32 miles per hour, and the machine would cover about 120ft. These rough figures can be easily corrected from the curves giving lift and resistance for any particular machine, but there can be no doubt that it would be a substantial gain if the high speeds, which are becoming more and more common, could be quickly and safely reduced before reaching the ground. No corresponding aid to starting, however, can be given except by some source of power external to the machine, and this will always limit the uses of the present types of flying machines in much-enclosed and rough country.

It is quite possible to imagine a flying machine made with lifting screws which would rise vertically from the ground and remain poised and stationary in the air, but no success has hitherto attended any attempts in this direction, partly because the inventors have not realised the very large blade area necesary for reasonable economy of power. One way of realising the stationary condition would be to connect two flying machines travelling at the same speed in opposite directions with a length of rope, and letting them circle round one another. No "banking" would take place, as the centrifugal force of each would be taken by the pull of the rope. If the latter were shortened as far as possible, the pair would, in effect, form a single machine with a lifting screw. The experiment would be dangerous, and is not recommended for trial, but is mentioned rather as indicating the size of the screw blades which the hovering type of machine would require.

Something may be said about the trials now being made both here and abroad to rise from and pitch on water. The floats attached to the machine for this purpose should be of the type with which Sir J. Thornycroft's skimming boats have made us familiar, but with well-shaped floats the difficulties are chiefly concerned with the fact that the centre of gravity and line of applied force are at a considerable height above the plane of resistance of the floats, so that both in starting and stopping there is a couple tending to make the machine dive, which, especially as regards coming down on the water, may cause accidents. A monoplane in which the lines of propulsive effort and water resistance are not far separated seems most likely to be successful, but in any case calm water is a necessity. Waves of the length of the fore and aft spacing of the floats (such waves would have periods lying between $1\frac{1}{2}$ and 2 seconds, and speeds 5 to 7 miles per hour) if at all steep would make rising from the water or coming down a difficult operation, though a long, smooth swell might be an assistance.

In taking a general view of the present condition of the art of flying it must be admitted that much remains to be done before it ceases to be a fine-weather sport, and I think the right course to pursue would be to try to evolve a type of machine which is fairly safe even in turbulent winds, and which can arise and alight on the smallest possible area. When the essential features of the design which secures these results are recognised, the machines may be specialised for war or other purposes, and additional improvements may be introduced for convenience, comfort, or speed.

The opinion seems to be gaining ground that flying machines are more likely to be usefully developed than dirigible balloons, and in this opinion I fully concur, more especially as regards the larger dirigibles, which I have always considered too frail and too liable to accident to be of much real service. All air craft, whether heavier or lighter than air, will for some time to come be designed for the purposes of sport or war rather than for commerce, and although for war machines cost takes a second place, it must be remembered that a dirigible costs rather more than a torpedo boat, whilst a flying machine costs rather less than a torpedo. Further than this, there are very few services to be performed by a dirigible which could not be carried out as well, or better, by a flying machine; the only, and rather dearly-purchased, advantages attaching to the balloon being its power of rising quickly, and of leaving the ground without the necessity of taking a run, and I think the best policy for us would be, while recognising the occasional usefulness of dirigibles of moderate size (and building a sufficient number for experiment), to devote our attention chiefly to the elaboration of the most efficient means of destroying them.

From the purely scientific point of view it cannot be said that the ascents of any large balloon have added much to our knowledge. The small balloons, however, recently used for carrying self-recording instruments have ascended to heights (60,000ft. or more) at which personal observation is impossible, and have brought back valuable information which could hardly have been attained in any other way; and although the records as a rule only deal with pressure and temperature, there is no reason why solar radiation should not also be measured by suitable apparatus. Such measures would give a better knowledge of the temperature of the sun than could be got by direct observation, even on the highest mountains.

In conclusion, and speaking generally, I may say that it seems desirable to encourage experiment on the widest scale, even if much of the work is not on strictly scientific lines; bearing in mind that great improvements may result from the working out of ideas which as originally conceived were unsound or even absurd; and that this is the more likely to be the case in such a subject as flight, for which, as I have endeavoured to point out, a considerable part is not yet subject to accurate theoretical treatment.

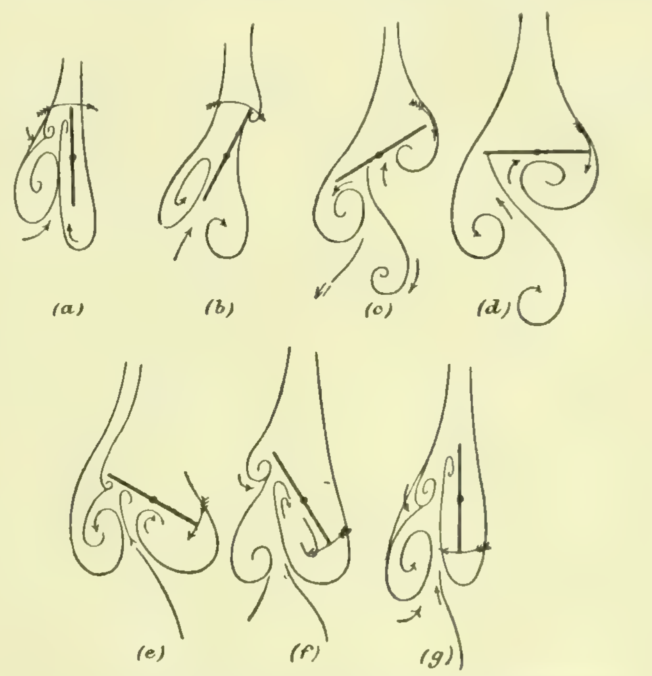


FIG. 15.—EDDIES FORMED AT THE REAR OF A PLATE SPINNING IN A CURRENT OF AIR.

APPENDIX I.

The relative densities of different gases at the same altitude may be conveniently expressed in terms of heights of homogeneous atmosphere of each. The height of the homogeneous atmosphere for a gas is defined as the height of a column of the gas of uniform density (equal to that which it has at sea level) whose weight produces the atmospheric pressure at its base. Thus the height of the homogeneous atmosphere H_a for air is in feet the number of cubic feet which weigh 2,100lbs. nearly, and since 1 cub. ft. of air weighs 0·080lb., $H_a = 26{,}000$ft. nearly.

For hydrogen $H_a = H_a \times$ the ratio of the densities of the two gases (viz., 16), so that $H_a = 416{,}000$ft. nearly.

If the distribution of temperature in the atmosphere is isothermal, the actual height h above sea level at which the pressure is p is $h = H \log \frac{p_0}{p}$. Thus when $h = H$ the pressure is p_0/e, and the pressure does not vanish until an infinite height is reached.

If, on the other hand, the temperature decreases according to the adiabatic law—that is, if the temperature of the air at height h and pressure p is what it would be if with surface temperature to start with it was lifted without loss or gain of heat to the given height

$$h = H \frac{\gamma}{\gamma - 1}\left(1 - \left(\frac{p}{p_0}\right)^{\frac{\gamma-1}{\gamma}}\right), \text{ or } H \frac{\gamma}{\gamma - 1}\left(1 - \left(\frac{\rho}{\rho_0}\right)^{\gamma-1}\right).$$

In this case, therefore, there is a definite upper limit to the atmosphere, for when $p = o$, $h = H\frac{\gamma}{\gamma-1}$ (rather over 17 miles for air, and 275 miles for hydrogen).

What the actual upper limit of the atmosphere may be is not known, but experiment shows that for the lower strata at anyrate the adiabatic distribution of temperature is not very far from the truth.

If we have two short columns, one of hydrogen and one of air, of the same length, and both at height h, then (putting $H\frac{\gamma}{\gamma-1} = K_a$ for air, K_H hydrogen, and N for the ratio of the densities, ρ_a/ρ_H at sea level) the density of the air at h is $\rho_a (K_a - h)^{\frac{1}{\gamma}}$, and of the hydrogen $\rho_H (K_H - h)^{\frac{1}{\gamma}}$.

If the balloon carries no weight, it will ascend until the densities are equal, which occurs when

$$h = N K_a \left(\frac{N^{\gamma-1} - 1}{N^{\gamma} - 1}\right),$$

or, since $N = 16$ for air and hydrogen, and $\gamma = 1{\cdot}41$, $N^{\gamma-1} = 3{\cdot}1$, $N^{\gamma} = 51$, and $K_a = 17$ miles,

$$h = \frac{16 \times 17 \times 2{\cdot}1}{50}, \text{ or } 11{\cdot}5 \text{ miles},$$

and no hydrogen-filled balloon could ascend higher than this if the temperature was the adiabatic temperature.

The ascents of the balloons with recording instruments, however, lead to the belief that at heights exceeding 6 or 7 miles the temperature is constant, or nearly so, so that the practicable heights of ascent may very considerably exceed the 11·5 miles just mentioned.

APPENDIX II.

The fact that, if a bird can enter at will winds of different velocity, it is theoretically possible for it to extract work from the air, has been pointed out by Lord Rayleigh, W. Froude, and others; but I do not know that any calculation has been made in order to see whether in such circumstances as are likely to occur, the work so obtained is sufficient to enable a bird actually to soar or maintain its level.

It has usually been supposed that the variation of wind velocity occurs at different levels, the wind being slower nearer the ground; but in one way this complicates the question, and it is simpler to suppose that the field of flight is divided into two regions by an imaginery vertical boundary, on one side of which there is a uniform velocity of $+v$, and on the other of $-v$ at all levels.

On this supposition I have computed an example for a bird whose wings bear a load of 1lb. per square foot, with a gliding speed of 60ft. per second, and gliding angle of 1/7. The wind in the two parts is supposed to have velocities of ± 10ft. per second, and the bird to have a speed of 60ft. per second over the ground.

On entering the first region against the 10-mile wind, the relative velocity of the wind and bird is 70ft. per second, and under these conditions it experiences a lifting force greater than its own weight, and therefore begins to rise. As it requires upward velocity, it alters its trim so as to always meet the resultant wind at the gliding angle. At the same time it meets with greater resistance, and therefore loses velocity in the path of flight.

This loss may increase to 10ft. per second, at which time the path will be level and the weight just air-borne.

If at this point the bird can turn instantaneously through 180° and immediately enter the other region where the velocity is $-$10ft. per second, it will again have a velocity of 70ft. per second relatively to the air, and the whole process of elevation can be repeated.

If the bird cannot turn instantaneously, or if the two regions are separated by an interval, level is lost at the gliding angle while passing from one to the other in descending at the gliding angle. Thus, if a constant average level is to be maintained, the length of the path traversed during the turns must not exceed $1/\alpha$ times the height gained between the turns.

In the computed example the force normal to the path between the turns is taken to be $A\alpha v^2$, the air resistance in the path $\alpha^2 v^2$, and θ the inclination of the path to the horizontal.

Then the acceleration normal to the path is

$$g\left(A\alpha v^2 - \frac{1}{\cos(\alpha + \theta)}\right),$$

and the retardation along the path $g\,(A\alpha^2 v^2)$. A is assumed to be $\frac{1}{519}$lb. per square foot.

Integration for velocity and position leads to long and cumbrous expressions, but by computation and plotting it is found that the gain in level, while the relative velocity of the bird and air is reduced to 60ft. per second, is about 10ft., and that this reduction takes places in rather more than 110ft., and occupies about 2 seconds.

Thus, if the two regions are sharply divided, and on one side to the other of an imaginary vertical plane the wind velocity varies from $+10$ to -10ft., a bird, if it could turn instantaneously, might, without expending any work on its own part, rise 300ft. per minute.

If, on the other hand, the effective distance between the two regions is 70ft., the bird would drop as much in passing from one to the other as it gained in each, and could just maintain its average level.

It may be noted that the difference in the relative energy of a bird which is just air-borne at 60ft. per second, and enters a region where the relative velocity is 70ft. per second, is $\frac{70^2 - 60^2}{2g}$ or a little over 20ft.-lbs. per pound of bird. If there were no resistance, therefore, the bird could rise 20ft. in each region, while its speed was being reduced 10ft. per second by the action of gravity, the difference between the actual gain—10ft.—and this being due to the air-resistance.

The figures obtained in the example rather favour the idea that differences of wind velocity may occasionally be of practical use to birds.

ELECTRIC FATALITY AT A COLLIERY.

AN inquest was held on Saturday last on a hewer who was electrocuted at Chopwell Colliery on the previous day. George Wallace, a coal hewer, said that on the morning of the accident deceased came from the face and went to the switchbox, which had gone wrong. Deceased, who knew there was a finger broken, and said he thought he could put it right, lifted the cover up and put it down again, and then shouted to the boy, who was standing against the main switch, to switch the current on. The deceased then became fast to the lever on the switchbox. Witness immediately shouted to the boy to switch the current off. Deceased fell as soon as the current was shut off. Artificial respiration was tried without success. In reply to Mr. Atkinson, H.M. Inspector of Mines, witness said the workmen were not authorised to attend to the motor, but they were never told not to do so. The deceased had often done that work. James Wills, a deputy-overman, said it was no part of the deceased's duties to interfere with the motor. If there was anything wrong with the motor switchbox, the electrician ought to have been sent for. John Morland, an electrician, answering Mr. Atkinson, said the switchbox was not earthed. The cables were put down the pit before the rules read by Mr. Atkinson came into force, therefore they were exempt. If the thing had been earthed the deceased would not have been killed. The jury found that the deceased had been accidentally electrocuted.

Royal School of Mines.—The governing body of the Imperial College of Science and Technology have appointed Mr. William Frecheville to be Professor of Mining in the Royal School of Mines, in place of Prof. S. Herbert Cox, who is about to retire. Prof. Frecheville is an alumnus of the Royal School of Mines, and has had a long and distinguished career as a mining engineer.

Aluminium Alloy.—An aluminium alloy has recently been patented by Gaston Jacquier, of Belgravia, near Johannesburg, Transvaal. It is composed of the following ingredients: Aluminium 92 per cent., copper 5 per cent., bismuth 2 per cent., silicon 1 per cent. This alloy, it is claimed, is much more non-corrosive than the ordinary alloys of aluminium and will stand the corrosive action of sulphuric acid, cyanide solution, &c. It is proposed to use it for castings used around a mine and which come in contact with corrosive waters.

THE MECHANISM OF CORROSION.*

BY J. NEWTON FRIEND, J. LLOYD BENTLEY, AND WALTER WEST.

ONE of the main causes of the fascination attaching to the study of corrosion is that new phenomena are constantly appearing which cannot be reconciled with our old stereotyped theories, and necessitate, therefore, a constant readjustment of our ideas. In a recent communication to this journal† a list was drawn up of the more important factors influencing the rate of corrosion of relatively pure iron at ordinary temperatures; and attention was drawn to the extreme care required in order to carry out two exactly similar experiments from which reliable conclusions may be safely drawn. During the past year the authors have studied a few of the factors requiring consideration in greater detail. The results obtained and embodied in this memoir serve both to corroborate and to extend our earlier work.

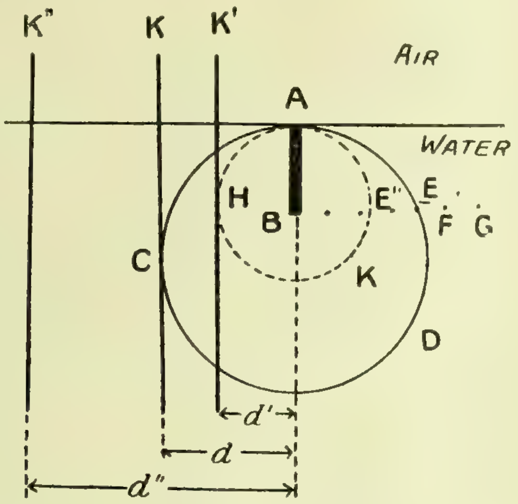


FIG. 1.

(1.) **The Corrosion Zone.**—When a plate of iron is suspended in stationary water, the surface of which has free access to the air, the layers of water in contact with the metal yield up their dissolved oxygen and thereby induce corrosion. Fresh supplies of oxygen from the surrounding layers of water now diffuse towards the metal, and in the course of a few hours an equilibrium is set up, the amount of oxygen diffusing towards the metal being exactly equal to that absorbed in producing rust. This condition is shown in Fig. 1, where AB is the metal plate, and ACDE represents what may be termed the corrosion zone, the amount of dissolved oxygen in the water gradually decreasing as we pass from any point on the circumference of the zone, say E to the metal itself at B. At all points outside the zone, such as F, G, &c., the amount of dissolved oxygen remains constant. The actual size of this zone must depend upon a large variety of factors, all of which may be grouped under two headings, namely: (1) The rate at which oxygen can diffuse towards the metal, and (2) the rate at which the metal can absorb the oxygen.

The former of these factors is influenced by the pressure and composition of the air in contact with the surface of the water, and also by the solubility of oxygen in the water—a function of the temperature and purity of the latter.

As regards the rate of absorption of oxygen by the metal itself, we have to consider the influence of temperature and light, the composition of the metal, its physical condition, and the effect upon it of any impurities in the water. Clearly the more corrodible the metal, the larger is the corrosion zone, other things being equal. When, on the other hand, the metal is protected by paint, zinc, or tin, the corrosion zone may be negligibly small.

Now it follows that unless due allowance is made for this, a serious source of error is liable to creep into experiments designed to throw light upon the relative corrodibilities of different pieces of metal. If we suspend AB in a tank, the side K of the latter must not be so near as to come within the corrosion zone as at K′ or the metal will not corrode at its maximum rate. Once beyond this zone, however, it is immaterial how far off the side is, the rate of corrosion of the plate being the same whether the side is at K or K″. Suppose, now, we have two plates, one say of nickel steel and one of ordinary carbon steel, and wish to determine their relative rates of corrosion. We will assume that the nickel steel corrodes only half as rapidly as the carbon steel. If the corrosion of the latter is taken as 100, that of the former will be 50, and the corrosion zone of the carbon steel may be represented by the curve ACDE, and that of the nickel steel by the broken curve AHK. Suppose these plates are suspended in a tank at a distance d' from the side (K′). They are then under what appear to be precisely similar conditions. In reality such is not the case, however, for whilst the nickel steel can corrode at its maximum rate because K′ lies without its corrosion zone, the carbon steel cannot corrode more than about 70 per cent. of its maximum amount since K′ lies so far within its corrosion zone. Hence the relative corrosions as determined in this way would be:—

$$\frac{\text{Corrosion of carbon steel}}{\text{Corrosion of nickel steel}} = \frac{70}{50} = \frac{100}{71}$$

If, now, we repeat the experiment, suspending the two plates at a distance d from the side K the nickel steel corrodes at the same rate as before, but the carbon steel is now able to corrode at its maximum rate. The observed rates of corrosion are in consequence, 100 to 50. There can be no doubt that many of the curious variations obtained by different investigators when conducting experiments of this kind are traceable to some such cause as this.

In order to gain some idea as to the magnitude of the corrosion zone, some pieces of Kahlbaum's pure iron foil were cleaned with emery-paper, weighed, and suspended by means of glass hooks in earthenware troughs of water at varying distances from the sides. The plates measured 3in. in length and 2·5in. in breadth, and were attached to the hooks by paraffin wax (see Fig. 2), so that the disturbing corrosive action of the silica of the glass was removed. After nine days the plates were cleaned and weighed, the loss in weight being taken as a measure of the corrosion. The results were as follows:—

Distance of Plate from Side, Inches.	Initial Weight of Plate. Grammes.	Loss in Weight. Grammes.	Corrosion Factor.
5	8·4214	0·1546	100
3	8·6286	0·1574	102
2	8·6264	0·1340	87
1	8·3866	0·1266	82
0·5	8·1574	0·1418	92
0·25	8·1256	0·1640	106

From the above table we gather that: (1) The maximum corrosion is reached when the plate is not less than 3in. from the side of the trough, that observed at 5in. distance being the same (within experimental error). (2) When the iron is very close to the side the rate of corrosion begins to increase abnormally. This came as a great surprise, but the next series of experiments showed that the anomaly was due either to the silica of the glaze or some other corroding material dissolving out of the pores of the earthenware. In the chemical activity of the apparently neutral walls of a containing vessel, therefore, a serious source of error may lie.

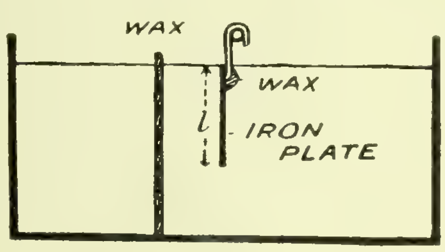


FIG. 2.

In order to avoid this disturbance, a similar series of iron plates were suspended, this time in the centre of the troughs and sheets of paraffin wax fixed at varying distances from them, as shown in Fig. 2. After 10 days of exposure the following results were obtained:—

Distance of Plate from Side. Inches	Initial Weight of Plate. Grammes.	Loss in Weight. Grammes.	Corrosion Factor.
10	8·6041	0·1585	100
5	8·0067	0·1566	99
2·5	7·8715	0·1334	84
1·2	8·5880	0·1302	82
0·6	8·4915	0·1247	79

Evidently, therefore, the closer the metal is suspended in still water to the side of the containing vessel, the less is it able to corrode.

These experiments were now repeated, using two plates of paraffin wax in each case, the plate of iron being suspended

* Paper read before the Iron and Steel Institute, May 9th, 1912.
† Friend, Carnegie Scholarship Memoirs, 1911.

midway between them. After 19 days the plates were cleaned and weighed, with the following results:—

(Area of plate = 6 × 6 centimetres.)

(Length of plate = l = 6 centimetres.)

Distance of Plate from Sides. In Centimetres.	Distance of Plate from Sides. In Terms of Length of Plate.	Initial Weight of Plate. Grammes.	Loss in Weight. Grammes.	Corrosion Factor.
12	$2l$	6·0760	0·1940	100
12	$2l$	6·1010	0·1970	
6	l	5·9530	0·1990	101
3	$l/2$	5·9530	0·1780	91
1·5	$l/4$	6·4219	0·1437	73
0·75	$l/8$	6·2782	0·0776	40

From this it is evident that the plates under the particular conditions of the experiments should not be suspended nearer than a distance measured by their length l, if the maximum corrosion is to be obtained. This, of course, assumes that the sides of the vessel are chemically inert.

If, now, the inert paraffin sheet is replaced by a second metal plate of similar corrosive properties, it will be evident that twice the above distance must be left between the two if maximum corrosions are to be obtained in either case. This was confirmed in part by suspending two plates of iron in each trough at varying distances from one another, and determining their loss in weight after seven days. The plates were 2·5in. square, and were suspended in a similar manner to the preceding. The results were as follows:—

Distance of Plates from each other. Inches.	Initial Weight of Plates. Grammes.	Loss in Weight. Grammes.	Mean Loss. Grammes.	Corrosion Factor.
Single Plate*	7·0136	0·0741	0·0752	100
Single Plate*	7·0370	0·0762		
4	6·3968	0·0700	0·0708	94
	6·4658	0·0715		
2	6·4704	0·0606	0·0611	81
	6·3933	0·0615		
1	6·4428	0·0600	0·0610	81
	6·2853	0·0620		
½	6·8088	0·0630	0·0645	85
	6·8744	0·0659		

* These were single plates in separate troughs. Unfortunately we did not possess a sufficient number of larger troughs which would enable us to place two plates in any one trough at a greater distance than 4in. without incurring risk of interference from the sides of the vessel.

From this table it is clear that where the plates were suspended at a distance of $\frac{4l}{2 \cdot 5} = 1{\cdot}6$ times their length apart, the maximum corrosion is not attained. Evidently, therefore, in order to obtain trustworthy results for the relative corrosions of various irons and steels by immersion in still liquids in troughs, the plates must be suspended considerably further apart than has hitherto been customary. With painted, galvanised, and tinned plates, of course the case is quite different, for, owing to the slow rate of corrosion, the corrosion zone is correspondingly reduced and the plates may be much nearer together. In moving water, likewise, the plates may be nearer, but in both of these cases it is better not to have them too close together, or films of dust may spread from plate to plate and thus galvanically connect them and induce serious corrosion. This was probably the case with the last two plates, at half an inch distance, as given in the above table, and which show a marked and unequal increase in their corrosion.

In the above experiments the troughs were kept in the dark during the periods of exposing the plates, in order to prevent the disturbing influences of unequal illumination. In actual practice the influence exerted by suspending two plates close together would be even greater than that indicated in the above experiments, since one plate would cast a shadow on the other and thus withdraw from it the stimulating action of light. The isolated plates, on the other hand, would suffer no retardation in this way.

(2) **The Mechanism of Corrosion.**—When layers of rust are analysed, they are frequently found to contain at least traces of iron rust. This is quite in harmony with the acid theory of corrosion, according to which the first stage in the corrosion of iron consists in the formation of a ferrous salt, which later undergoes oxidation to the ferric condition, yielding hydrated ferric oxide or rust.

The numerous analyses of rust usually teach us but little beyond this, however, inasmuch as the exact conditions under which the various samples of metal rusted were unknown. It occurred to us that, if we allowed pure iron to rust under a series of well-defined conditions, and then analysed the rust produced, fresh light might be thrown upon some of the hitherto obscure problems. To this end Kahlbaum's pure iron foil was always employed, as its composition has been proved by repeated trials to be most uniform, and hence to be particularly suitable for the purpose in hand.

The Influence of Light.—Attention has already been drawn in previous papers to the fact that light greatly accelerates the rate of corrosion of iron. An engineer criticised this statement shortly after publication, stating it to be contrary to experience, instancing an iron bridge, the under and shaded portions of which were more corroded than the upper ones. This illustrates the difficulty experienced by practical men of realising how essential it is that conditions shall be exactly comparable before trustworthy conclusions may be drawn. By shutting out the light in the above case, the free access of fresh, warm, and dry air was also cut off, so that the under portion of the bridge was always moist, whereas the upper and exposed places were usually dry. Clearly the effect of constant moisture must far outweigh the purely stimulating action of light, since a dry surface cannot rust.

The question which now arises is: How does the light accelerate corrosion? This it may do in one or both of two ways:—

(1) By accelerating the initial stage of corrosion, namely, the oxidation of the metal to the ferrous condition . . . . . Reaction 1.

(2) By accelerating the second stage of corrosion, namely, the oxidation of the ferrous iron to ferric (rust) . . . . . . Reaction 2.

Solutions of ferrous sulphate, slightly acidified with dilute sulphuric acid, were placed in similarly shaped glass bottles, some of which were transparent, others being rendered opaque by a thick coating of paint on the outside. These were kept at a uniform temperature in a glass water-bath and exposed to diffused sunlight. After varying intervals of time, portions of the solutions were removed and the relative proportions of ferrous and ferric iron determined by titration with bichromate. At the beginning of the tests there was no ferric iron present, hence the figures in the third column of the table give the relative rates of oxidation of the ferrous sulphate in the light and dark respectively:—

No.	Condition.	Length of Exposure (Days).	Ferric Iron as Per Cent. of Total Iron
1	Light	15	14·4
	Dark	15	13·0
2	Light	44	26·8
	Dark	44	23·4
3	Light	53	28·4
	Dark	53	24·6
4	Light	71	39·3
	Dark	71	34·8
5	Light	71	30·3
	Dark	71	26·8

Clearly the light stimulates the oxidation of ferrous iron to the ferric condition—but only relatively slightly. Whilst, therefore, during ordinary corrosion of iron the light undoubtedly stimulates Reaction 2 (above), it would seem that this acceleration is too small to wholly account for the increased corrosion actually observed. Probably, therefore, light also accelerates Reaction 1, namely, the oxidation of the metal to the ferrous condition. In order to test this, plates of iron measuring 4 by 6 centimetres in area were exposed in beakers of water in such a manner that their four corners rested in contact with the sides and bottom of the beakers. Each beaker held one plate and 100 cubic centimetres of distilled water. Four of these, Nos. 1 to 4, were placed in the light, and an equal number (Nos. 5 to 8) in a dark cupboard. Each week one beaker was taken from the light and dark respectively, the loss in weight of iron and the amounts of ferrous and ferric oxide produced being quantitatively deter-

mined. The results are given in the following table, the weights of iron being expressed as grammes:—

No.	Condition.	Time. Days.	Initial Weight of Plate.	Weight of Ferrous Iron.	Total Loss in Weight.	Percentage of Ferrous Iron.
1	Light	8	3·4994	nil	0·0326	nil
5	Dark	8	4·1144	nil	0·0276	nil
2	Light	15	3·9894	0·0011	0·0611	1·8
6	Dark	15	3·8162	trace	0·0521	trace
3	Light	23	4·2014	0·0101	0·1029	9·8
7	Dark	23	3·9014	0·0011	0·0709	1·5
4	Light	29	4·1522	0·0178	0·1278	13·9
8	Dark	29	3·8118	nil	0·0800	nil

From the above we gather: (1) That the plates exposed to the light rusted more rapidly than those in the dark—confirming earlier work. (2) An appreciable amount of ferrous oxide is produced on prolonged exposure to daylight. (3) No appreciable quantities of ferrous oxide are produced in the dark—under the particular conditions of the experiment.

Evidently, therefore, light not only accelerates the oxidation of ferrous iron to ferric, as we have seen, but it has a more pronounced accelerating influence on the initial oxidation of metallic iron (Reaction 2, above), so that the formation of ferrous oxide outstrips that of ferric. In the dark, however, the two reactions apparently proceed at practically the same rate, so that the ferrous oxide is oxidised to rust as rapidly as it is formed.

As time goes on the accumulation of rust and ferrous oxide becomes so thick that light cannot easily penetrate, and the corrosion proceeds as if the metal were in the dark. Hence the reaction slows up, and the percentage of ferrous iron in the rust begins to fall. This accounts for the relatively small quantities of ferrous iron found in thick rust deposits, even when metallic iron still remains. When all the iron has been oxidised, of course, the ferrous oxide slowly follows suit, until even the last traces may be oxidised.

There can be little doubt that numerous other factors, such as galvanic action, temperature, nature of the corroding medium, &c., will affect the relative proportions of ferrous and ferric oxide produced during the corrosion of iron. Experiments are now in progress with a view to determining the respective values of each of these factors, and we hope to communicate the results in a later memoir.

VALVES FOR MULTI-CYLINDER STEAM ENGINES.

A METHOD of distributing the steam in a multi-cylinder engine, having two cylinders arranged one above the other or side by side, consists in the use of an intermediate ported cylindrical valve common to the cylinders and provided with steam passages, the steam laps being reversely arranged in its opposite sides. The main objection to this system is that the eccentricity, the diameter and the stroke of the slide valve, having to be proportioned for the larger cylinder, are unnecessarily large for the smaller cylinder. In cylinders arranged side by side this causes the passages in the bearing surface of the slide valve, which is common to both cylinders, to be far from each other, so that apart from the great length of the cylinders the clearance of the S-shaped connecting ducts from and to the cylinders is much too great.

In the arrangement under notice, the invention of R. Wolf, Maschinenfabrik, Magdeburg-Buckau, Germany, the ported cylindrical valve, which is hollowed to form an inner chamber to serve as a steam receiver, has all its ports extending around its peripheral wall. These ports are of small breadth, measured longitudinally of the valve, as compared with the breadth of the ports in the case of the ported cylindrical valve above referred to. In this new valve the theoretical requirement that the cross section of the steam passage must be made to correspond with the volume of the piston stroke, taking account of the smallest permissible eccentricity and total length of the valve for the smaller cylinder, is so fulfilled that for the admission of the larger cylinder the number of the ports in the wall of the valve is made, in correspondence with the greater volume of the stroke of this cylinder, larger than the number for the exhaust of the smaller cylinder, so that the diameter of the ported cylindrical valve, the eccentricity, the space traversed by the valve, the distance between the passages for the exhaust of the smaller cylinder and for the admission of the larger cylinder, the capacity of these passages and consequently the clearance can be made essentially smaller and more advantageous for the attainment of the greatest economy.

In the accompanying illustrations two constructions are shown in longitudinal section through the slide valve. In the form shown in Fig. 1, A shows the width of the port and B the lap for the smaller cylinder C; D the width of the port and E the lap for the larger cylinder Z. A + B is equal or approximately equal to the eccentricity R = D + E. Having

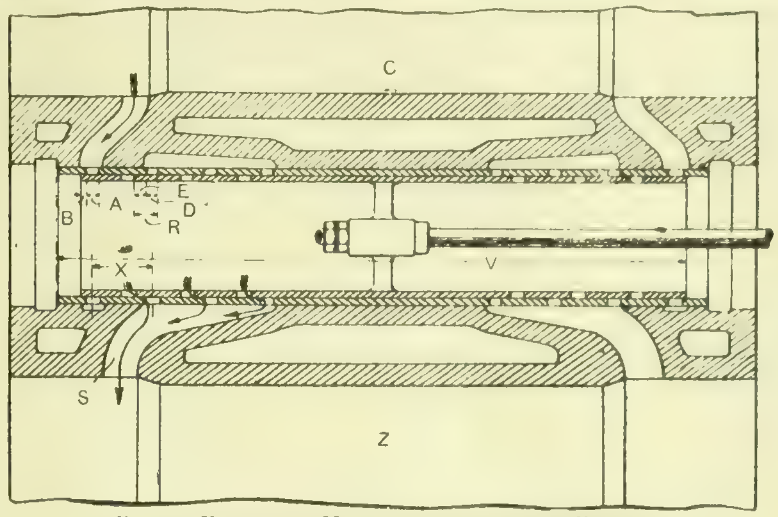


FIG. 1. VALVE FOR MULTI-CYLINDER STEAM ENGINES.

regard to the ratio of the cylinders to each other, the number of the ports of the larger cylinder is made three times as large as for the smaller cylinder. The clearance X and the volume V traversed by the slide valve are considerably smaller than in the case where the ported cylindrical valve of known type is employed.

In multiple expansion engines the exhaust of the last stage to the condenser can, with this construction, be distributed by the same valve which distributes the exhaust of the penultimate stage and the admission of the last stage, if the exhaust passages to the condenser are situated within the space traversed by the slide. In this manner the theoretical requirement that in the last stage the cross section of the exhaust must be made, correspondingly with the far larger volume of the piston stroke, much greater than in the

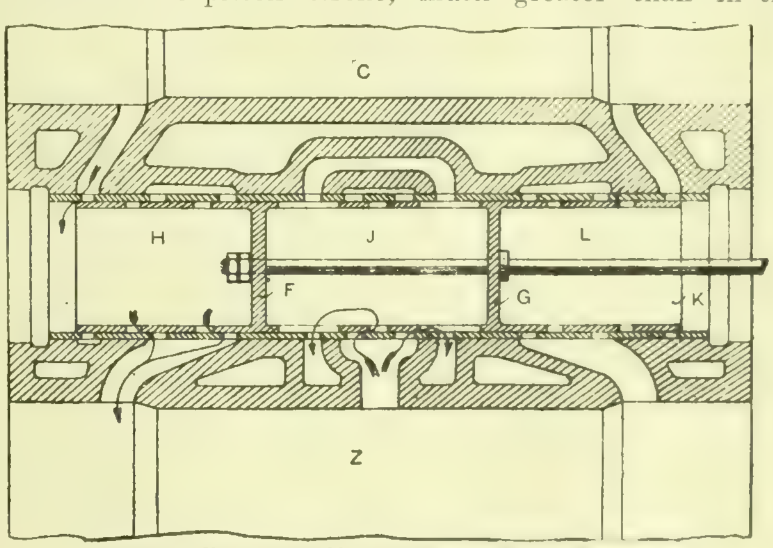


FIG. 2.—VALVE FOR MULTI-CYLINDER STEAM ENGINES.

penultimate stage, is so fulfilled that the number of the ports in the piston valve for the exhaust of the last stage is made larger than the number of the ports for the exhaust of the penultimate stage. By arranging the exhaust passages at any desired part of the path of the working piston it is attained that the passage is as short as possible and therefore the clearance of the corresponding passage can be made as small as possible and thus any desired multiple opening corresponding with the theoretical requirements can be used both for the admission and for the exhaust. An example of this is shown in Fig. 2. A ported cylindrical valve K is subdivided by partitions F, G into three chambers H, J, L. In the last stage, the number of ports in the ported cylindrical valve for the exhaust is made double the number for the penultimate stage. The exhaust passage is in this case common for both cylinder ends and is arranged in the middle of the piston stroke.

STEAM-CONDENSING EQUIPMENTS.*

A. G. CHRISTIE.

It is a matter of general knowledge that the atmosphere surrounding the earth consists of a mixture of gases, principally of oxygen and nitrogen, and that this atmosphere extends to a sufficient height above the earth's surface to produce a pressure at sea level of 14·7lbs. per square inch absolute. For ordinary purposes of life this pressure is not

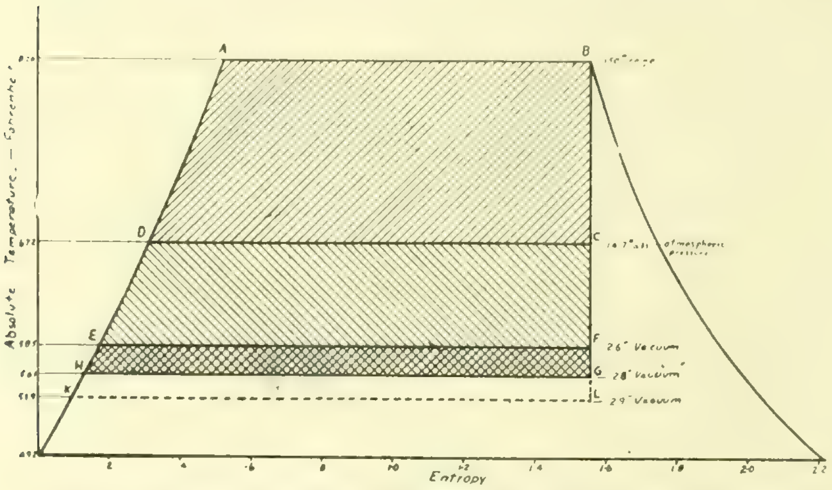


Fig. 1.—Temperature Entropy Diagram Showing Adiabatic Expansion from 164·7lbs. Absolute.

objectionable, but in certain phases of engineering, especially when steam is used, this pressure is detrimental and steps have to be taken to reduce it. It is usually desired to make this reduction of pressure in a closed chamber, such as an engine or turbine cylinder. Such a reduction of pressure, in ordinary engineering terms, is known as "producing a vacuum." Hence we can define a vacuum as a reduction of the pressure in a chamber below that of the surrounding atmosphere. The equipment to produce a vacuum in steam engines is known as the condensing outfit and consists of the condenser and its accompanying pumps.

The pressure of the atmosphere is usually measured on a barometer, which indicates this air pressure by the height in inches of a column of mercury. Hence 14·7lbs. per square inch absolute corresponds to a barometer of 29·97in. of mercury, which is usually spoken of as a 30in. barometer. Now, if the air pressure in a closed chamber is reduced below that of the surrounding atmosphere, and if this chamber is connected to one end of a glass tube, the lower end of which

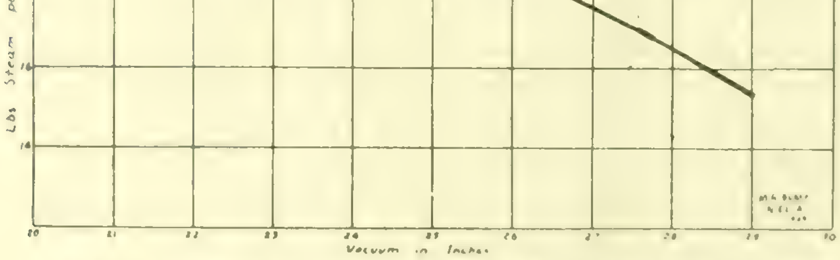


Fig. 2.—Water Rate Curve of Standard 1,000 kw. Turbine with Variation of Vacuum. Steam Pressure 175lbs. Gauge. Superheat 100 Fah.

is placed in a bath of mercury, then the atmosphere will force the mercury up the tube until the height of the mercury column equals the difference in pressure between the inside of the chamber and the atmosphere. Thus we have the common means of measuring vacuum by the height of a column of mercury in inches equal to the differences of pressure on the inside and outside of an engine exhaust. Hence one hears an engineer remark that he carries 28in. of vacuum on his turbine exhaust.

One of the advantages to be gained by producing a vacuum in an engine exhaust is the increased energy made available by the expansion of the steam, and, consequently, the more useful work each pound of steam will produce in the engine. This can be shown very clearly in Fig. 1, which shows on a temperature entropy diagram the ideal or adiabatic expansion of 1lb. of dry steam from 150lbs. pressure above atmosphere to a pressure of 1lb. per square inch. Without entering into a discussion of the construction or meaning of this diagram, it will be sufficient to say that the area ABCD is proportional to the energy available for work when steam expands without external losses from 150lbs. per square inch above the atmosphere to atmospheric pressure. The area ADFE is proportional to the energy available for work when the expansion is carried further from atmospheric pressure to a pressure corresponding to a 26in. vacuum, as is usual with a steam engine, while the area ADGH represents the corresponding energy with a 28in. vacuum, as used on steam turbines. A glance will show that the energy available for work by expanding the steam from atmospheric pressure into a 28in. vacuum is almost equal to the energy available by expanding the steam from 150lbs. per square inch to atmospheric pressure. It is, therefore, obvious that a suitable engine operating with 28in. of vacuum

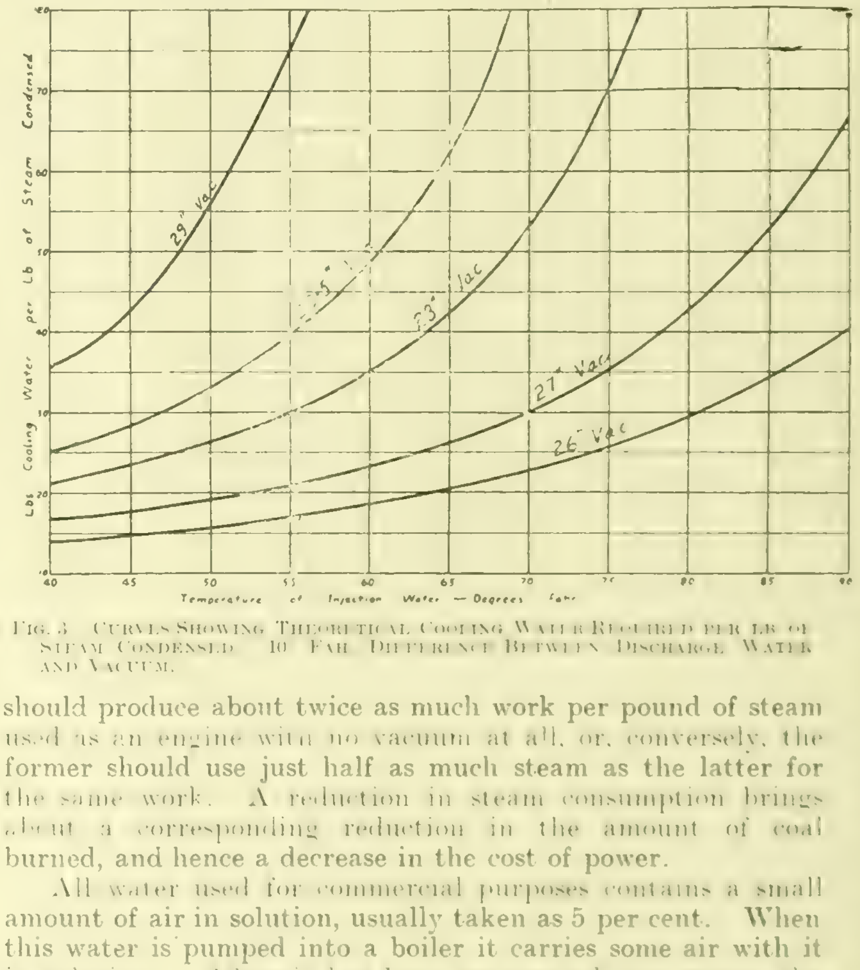


Fig. 3.—Curves Showing Theoretical Cooling Water Required per lb. of Steam Condensed. 10° Fah. Difference Between Discharge Water and Vacuum.

should produce about twice as much work per pound of steam used as an engine with no vacuum at all, or, conversely, the former should use just half as much steam as the latter for the same work. A reduction in steam consumption brings about a corresponding reduction in the amount of coal burned, and hence a decrease in the cost of power.

All water used for commercial purposes contains a small amount of air in solution, usually taken as 5 per cent. When this water is pumped into a boiler it carries some air with it in solution. After it has been evaporated into steam, the mixture of air and vapour passes over to the engine and out the exhaust. If the expansion of steam is carried below atmospheric pressure to a vacuum at exhaust, there will be a tendency for the atmospheric pressure to force air in through stuffing boxes, packing, or any other possible opening. When air leaks into a vacuum in such a manner its volume is increased many times.

The exhaust from an engine is then a mixture of air and steam vapour, and, in order to maintain the vacuum desired, this must be at once removed. The steam may be converted into water again by removing its latent heat by means of some cooling medium, usually cold water from another source of supply. Hence we have arrangements in condensers whereby cold water is either brought into contact with the exhaust steam itself or is circulated on the inside of metal tubes, which are surrounded on the outside by the steam. These are the two fundamental types of condensers. The former is known as the jet condenser, while the later is called the surface condenser. In jet condensers, the water is often forced into the vacuum of the condensing chamber by the

*Paper read before the University of Toronto Engineering Society.

pressure of the atmosphere. But for all other purposes a means must be provided to circulate the required amount of cooling water, and what is known as a circulating pump is usually used for this purpose.

The air which has been carried along with the steam must also be removed if a vacuum is to be maintained in the condenser. It cannot be condensed, and hence must be pumped out by some means as fast as it enters. The form of air compressor used for this work is known as an air pump. Hence we have as our essentials to maintain a vacuum a condenser, its circulating pump, and its air pump.

Referring again to Fig. 1, it would seem that the higher the vacuum the greater would be the energy available and

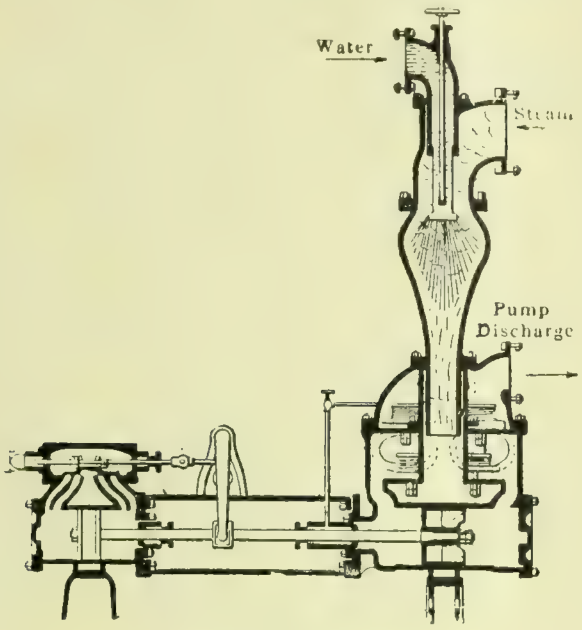


FIG. 4.—JET CONDENSER.

the more efficient the engine would become in its use of steam. The limitations of the cylinder sizes and other factors in reciprocating engines are such that usually no further expansion is profitable beyond 26in. of vacuum. But there is no limit in steam turbines to the vacuum which may be carried if the blading is suitably designed. Fig. 2 shows the decrease in steam consumption of a steam turbine as the vacuum increases, as found by actual test.

The cooling water leaving the condenser cannot be hotter than the steam temperature corresponding to the degree of vacuum, and, in many condensers, is usually 10° Fah. below this temperature. The temperature of steam with 26in. vacuum is 125° Fah., with 28in. vacuum 101° Fah., while with 29in. of vacuum it is only 80° Fah. The corresponding outlet water temperatures allowing 10° Fah. drop as above would be 115° Fah., 91° Fah. and 70° Fah. respectively. If the average temperature of the water supply is 55° Fah., then each pound of cooling water will carry away 60 B.T.U., 36 B.T.U., and 15 B.T.U. in the three cases. The heat to be removed from the steam to condense it for approximation can be said to remain constant in all three cases, so that the quantity of cooling water to condense the same weight of steam in the three cases will be about as 1 : 1·66 : 4. As it takes power to pump this water, it can be seen at once why it costs more to maintain the higher vacuums.

Fig. 3 shows the actual amount of circulating water required in practice for different vacua. For high vacuum there must be a much greater supply of cold water than for a low vacuum.

Now the volume of the air increases rapidly with the higher vacua and hence the volume of the pump cylinder must be increased to provide for it. More power will be required to compress this air to atmospheric pressure. Consequently an increase in vacuum means a corresponding increase in operation costs on the air pump.

The condensation problem then resolves itself into an equation of costs. If the water supply is limited, then the vacuum that may be carried will be fixed by this consideration. But if there is ample cold water, then one must determine when the saving in fuel costs, due to decreased steam consumption on the main engine, equals the increased operating costs of pumping, cooling water, and removing air, together with the upkeep, interest, and depreciation of this larger and more expensive apparatus. Usually the limiting factor is the amount of air leakage into the engine cylinder, the exhaust line, and the condenser, and every step should be taken to reduce this to a minimum. A treatment of the economics of such an engineering problem, while of very great practical interest, is beyond the limits of this discussion, and the remainder of the article will deal with present day commercial forms of condensing equipment.

Some engineers hold that it is not possible to maintain as relatively high a vacuum at a high altitude as near sea level. Now, the absolute pressure in a condenser is equal to the difference between the vacuum and the barometric pressure, and this can be maintained constantly irrespective of altitude with any given equipment. Moreover, it can be shown that not only is it possible to hold as good an absolute vacuum at the high level, but the power to drive auxiliaries is decreased to a considerable extent at the same time. Hence the cost of producing the same relative vacuum remains constant or decreases slightly as the altitude increases.

The essential requirements of a condensing plant may be stated as follows: Sufficient cooling water must be supplied to provide the necessary vacuum; there must be a rapid transfer of heat from the steam to the cooling water in order to produce quick condensation; and the accompanying air must be removed with the least expenditure of power. In commercial practice there are three simple types of condenser used to provide vacua up to 26in., such as are required in steam engine work.

The simplest of these is the ordinary jet condenser shown in Fig. 4. This consists of a vacuum chamber, in which the cooling water and steam are brought into intimate contact, and after condensation all water and the accompanying air are removed by a piston pump attached to the bottom of the condenser. In the usual designs of this type there is seldom an intimate mixture of water and steam, and hence more water is required than should be necessary. But even under these conditions the amount of cooling water is often much less than that required by ordinary surface condensers. The equipment is cheap in first cost and occupies very little space. As the cooling water carries air in solution, air pumps of large capacity are required with consequent large power expenditure. There is also the disadvantage that the condenser discharge cannot be used to feed boilers unless the cooling water is unusually pure and free from acids or alkalis. Unless care is taken in operation there is also the possibility of water being drawn over into the low-pressure cylinder of the engine should the load go off suddenly. Such an occurrence usually

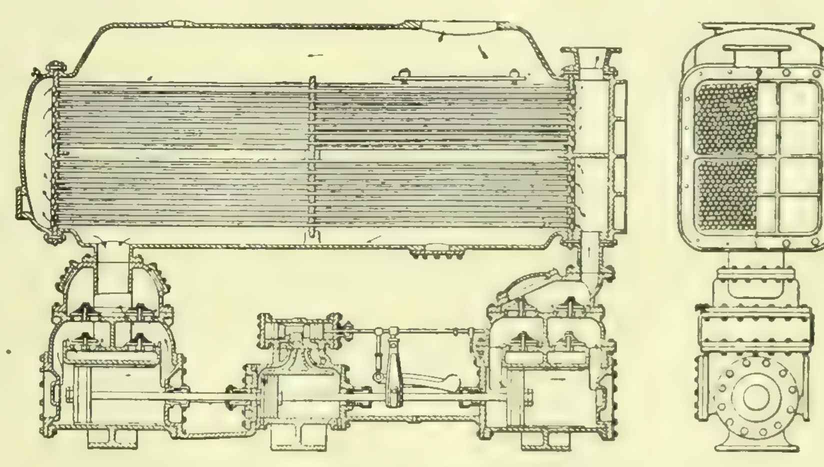


FIG. 5.—SURFACE CONDENSER.

wrecks the engine. Improvements, which will be referred to later, have recently been made on this type to adapt it to the requirements of high vacuum work, so that it is still one of the most important types of condensers.

The barometric condenser is a modification of the simple jet. The cooling water and steam are led in separate pipes to an elevated condenser head, at least 34ft. above the level of the hot well, where the two are mixed. The resulting mass of water all passes out through a tail pipe, which is submerged in the hot well. The air present in the condenser is entrained by various methods as the water leaves the head, and is thus carried away at the same time. This condenser arrangement costs more than the simple jet to instal, but is very cheap to operate. If near the cooling water supply the head to be lifted against by the circulating pump is equal

only to the difference between the height from supply level to condenser head and the equivalent head of vacuum. A vacuum of 26in. can be easily maintained in most condensers without an air pump. There is no possibility of flooding engine cylinders with this arrangement of piping. The condenser head can be so arranged that the mixing of water and steam is very intimate, and thus the least amount of water can be used to maintain a given vacuum. This type of condenser is especially adapted for using very foul water, and if

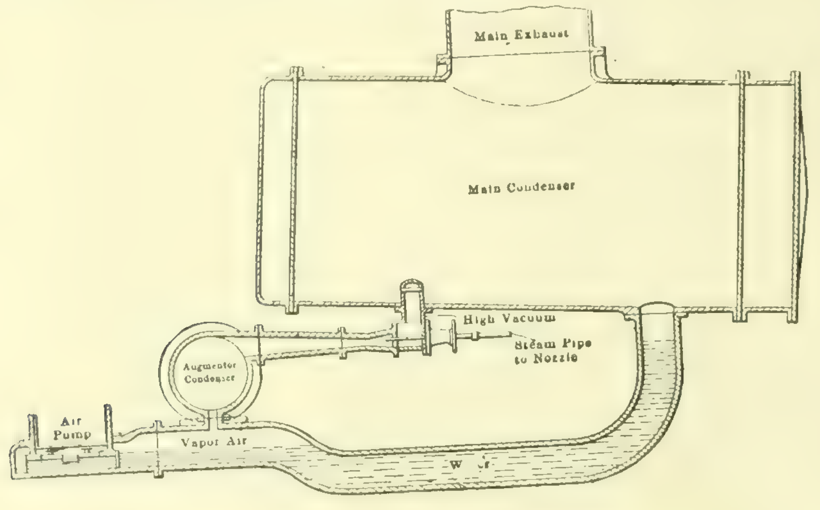


FIG. 6.—PARSONS AUGMENTER CONDENSER.

the pump and condenser are lead lined, it can be even used with acid mine water.

A typical surface condenser for steam engine work is shown in Fig. 5. It consists of a closed vessel, usually of cast iron, of either circular or rectangular section, into which the exhaust steam is led. This chamber is traversed by a large number of thin brass tubes, through which water is circulated. The steam strikes these cold tubes, condenses, and falls to the bottom of the shell. The air being heavier than the steam, also collects in the bottom, and these together are removed by the wet air pump. This pump is driven by a small steam cylinder. The pump for circulating the cooling water is placed on the other end of the common piston rod. The cooling water and condensed steam do not mix, and hence the latter is pure distilled water, which can therefore be fed directly into the boilers, provided it is not rendered useless by the presence of too much cylinder oil. Water absolutely unfit for boiler feed may be used for cooling, and thus we find that in marine work the surface condenser is used almost exclusively. As there must necessarily be a difference in temperature between the cooling water and the steam in order that heat may flow through the metal tube, a greater amount of cooling water will be required with this type of condenser than with either of the preceding types. The first cost of this equipment is high and its repair charges are also high. Since the amount of air to be removed is relatively small as compared with the jet or barometric condenser, its air pump is also small, and hence its operating costs are low. In surface condensers the cooling water is usually arranged to enter the lower tubes and leave from the upper tubes, so that each tube is filled with water irrespective of the amount circulated.

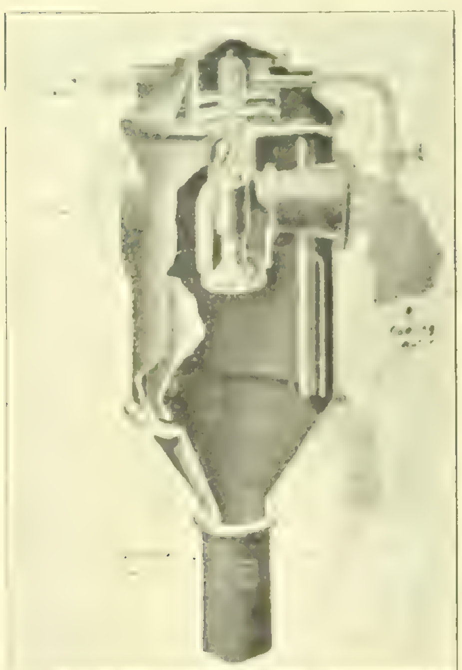


FIG. 7.—[illegible]

The condensers dealt with so far have been those intended for use with reciprocating engines. At the present time, however, steam turbines are invariably installed for most purposes where the power exceeds 100 h.p. in one unit. In steam turbines, as already pointed out, the maintenance of high vacuum results in improved operating economy. Therefore the condensing equipment chosen for use with steam turbines should aim to provide the highest vacuum possible under the conditions of operation.

A number of considerations should enter into the selection of the type of condenser for high vacuum. The amount and average temperature of the cooling water may place limitations on the vacuum to be obtained. Its quality and its suitability for boiler feed purposes are factors which influence largely the selection of the type of condenser. It has been the experience of the writer that power plant designers very frequently overlook the adaptability of the water supply to boiler feed purposes. Barometric condensers have been installed where the water supply, on account of the scale-forming substances held in solution, was absolutely unfit for feeding into boilers. At other times surface condensers have been installed where the water was quite soft and where a cheaper equipment could have been easily justified. This is a very important consideration, and should receive most careful attention if the operating costs are not to be excessive.

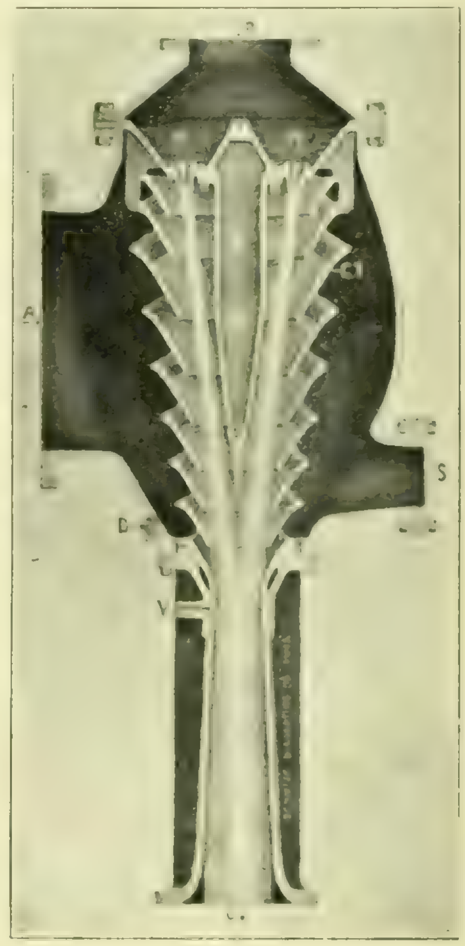


FIG. 8.—KOERTING EJECTOR CONDENSER.

To obtain high vacuum there must be sufficient cooling water for the type of condenser selected.

This condenser must be of such construction as to provide a rapid transmission of heat from the steam to the cooling water. Air pumps are always used for high vacuum, and these must be of ample capacity to remove the mixture of air and water vapour which is always present under these conditions. In order to make the capacity of this air pump as small as possible the air should be removed from the condenser at a point where it will be coldest, and hence occupies the least volume.

In the modern high vacuum surface condenser the cooling water is forced through the tubes at a high velocity, usually by a centrifugal pump, either motor or engine driven. The tubes are of brass, and as thin as permissible for the service. These must frequently be cleaned of foreign material, which is carried in by the cooling water. The size of shell and the arrangement of tubes and baffling is such that the steam is directed against the tubes at a high velocity, thus ensuring a very rapid transmission of heat and quick condensation. It has been noted that when the condensed steam from one tube is allowed to drip over all those below it, this film of water impairs the cooling qualities of each tube it passes over. Hence baffles are provided at intervals to carry the condensed steam to the sides of the shell. The circulating water, which makes three or more passes through the condenser, enters the bottom tubes first. Since the water in this portion is coldest, a certain number of tubes in the bottom are protected by a baffle from direct contact with the entering steam. The air is led through these tubes and cooled on its way to the pump suction.

Hon. C. A. Parsons introduced an additional feature shown in Fig. 6 to improve the efficiency of his surface condensers. It is known as a vacuum augmenter, and consists of a small steam jet placed in the throat of an ejector nozzle, which produces an additional vacuum to that of the pump and thus draws out the air from the main condenser and slightly compresses it. This mixed air and steam is passed through an auxiliary cooler, where the steam condenses. The air is next

removed by the wet air pump, which has much less volumetric capacity than would otherwise be required. The hot well pipe is provided with a water leg, as shown, to prevent the air leaking back into the condenser. It is said that this jet does not take more than 1½ per cent. of the steam of the main turbine and increases the vacuum about 1in.

In a condenser complete with its air and circulating water pumps the ends of both suction and discharge piping for the cooling water are usually submerged. Hence the circulating pump has only to overcome the friction head of the piping after water has started to flow through the condenser, provided the equipment is not placed too high above the source of supply. The surface condenser thus provides a high vacuum at a low operating cost. The condensed steam from the turbines can pass directly back into the boilers. The condenser is fairly reliable in operation. Its first cost is high, and it occupies considerable space. It requires a large quantity of cooling water and must be frequently cleaned.

Fig. 7 shows an Alberger barometric condenser for steam turbine work. The water is sprayed over the chamber by a distributing cone, which is regulated automatically by the amount of water supplied, which acts against a light spring. A small pipe carried a portion of the cooling water into a chamber at the top in order to thoroughly cool the air which passes up through the hollow stem of the spray nozzle. The air pump suction is thus taken off from the coldest point. The water is thoroughly mixed with the steam before passing down into the tail-pipe. A certain amount of air is carried down the tail-pipe with the water, so that in case the air pump is shut down it is still possible to operate with a small vacuum. The circulating pumps can be installed in duplicate, thus ensuring against breakdown.

The cooling water is usually supplied by a centrifugal pump driven by a motor, a steam turbine, or a single engine, as conditions may require. Some manufacturers provide a so-called entrainer on the exhaust pipe. This pocket partially fills with water until the velocity of the steam is such that any further supply of water is carried along by the steam into the condenser. In order to obtain this high steam velocity there must be a marked difference of pressure between the turbine exhaust and the condenser head, which is most undesirable. If it is necessary to remove condensation from an exhaust pipe, it is best to provide a drip pocket in the pipe just before it rises to the condenser, and connect this pocket to a receiver and float controlled duplex pump or a motor-driven centrifugal pump. Such a pump will readily remove all condensation. This arrangement causes no obstruction in the path of the exhaust steam.

There is practically nothing that can go wrong with a barometric condenser, and as it is impossible to flood the turbine with cooling water, it is the most reliable of all types. Since the water and steam mix very intimately, it will provide the highest degree of vacuum with the least amount of water, and is hence especially adaptable to places where the water supply is small or at a high temperature. It occupies little floor space, and its upkeep is small. The air pump, however, must deal with greater quantities of air and vapour than in the case of the surface condenser, and hence must be larger and more expensive. The circulating pump for the cooling water has to lift a smaller quantity of cooling water against a greater head, and hence may be slightly more expensive to operate than in the case of the surface condenser. The first cost of the equipment, however, is about two-thirds of that of a surface condenser, piping included. The condenser discharge is not always suitable for boiler feed purposes.

Another similar type of condenser is the Koerting ejector condenser, shown in Fig. 8. Water is supplied by a circulating pump at a head equivalent to 20ft. of height. This water discharges through specially arranged nozzles into an ejector throat which forms the condensing chamber. The resulting condensed steam and any air present are carried along by the velocity of the water and discharged through the tail pipe below. These condensers are cheap in first cost as no air pump is required, and with sufficient cool water will be guaranteed to maintain 28in. vacuum. Operating costs, when the load is variable, are higher than with a barometric condenser, as the same quantity of water must be pumped at all times, and as this water is under pressure there is also the danger of it entering the engine. The condenser will not work well with warm cooling water. The nozzles are easily stopped up by foreign substances if the water is dirty, and this would tend to destroy the vacuum.

The advent of the steam turbine has probably brought about greater improvements in jet condensers than in any other type. These condensers are frequently used on account of low first cost, of small floor space, and of small amount of cooling water necessary. But the condenser discharge is not always suitable for boiler feed purposes. Reciprocating air pumps have to be large to maintain high vacuum, but simple rotary pumps will be described later, which have proved very satisfactory and economical. There is also the possibility of flooding the turbine with water with these condensers, and each type is provided with some automatic vacuum breaker to prevent this. A few of these new condensers will be described.

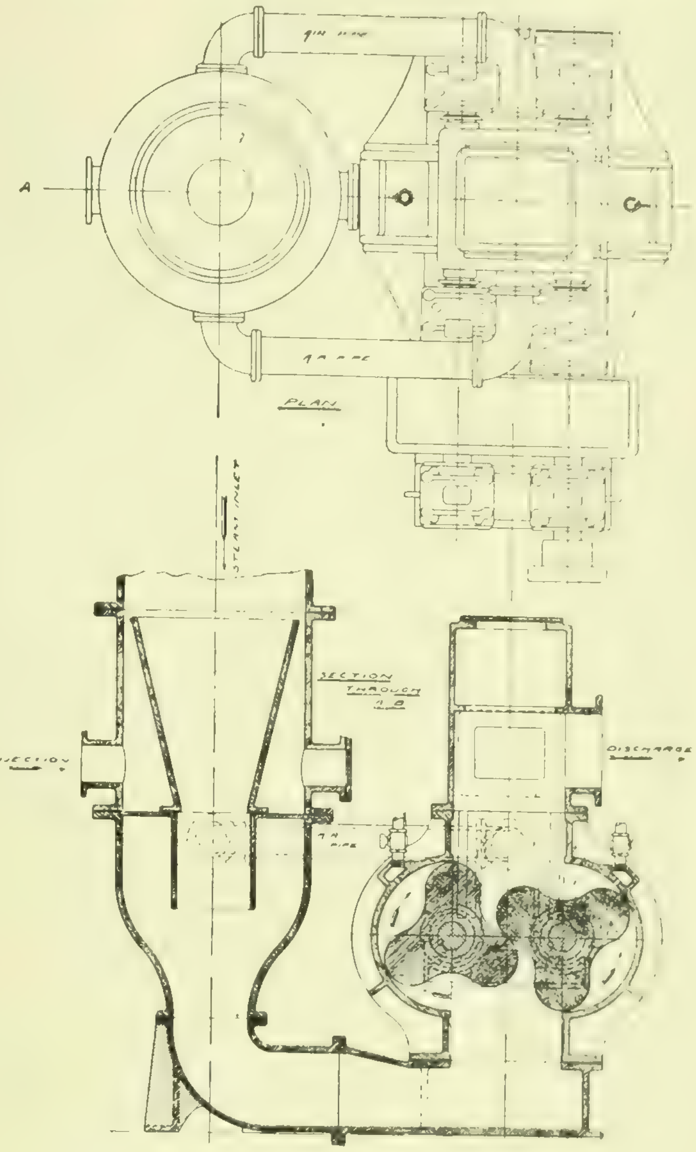


Fig. 9. Connorsville Jet Condenser.

Alberger's jet condenser is almost identical with their barometric condenser, except that it is placed at a low level, and the water is forced in by atmospheric pressure. Its tail pipe has been replaced by a centrifugal pump which discharges both the cooling water and the condensed steam. The air is removed by a standard dry air pump.

Fig. 9 shows a condenser manufactured by the Connorsville Blower Company. The pressure of the atmosphere forces the water into a reservoir in the condenser shell, from which it flows in a thin sheet down the funnel-shaped condensing chamber. The steam enters this chamber from above at high velocity. The velocity of the condensing steam is transferred to the water, which rushes through the throat of the funnel carrying the air along with it and completing the condensation. The air rises in the chamber around the throat piece, and is cooled by the large body of cold water above it. The cooling water and condensed steam pass to the air pump. This pump is also connected to the air chamber by pipes, and ports are provided in the air pump casing, so that this air enters directly above the water and passes into the space between impellers just before the water is picked up. The pump itself is of the rotary cycloidal impeller type and works

on the displacement principle. The clearances between the tips of the impellers and the casings and between the impellers themselves are small and practically no leakage results, as these are water sealed as are also the stuffing boxes. The two impellers are geared together at one end of the shaft and may be either engine or motor driven. Two small cocks are placed on the casing above the impellers, to break the vacuum

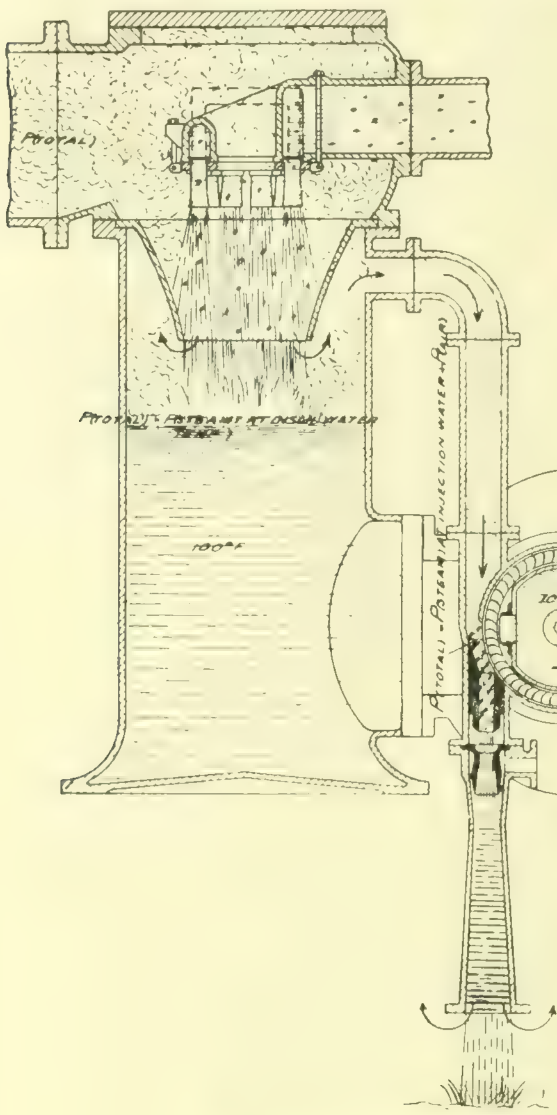


Fig. 10. Leblanc Condenser.

before opening to discharge. This makes the pump very smooth running. This is a cheap and very good equipment for water which will not corrode iron. It is also quite economical in the power required to operate it, and has given good satisfaction in a large number of turbine plants where it has been installed.

The shell of the Allis-Chalmers Type C jet condenser is circular in shape, and is erected in a horizontal position. The main idea of the designers was to produce a "rain-storm" effect in the condenser, so that each particle of cooling water, by being brought into intimate contact with the steam, would absorb the maximum amount of heat possible. Hence very little more water need be supplied than that theoretically necessary to condense the steam. The water enters at one end and passes into cast-iron troughs, from which it overflows through saw-tooth openings. The steam enters at high velocity from the top of the other end and starts to condense on meeting the cooling water. The water then strikes the spray plates below, from which it splashes in all directions, and condensation is completed. The entrained air rises through the water in the left hand portion of the condenser, and thus is cooled on its way to the air ejectors. The water overflows at the bottom of the condenser to a centrifugal pump, which forces it out into the waste channel. A second small centrifugal pump, which takes water from the cold well, is mounted on the same shaft as the cooling water discharge pump. This cold water is forced under pressure into an air ejector nozzle, which forms the air pump for maintaining the vacuum. The end of this air ejector pipe is not submerged, so that in case of the pump stopping, air rushes in and breaks the vacuum before flooding of the turbine can occur. These pumps may be motor driven, or may be turbine driven, which is the more usual arrangement. This condenser is very efficient in its use of water, but the method of pumping air requires considerable power. A similar method of removing air is used by Brown-Boveri and others in Europe.

The Leblanc condenser, manufactured by the Westinghouse Machine Company, is one of the simplest and most compact units at present built. As usually constructed, the water discharge pump and air pump casings are made part of the same casting as the condenser body itself. Fig. 10 shows the general arrangement of parts. Steam enters on the left-hand side of the condenser head, while cooling water rushes in from the right-hand side. The water is sprayed by a distribution head in such a way that it mixes thoroughly with the steam. The discharge centrifugal pump in the base removes this water and condensed steam from the chamber. The air rises into the annular space around the condensing cone and is carried to the Leblanc air pump through the pipe shown. This pump is on a new principle. Water enters at the centre of the wheel and passes out through the chamber to the rotor. The rotor is provided with a large number of small crescent-shaped bronze blades, somewhat resembling a Sirocco blower. It revolves at high speed and acts like a centrifugal pump, apparently discharging the water delivered from the central chamber in thin solid sheets like so many panes of glass one behind the other with the air trapped between these sheets. In practice this ideal is scarcely realised in full, as the lower sheets of water are disturbed by the splashing of the upper ones on the sides of the air pipe. Whatever the action is inside the pump, the air is very effectually removed, and a high vacuum can be maintained with a total expenditure of power for condenser purposes of about 3 per cent. of that of the main turbine. The pumps may be either turbine or motor driven.

Dry air pumps play a very important part in the maintenance of high vacua. Fig. 11 shows a section of an Alberger dry vacuum pump, which will illustrate the general principles of reciprocating pump construction. The cylinder is water-jacketed throughout to prevent undue heating in compression and to provide a large volumetric efficiency. The air valve is of the rotary type with ordinary pot discharge valves. The air and vapour enter one side of the piston on one stroke, and are compressed and discharged on the return stroke. The valve gear is so arranged that when the piston is at dead centre and about to return, a small port connects the two ends of the cylinder. Since the admission has just been cut off from one end, this port allows the highly compressed air in the clearance of the other end to rush over and to partially compress the air which has just entered. In this way the volumetric efficiency of the pump is greatly increased.

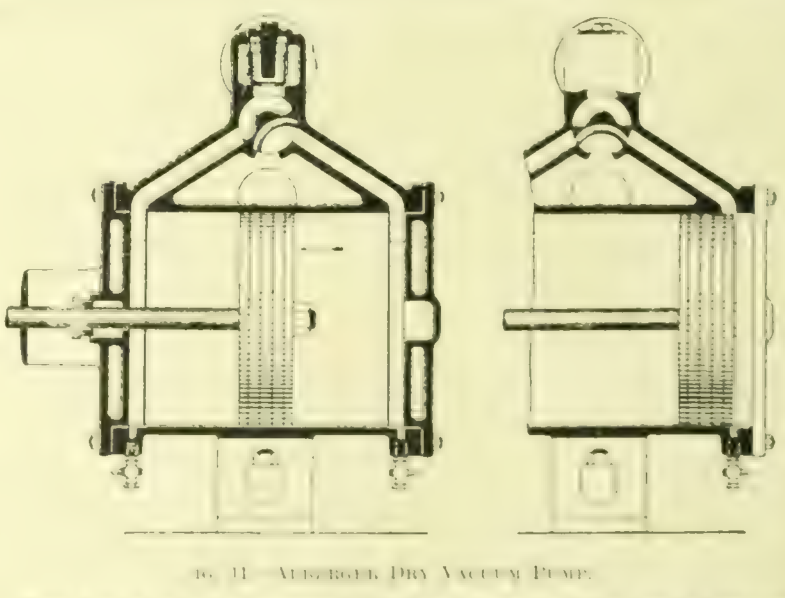


Fig. 11. Alberger Dry Vacuum Pump.

Two types of air pumps which are very widely used deserve especial attention. One of these, the Mullan Suction Valveless Air Pump, is manufactured by the Wheeler Condenser and Engineering Company. The cylinder is long and the piston fills almost half the cylinder volume. The air and vapour to be removed rush in when the piston uncovers the port in the middle and are compressed and discharged through the valves in the head on the return stroke. This pump is not provided with the by-pass port described with the Alberger pump.

The other type is known as the "Edwards," which is a ver-

tical wet air pump, and is particularly adapted for working at high speeds. The piston, which is solid and has a cone-shaped bottom, descends to the bottom of the cylinder, which is of similar cone shape. The casing is so designed that the air and condensed steam are driven through ports into the space above the piston. On the return stroke water and air are forced out through the discharge valves in the deck at the head of the cylinder. As the water lies directly above the piston, it fills all clearance spaces before being forced through the valves and acts as a water seal of three to four inches deep on the valve above, very high vacua can be maintained by this type of pump. These pumps are almost invariably used with surface condensers. They are usually built with three cylinders worked from a three-throw crank shaft and motor-driven through gearing. An Edwards pump must be placed at a lower level than the main condenser.

In Germany and other parts of the Continent rotary air pumps are being introduced very largely. There are many excellent types of these pumps, but only one will be described. This pump is manufactured by Thyssen. It is essentially a centrifugal pump with full discharge all around the periphery. The discharge from the pump impeller enters a stationary diffuser nozzle, which, in turn, discharges into an air ejector chamber. This pump has proved very satisfactory and quite economical. The A. E. G. air pump is also used extensively. It is quite probable that many of these rotary air pumps will soon be introduced into America, largely on account of their simplicity, freedom from breakdown, low first cost, small size and ease in operation.

In Europe motor-driven condenser auxiliaries are generally installed, while in America these are steam-driven. If steam is needed to heat the feed water, or if absolute reliability is required, steam-driven pumps should be used. But in other situations, motor-driven auxiliaries may be used. It must be remembered, however, that should the main switches open from a short circuit on the electrical system, the condensing plant will shut down, and all these motors must be started individually before the load can be put on the main engine again. Motors will give trouble if installed in the wet or damp basements provided with poor ventilation, and in which condensers are often located.

In conclusion, then, the selection of a condenser should be governed by: (1) The degree of vacuum required; (2) the quantity, quality, and temperature of the cooling water; (3) the requirements of boiler feed; (4) and, most important of all, the first cost and total operating costs of the equipment.

IMPROVEMENTS IN ELECTRIC FURNACES AND THEIR APPLICATION IN THE MANUFACTURE OF STEEL.*

BY HANS NATHUSIUS, DR.ING.

The various systems of electric furnace are so well known that it is unnecessary to describe these apparatus in detail. The author will therefore confine himself to a few general remarks with respect to the two most important systems—the induction furnace and the arc furnace—and to a detailed description of some recent improvements in the latter type, with special reference to the combined arc-resistance furnace. The subject is one which cannot fail to be of special interest to metallurgists, since it appears in the light of recent experience that so far as the manufacture of steel by electric means is concerned the arc furnace is the furnace of the future.

The Induction Furnace. — The hearth of a simple induction furnace consists of an annular trough in which the ring of metal constitutes the secondary winding of an alternating current transformer. The source of heat is the electric current, which is induced in the metal by the alternating current in the primary circuit of the transformer.

The idea of generating the requisite heat in the very material which is to be melted and of introducing heat by induction of an electric current, thus avoiding the use of electrodes, seems highly promising, at least in theory. Unfortunately, however, this system of furnace has shown many serious defects in practical working.

The above-mentioned advantages of the induction furnace can only be realised to the full when the furnace is used as a crucible, that is when small charges (1 to 2 tons in weight) are to undergo a pure and simple smelting process As a refining furnace the induction furnace is, for the following reasons, quite unsuitable.

The restricted space within the ring of molten metal is inconvenient for any metallurgical work such as rabbling the slag, the regular distribution of additions, sampling and controlling the process of charging. The molten metal is also exposed to a considerable cooling action, due to extensive cooling surfaces, and the slag is apt to solidify in consequence.

The electrically induced heat can, of course, only be generated in the metal bath and not in the slag, which must therefore be heated indirectly by the underlying metal. Now it must be evident that it is against all principles of economy to heat the slag by means of the molten steel, the melting point of which is considerably lower than that of the slag. Consequently a much higher temperature has to be imparted to the bath than is necessary for the desired reactions.

The entire design of the induction furnace—which rather resembles an electrical apparatus than a metallurgical furnace—makes it impossible to work with large fluid masses of slag capable of producing reactions. The magnetic field of the transformer sets up lines of forces in the liquid steel and causes it to rotate at such a speed that the slag is thrown against the sides of the channel, causing it to cool to a temperature below that at which it can react on the charge. Further, the speed of rotation causes the surface of the bath of metal to slope at an angle, so that only a small portion of the metal in the ring is covered with slag, and the reactions are thus prevented. The lining of the furnace is also injuriously affected by the whirling of the particles against the sides of the furnace, due to the centrifugal force, an action which results in their being both mechanically and chemically attacked. Further, it is impossible to treat entirely cold charges in an induction furnace, for unless a portion of the preceding charge is allowed to remain in the furnace the charge does not form a sufficiently perfect conductor for the secondary current. This is a particular disadvantage in cases where it is desired to produce steels of very different qualities.

A further disadvantage noticeable in some types of induction furnace, for instance in the Röchling-Rodenhauser furnace, consists in having two heating channels which form the secondary coil of the furnace transformer, the latter being built into the furnace in such a manner that one leg of the transformer passes through a corresponding opening in the hearth.

From a purely metallurgical point of view it is desirable that delicate apparatus such as a transformer should not be attached to the furnace, which, when hard pushed, may become red hot, nor should a transformer be exposed to risk from splashes of molten metal, dust, and rough handling. The conditions are not greatly improved even when it is most carefully protected and cooled by an air current supplied by a somewhat expensive compressor plant. The air-cooling on the transformer side necessarily increases the heat losses. To this must be added the unpractical shape of the hearth due to the presence of the transformer, which increases the length of time between heats due to the increased difficulty of making repairs. Lastly may be mentioned a most vital disadvantage of the induction furnace as compared with the arc furnace, namely, the cost of installation. Not only is the induction furnace more costly on account of its complicated construction and its character as an electric rather than a metallurgical apparatus, but also because the current supply is considerably more expensive with this class of furnaces than with arc furnaces. All large induction furnaces with a capacity of more than 3 tons require motor generators or separate generators when the frequency of the generating plant is higher than 25 cycles per second. It is evident that the instalment of motor generators must add to the cost of the electric equipment and of the necessary foundations and buildings.

The electric generator for an induction furnace must, even with installations of medium size, be designed for a frequency of 20 or less and for a power factor of between 0·6 to 0·7. The machine must therefore be in the ratio of [illegible] or $\frac{1}{0\cdot7}$ to, or 1·54 times larger than, an equaliser for a 3-phase arc furnace. On account of the lower frequency the alternator will

* Paper read before the Iron and Steel Institute, May 9th, 1912.

be considerably more expensive. The cost of an equaliser for a 3-phase arc furnace with an output of 750 k.v.a. at 750 revs. and 50 cycles is only 43 per cent. of that of a generator for an induction furnace of the same capacity. The lower speed which is required to produce the low frequency of the generator for an induction furnace influences the price of the machine the more unfavourably the greater the output of the machine.

When the current is not supplied by a separate alternator at the generating station but by a motor-generator, the price is scarcely affected on account of having to instal a motor for the furnace transformer. In fact, if anything, it may be increased, as such a motor is more expensive if desired to run at lower speeds, and it must in any case be adjusted to the maximum permissible speed of the generator.

The first cost of an induction furnace installation may, of course, be reduced by making an extension to the central

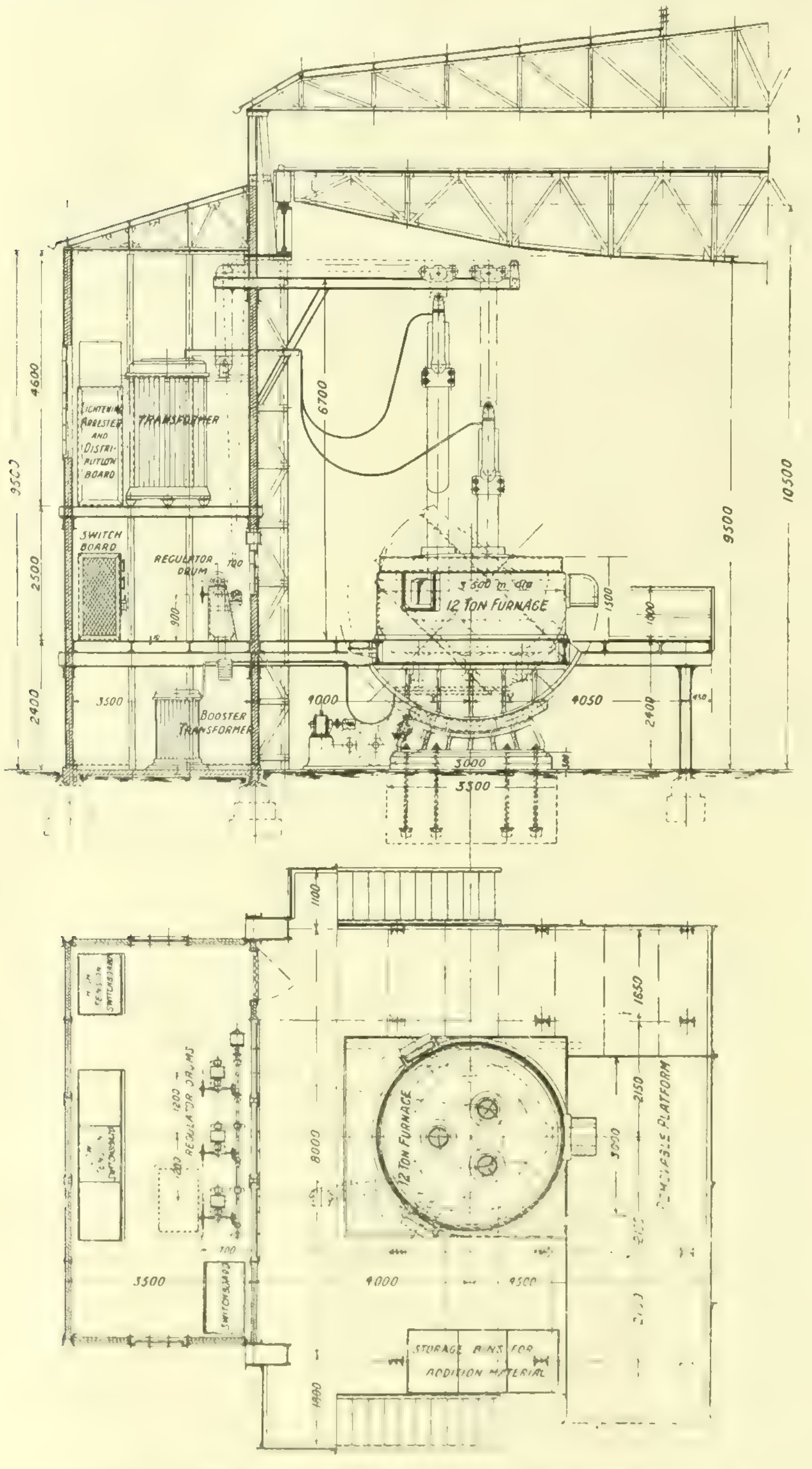


FIG. 1. ELEVATION AND PLAN OF 12-TON NATHUSIUS FURNACE.

power station instead of transforming existing electric current. In that case, and if the prime movers are blast furnace gas driven engines, the electric generators for arc furnaces must also be designed for slow speed. The difference between the cost of an induction furnace and that of an arc furnace installation will then disappear, but only under the above-mentioned conditions. The induction furnace transformer always requires a separate set of conductors for low frequency, and also a regulating transformer or tension regulator unless a decentralisation is to be carried out, which is not always possible and generally introduces economical disadvantages. But even in the latter favourable case it will hardly be possible to equip an induction furnace at the same cost as an arc furnace, and certainly not at a less cost.

In addition to the greater cost of an induction furnace there is that of the plant for compressing the air for cooling. There also has besides to be added to the working expenses of an induction furnace the wages of two skilled attendants (for day and nights shifts) for the special machines—be it a separate generator or a motor generator—and to carry out necessary repairs. In this respect the working expenses of an induction furnace are considerably higher than those of an arc furnace, which can be equipped with static oil transformers.

Further, rotary machines are likely to run hot, and the insulation of the moving coils is also more liable to puncture than that of the windings of a static transformer, built for the same voltage. An oil-transformer when once installed requires no attention beyond overhauling once a year. Generally speaking, the chance of a breakdown with a rotary furnace transformer is double that with a machine in the generating station. When the current is delivered direct from the generating plant—with or without a transformer—a breakdown is of less consequence, as the whole plant is kept in reserve, and, if necessary, another generator may be switched on to the furnace circuit. The time required to remedy any fault is therefore considerably shorter.

Finally, the working expenses with induction furnaces are much increased by the low efficiency which, including transformer losses, amounts to 72 to 82 per cent., whereas the efficiency of a corresponding arc furnace plant is 95 to 99 per cent.

That the above-mentioned defects of the induction furnace are admitted by those who have developed this system of electric furnace is clearly proved by the numerous new remedying devices which are always being patented. Rodenhauser has, for instance, introduced dams or lips in the channel-bottom in such a way as to allow only the layer of slag to rise above the upper edge of the lip. But the electric current is then obliged, at these points, to pass through the thin and comparatively bad conducting layer of slag. Another inventor has placed bridges below the surface of the molten metal at the entrances of the narrow lateral channels of the hearth, with the object of retaining the slag, so as to prevent it altogether from entering them. In another modification of this device the lower edges of these bridges are placed at the level of the surface of the bath, or just below it. By this contrivance the slag is prevented from entering the channels, and any which may have penetrated into them can easily be removed. In order to facilitate repairs spare interchangeable channels of compressed material with special coatings of alumina or silicates are kept in readiness for use. How far these and other improvements will really prove successful in practice remains to be seen. It is nevertheless interesting to observe that the induction furnaces have lately been so much modified as to have lost their original character by making them approximate more and more to the arc furnace type.

Arc Furnaces.—The construction and method of operation of arc furnaces are now well known, and a considerable number of them have withstood several years' practical test in every respect in numerous metallurgical works. The principal advantage of the arc furnace consists in the ease with which the heating of the charge can be regulated to any desired temperature from above by electric arcs directed upon the slag which covers the metal bath. This method of heating, combined with other advantages of the electric furnace such as a neutral atmosphere in the melting chamber and absolute purity of the heating agent have enabled the production of reactions between the slag and the metal with respect both to oxidation and reduction which it was impossible to obtain with the resources previously available, and after a long experience in the working of electric furnaces the author has gained the conviction that absolutely new processes will in time be developed to supplement or perfect the present ones.

The readiness with which the arc furnace has been adopted is not only due to the abovementioned advantages, but also to the fact that the electric conditions permit its construction to resemble closely that of the familiar converters and open hearth furnaces. The usual type of arc furnace, such as the Heroult, Girod, Keller, Stassano, and others, resemble the

gas fired furnaces in that the heat is applied to the charge at the surface, the gas flame being replaced by an electric arc.

The author has for many years made a special study of arc furnaces and their working conditions, and he was soon obliged to acknowledge the great advantage of electric arc heating. At the same time the idea occurred to him that it might be possible to combine the advantage of the arc furnace (good heating of the slag) with the advantage of the induction furnace (heating in the charge itself), and thus to avoid the disadvantages of both systems. It became evident to him at once that the electric current offered the possibility of applying heat not only at the surface of the charge, but also at any part where an intense heat is required, such as in the charge itself or especially at the bottom of the furnace.

The transformation of the electric energy into heat in the substance of the material which is to be heated is neither a contact nor a transmission phenomenon, but a thermodynamical frictionless heating, with 100 per cent. efficiency even at the highest temperatures. The only losses are those due to radiation and conduction. Hence in this process of heating the question is not how much heat is imparted to the charge, but how much of the heat generated within the charge itself can be retained therein.

In the author's opinion it would be a mistake not to take this advantage into consideration. Besides, the natural method of heating consists in applying the heat not from above but from below. If this could be effected by some simple means then a most substantial advantage over other arc furnaces would be gained, as the following thermotechnical considerations will show.

From the practical point of view the best method of heating is undoubtedly that which can be applied with the least possible loss, with the greatest possible regularity, and is so adjustable that the temperature of the furnace can be regulated at will between the required maximum and minimum.

These conditions are badly fulfilled in the simple arc furnace. The losses through radiation and conduction are considerable, being greater than those in a gas fired furnace, on account of the much higher temperature. The overheating of the surface is also greater for the same reason. On the other hand, the heat losses due to the heating of quantities of air passing through the furnace are avoided in an electric furnace.

All these disadvantages are more or less eliminated in the induction furnace, which certainly best fulfils the required conditions, and the question then arises as to why the arc furnace has made more rapid headway than its rival. The answer is simple! The problem of electric furnaces in technical metallurgy is less concerned with the thermotechnical side than with the metallurgical side, and the metallurgical requirements must always determine the choice of the system of furnace.

The processes which the steel metallurgist has to carry out in his furnace may be divided into three groups: (1) The melting process. (2.) The refining process (oxidation by means of atmospheric air, or by iron ore). (3.) Deoxidation or finishing process (alloying), degasifying, quietening.

The induction furnace is only to be recommended when it is a question of a melting process, and when its otherwise serious defects are not preventive. Notwithstanding its higher thermal efficiency, the working of an electric furnace is too costly to enable it to be used ordinarily for a melting down process. For purely economical reasons the less perfect but cheaper gas fired furnace is preferable for this purpose. On the other hand, for a process of refining metal already melted, the arc furnace is particularly well adapted. To produce reactions which depend on the reciprocal action of the slag and the metal, it is requisite to have a very hot slag, and to be able to work with fluid masses of slag in large quantity. This cannot be done in the induction furnace, and the arc furnace alone lends itself to such operations. In finishing the charge, however, the steel has to be alloyed with other metals, and must remain quiescent for a period. For this purpose heating by an ordinary electric arc is less favourable. The reactions take place only within the bath; the slag has ceased to react, has become neutral, and serves now only as a protecting cover. It is, however, impossible to make use of an arc furnace for one part of the process and an induction furnace for another. The difficulty can only be met by means of a combined arc and resistance furnace.

The Nathusius Furnace.—In the author's furnace the charge is heated on the surface by several electric arcs, so distributed that the heating is effected as equally as possible. Heating by means of a single arc is absolutely impracticable, because the arc, though a very intensive, is a highly localised source of heat.

It has been said, with some truth, that the arc in the electric furnace is a necessary evil. It is necessary for heating the slag, but its disadvantage is that its temperature must at least be that required to volatilise carbon (3,000° C.), since this is the essential condition of its existence.

Since the maximum desired temperature of the furnace is between 1,900° and 2,000° C., it has been the author's endeavour to weaken the intensity of the arc as much as possible, and to reduce the unavoidable over-heating on the surface of the charge to a minimum. In order to effect this he transferred as much as possible of the energy required for a particular furnace to the bath, or rather to the bottom of the bath, and the method of heating thus approximates to that of an induction furnace. By the aid of special means for the distribution of the current, it is possible to transfer a larger amount of energy to the arcs at the surface, or to the bottom electrodes as desired.

From the illustration Fig. 1 it will be seen that the furnace is circular in form. The radiation and conduction losses are thus reduced to a minimum, and the doors allow of a convenient access to the hearth for the performance of the required metallurgical operations, such as drawing off the slag, sampling, or repairs to the bottom. The furnace can be tilted by electric or hydraulic means. Small furnaces up to 6 tons capacity are tilted on trunnions resting on vertical supports (in the same manner as converters), and larger sized furnaces have rockers resting on rollers (like tilting open-hearth furnaces and mixers).

The characteristic of the furnace, as illustrated, is that it has three carbon electrodes above the surface of the charge which project through the roof into the furnace, and three or a multiple of three (3, 6, 9) bottom electrodes of mild steel rammed in the hearth. The upper as well as the bottom electrodes are arranged in a regular triangle. No regulating devices or other electrical apparatus, such as transformers or motors, are attached to the furnace itself, but these are installed in a separate well-closed room behind the furnace as shown in Fig. 1.

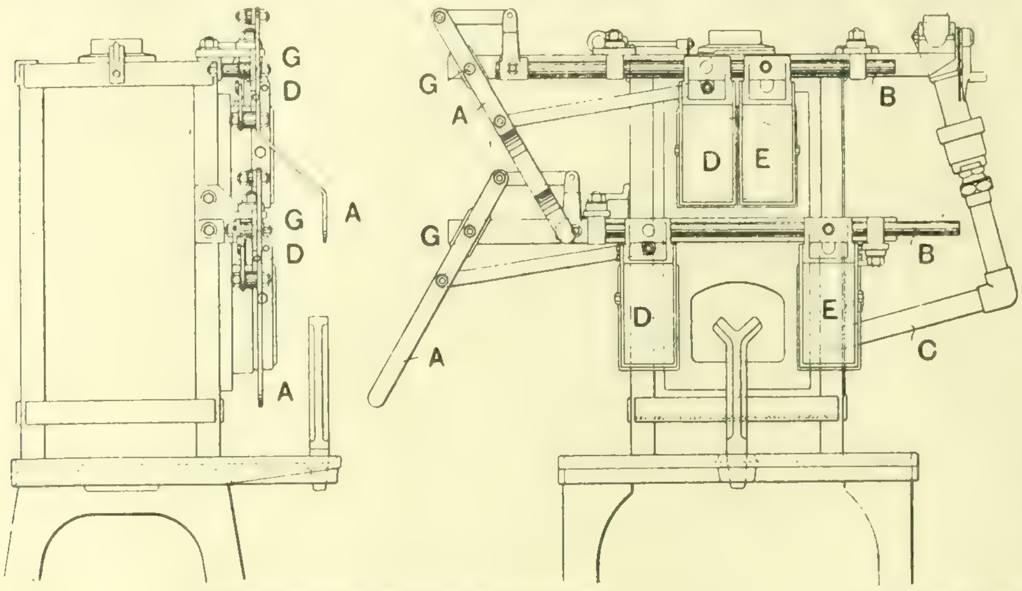
The furnace is purely a metallurgical apparatus, and all operations may be performed without risk of burning a motor or transformer, or exposing a regulator to dust. The carbon electrodes, which require continuous adjustment, are suspended by cables from overhead runways, and are either adjusted electrically or by means of handwheels from the switchboard. From the room where these are installed a good view of the furnace is possible. The independent suspension of the carbon electrodes comprises a number of advantages; first, it allows of tilting the furnace without having to tilt the electrodes. The breaking up of the electrodes is thus considerably reduced, as this generally takes place when the furnace is being tipped. When tilting the author's furnace the electrodes are simply drawn up; secondly, by suspending the electrodes from runways they can be readily drawn away to one side by means of a chain and quickly changed.

(To be continued.)

Machine-made Cores.—At a meeting of the Sheffield branch of the British Foundrymen's Association, Mr. H. S. Green, of London, read a paper on "Mechanical Core-making." The first attempt was made to construct a machine for core-making in 1893. This was for loam cores for pipes. Three years later a machine was made for turning out sewing machine arm cores. From that time great progress had been made, and the machines now in use had as their prominent features the making of more accurate cores, an increased rate of production, superior cores in that they vented better owing to greater uniformity in ramming, and there was less likelihood of swelling taking place. Where repetition was needed there was undoubtedly great advantage in the machine core maker, but he did not claim superiority of machine work over hand work where only small numbers were required.

BRAYSHAW'S TOOL-HARDENING FURNACE.

THE accompanying illustrations show a design of twin furnace for heating tools or other articles for hardening or similar purposes, the joint invention of S. N. Brayshaw and E. R. Brayshaw, Mulberry Street, Hulme, Manchester. The principal feature of the design is the arrangement for operating the doors, the furnace being constructed in the usual way with two chambers, doors suspended from a bar, a flue leading from one chamber into the other, and a gas or oil burner C to heat the furnace. The doors D E of both chambers are hung or suspended from a bar B placed above the furnace



BRAYSHAW'S TOOL-HARDENING FURNACE.

mouth. The bar B is fitted loosely in brackets, and is free to move longitudinally therein. The door D is mounted loosely on the bar B so as to be capable of being moved or slid laterally thereon, but the door E is fixed to the bar B and moves along with it. An operating lever A is pivoted on a fulcrum G to a fixed part of the furnace structure, and to the lever A a link is connected above the fulcrum G and a link below it. The upper link at its other end is connected to a bracket affixed to the bar B, and the lower link at its other end is connected to the door D. By rocking or moving the operating lever A about its fulcrum pivot G the bar B and with it the door E are moved in one direction, while the door D sliding on the bar is moved in the opposite direction. The operating lever A for the upper chamber is cranked to allow it to swing clear of the operating lever for the lower doors.

INDUSTRIAL AND TRADE NOTES.

More Oil Steamers Ordered.—The Palmer Shipbuilding Company, Jarrow, have, we understand, received orders for two additional oil-carrying vessels of large dimensions. It is stated that one of the vessels will be fitted with Diesel oil engines.

Wireless Telegraphy on the British Gold Coast. Marconi's Wireless Telegraph Company, Ltd., have contracted to supply and erect a radiotelegraph station at Accra, a port on the Gulf of Guinea, about 80 miles east of Cape Coast. The station will be employed mainly for communication with ships.

World's Petroleum Production. The world's output of crude petroleum in 1910 was 327,472,256 barrels of 42 gallons each, against 298,326,073 barrels in 1909. Of this amount the United States alone produced 209 million barrels, Russia 70 millions, Galicia 13 millions, Dutch East Indies 11 millions, Roumania 10 millions, and India 6 million gallons.

Extension of Light Railways. According to a White Paper just issued, comprising a report of the Board of Trade's proceedings up to December 31st, 1911, and those of the Light Railway Commissioners up to the same date, the Board confirmed all orders submitted (except two still under consideration) authorising the construction of 45 miles of line at an estimated cost of £190,521.

Scottish Blastfurnacemen's Wages. As a result of the report by Mr. John M. MacLeod, C.A., Glasgow, to Messrs. James C. Bishop and James Gavin, joint secretaries of the Board of Conciliation between the owners of blastfurnaces in Scotland and the blastfurnacemen as to the price of Scotch pig iron warrants in the Glasgow market for the months of February, March, and April, 1912, there is a rise of 5 per cent. in the workmen's wages.

Light Railways.—The Board of Trade have recently confirmed the undermentioned Order made by the Light Railway Commissioners: Southend-on-Sea Light Railways (Extensions) Order, 1912, authorising the construction of a light railway in the borough of Southend-on-Sea in the County of Essex, in extension of the light railways authorised by the Southend-on-Sea and District Light Railways Orders, 1899 to 1909, and amending those Orders, and for other purposes.

Museum of Safety Appliances. With reference to the article on this subject in our last issue, we note that Mr. Wardle recently asked in Parliament whether any arrangements had yet been made for a museum of safety appliances in this country. Mr. McKenna said the Government had decided to establish such a museum, and the arrangements were in hand. The selection of the site had taken a little time, but the offer of a suitable site in a central position in Westminster had now been accepted, and provision had been made in the Estimates for commencing the erection of the building in the course of the present year.

The Shipyard Agreement.—The 17 trades signatory to the National Shipbuilding Agreement have concluded their respective voting on the question of ending or amending the agreement which has been in existence a little over three years. The Boilermakers' Society's vote, we understand, resulted in a majority for no agreement at all, and notice to terminate was accordingly given to the employers. The other 16 trades favour amendments to the agreement to facilitate its operation, and among all the societies there is a very strong feeling in favour of an independent chairman being added to the constitution. The unions interested have, in their collective capacity, it is stated, intimated to the Shipbuilding Employers' Federation a desire for an early meeting to discuss the whole question.

Triple-Screw Tunnel Motor.—The Ailsa Shipbuilding Company, Troon, launched, a few days ago, the triple-screw tunnel motor vessel "St. George," which they have built to the order of the Foreign Office for use on the river Congo. The vessel, which has a length of 110ft. on the water line and a breadth of 20ft., has a draught in loaded condition of 3ft. The propelling machinery consists of three sets of Kromhout paraffin motors, driving screws in three separate tunnels, and designed to give a speed of 10 knots when the vessel is loaded. All the auxiliary engines are oil driven and use paraffin. The vessel has been built in sections for convenience in shipment, and after the trials she will be dismantled and shipped to Matadi, and transported by rail to Leopoldville, where she will be re-erected and handed over. It is understood that the "St. George" is the first triple-screw tunnel vessel built.

New Dredger for Cardiff.—Messrs. Wm. Simons & Co., Renfrew, launched on the 3rd inst. the barge loading bucket dredger "Robert Vassall," which they have constructed to the order of the Taff Vale Railway Company. The vessel was launched complete, with steam up and ready for work. The bucket ladder, which is constructed in accordance with the builders' latest practice, is designed for dredging to a depth of 40ft. below water level. The nominal bucket dredging capacity is 700 tons per hour. The vessel is propelled by one set of compound surface condensing engines supplied with steam by two marine multitubular boilers constructed for a working pressure of 120lbs. The propelling engines are arranged for also driving the dredging gear, and change gear is provided, so that a constant speed of engine can be maintained whether the dredger is working on soft or hard material. Independent manœuvring winches are supplied at the bow and the stern for regulating the cut of the dredger, and independent hoist gear is fitted for controlling the bucket ladder.

Submersible Electric Motors. A demonstration was given a few days ago in the Thames at Hammersmith of a new submersible electric motor pumping set, constructed by the Submersible and J. L. Motors, Ltd., Southall. The motor is coupled to a Gwynne pump, and is unenclosed except for a light covering intended to keep floating debris from the working parts. It is claimed that it is equally efficient whether sunk in 50ft. of water or running on dry land. At the demonstration the apparatus was set to pump out a 100-ton barge which had previously been submerged, and performed the test very satisfactorily. An 11 h.p. set is capable of discharging 30,000 gallons an hour to a height of 30ft., and

the overall efficiency of motor and pump is said to be 53 per cent. Motors of the type occupy very little space, and, coupled to any sized centrifugal pump, may be placed in the main watertight compartment of merchant steamers or war ships. They can be started at once although under water provided the vessel's dynamos are available. The Admiralty has, we understand, ordered a number of pumping sets. The motors are suitable for mining work and other engineering undertakings, such as dock works where the presence of water is a difficulty.

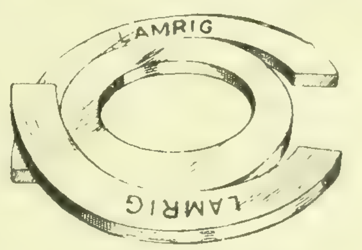
Industrial Position of Japan.—According to the annual statistics on the amount of capital invested in business just published by the Bank of Japan, the total of new capital invested in 1911 was £36,113,900 as against £58,700,000 in the preceding year. Of this amount no less than £8,500,000 went into electrical undertakings. Looking back on previous years, the report recalls that the record was touched in 1907, when the amount of new capital invested was £67,000,000. This boom, however, soon collapsed and a reaction followed. In the lean years of 1908 and 1909 the investments were respectively £13,500,000 and £12,800,000. Attention is drawn to the expansion of the gas industry, which absorbed £3,900,000, but it is pointed out that the development of manufacturing industries was unimportant and the amount of capital invested quite insignificant. It is noteworthy that light railways show a steady development, and it is a matter of comment in some quarters that the Government should so freely give concessions for lines, which in many cases compete severely with the State lines, which were nationalised only a few years ago.

Foreign Trade of Italy in 1910—The recently issued report on the foreign trade of Italy for the year 1910 states that the output of the Italian iron mines, chiefly situated in the Island of Elba, amounted in 1910 to 551,259 tons, being an increase of 46,064 tons over the figures for the preceding year. The production of pig iron amounted to 353,239 tons, as against 207,800 tons in 1909, all being consumed in the country, in addition to 205,975 tons imported from the United Kingdom and Hungary. The low price of steel in Italy has fostered the manufacture of rails, of which up to 1907 Italy had to import large consignments. Local production has now almost doubled, and imports have decreased in proportion, Belgium, Germany, the United States, and Great Britain being the chief supplying countries in the order named. In motor cars there was a slight decrease, both in exports and imports. Italy's best customer is the United Kingdom, which, during 1910, purchased no less than 813 cars out of a total of 2,120 exported. Comparing the values of the trade with different countries, it is noteworthy that Germany still maintains the first place, both on the lists of imports and exports. As to exports the United Kingdom has made great progress, and now ranks fifth among Italy's customers. In regard to imports the United Kingdom is second in rank, but the values show a decrease as compared with 1909, owing to the fall in price of coal. In rubber goods the United Kingdom has made notable progress from £98,450 to £110,963. England has also more than doubled her exports of copper, brass, and bronze wares to Italy, and is competing keenly with Germany in the supply of tools for working wood and metals.

Steam Engine Makers' Society and Strikes.—The annual report of the Steam Engine Makers' Society for the year 1911 just issued states that the year 1910, like its predecessor, has been one of turmoil and unrest, but happily, on the whole, the engineering trade has not been to any large extent affected directly by the prevalent epidemic of the strike. Their troubles and difficulties in the main have been effectually settled across the conference table, and with results far better, on the whole, than could possibly have been achieved by any other method, and what is more, neither the members nor the Society are impoverished in the process. Industrial warfare has beyond a doubt been a veritable curse during the past twelve months under review, and any advantages, if any, have been gained at a cost far indeed out of proportion to the benefits received. The engineering trade has been exceptionally good during 1911, and in all branches of the industry. This being the favourable position, advances in wages have been general throughout the country, and thanks to the often much abused terms of agreement this substantial and regular progress has been attained without the assistance of the much belauded strike, and what is more, without the personal sacrifice that any such policy entails. Employment has been exceptionally good among members of the Society, showing the very low percentage of 1·1 unemployed upon the average membership of the year, compared with 2·14 in 1910, and 5·5 in 1909. The figures for the opening of the present year are extremely promising, and if only strife and discord could be obviated and avoided, and, what is of more vital importance, the spirit of discipline and order prevail in the ranks of trade unionism, the outlook for 1912 is bright indeed.

Marine Engineers' Wages.—In October of last year the representatives of the Marine Engineers' Society approached the Shipping Federation with a view to an improvement in the rate of wages paid to sea-going engineers, and the conditions under which they worked on board ship. It was urged that the wages of the marine engineers had not increased in proper ratio to the increased cost of living, or to the increase of wages in other trades. The representatives of the owners and engineers met on March 12th, and after considering suggested scales of wages it was agreed that the scales proposed should apply to the ordinary type of cargo steamers only, and not to liners, oil tank steamers, or weekly boats under 1,000 tons deadweight capacity. No final agreement was arrived at on this occasion, but several meetings have since been held, and after exhaustive discussion the appended scale was drawn up and accepted by the representatives of the owners and engineers. The owners' representatives recommended that in any cases where owners paid their engineers in excess of the scale for personal or special services they should not make the scale a ground for any reduction in the wages paid by them at present. The annexed scale, which comes into force at once, provides for a national rate of wages to be paid by all shipowners, and the old method of having different scales for the various trades has been abolished. The only variation in the scale will be according to the size of the vessel, and it is based on the deadweight capacity at the summer load line. The national scale agreed upon is as follows: Vessels over 8,000 tons deadweight summer F.B. Chief engineer, £18 per month; second, £13; third, £9; fourth, £7. Vessels 5,000 to 8,000 tons.—Chief, £17; second, £12. 10s.; third, £8. 10s.; fourth, £7. Vessels 3,500 to 5,000 tons.—Chief, £16. 10s.; second, £12.; third, £8; fourth, £6. 10s. Vessels 2,000 to 3,500 tons. Chief, £16; second, £11. 10s.; third, £7. 10s. Vessels under 2,000 tons. Chief, £15. 10s.; second, £11; third £7. Coasting and home trade.—Chief, £3. 15s. weekly; second, £2. 12s. 6d.; third, £2. 2s. The above rates (with the exception of those for the home and coasting trade) are in addition to food or an allowance of 1s. 6d. per day in lieu of food.

The "Lamrig" Spring Lock Washer.—The loosening of nuts and screws due to vibration is a frequent source of accident in connection with machinery. To prevent such occurrences a neat and compact design of spring lock washer known as the "Lamrig" has been introduced by The Harvey Spring Lock Washer Company, Ltd., of Norfolk House, Laurence Pountney Hill, London, E.C. This is shown in the accompanying cut, from which it will be seen that the design is novel and the construction such as to make it impossible for nuts and screws



THE "LAMRIG" WASHER.

to work loose. The side strain on bolts, another familiar trouble to the engineer, is also eliminated, owing to the symmetrical form in which the washer is made. The fixing of the washer is an easy operation, no special method being required. It is produced in a variety of sizes ranging from ⅜in. up to the largest diameter of bolts in use. Each washer is, it should be mentioned, subjected to severe tests before leaving the works, so that it can be thoroughly relied upon. The initial cost is only slight taking into consideration its numerous advantages. Further, the washer can be used many times without suffering deterioration of any kind. We understand that the manufacturers are exceedingly busy with orders for both home and abroad.

British Foundrymen's Association.—The sixth meeting of the Scottish branch of the British Foundrymen's Association was recently held at Glasgow. Three "foundry problems" were submitted for discussion after the business meeting. The new president, Mr. W. Mayer, was elected, and four new council members. Chief interest centred round the discussion on the relative merits of the positive blower and the fan for producing cupola blast, and opinion was equally divided as to which was the better. The second problem dealt with a difficulty experienced in making small castings with a plate mould, and various suggestions were submitted to overcome the fault. The brittle skin on malleabalised white iron by annealing in iron ore was described and accounted for by too large a reduction of the carbon.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Solidification of hydrocarbon oils. Armstrong & Mordan. 868 and 869.
Pneumatic rotary-drilling machines. Craven. 3926.
Making castings in steel, brass, phosphor bronze, &c. Vaughan-Sherrin. 4387.
Reciprocating engines of the steam, internal-combustion, or other type. Austin. 9083.
Toothed gearing. Westinghouse. 9131.
Draught and pressure meters. Hommel. 9157.
Carburetters or vaporisers for internal combustion engines. Barrett & Wilson. 9252.
Slide valves for steam engines. Duggan. 9299.
Power-operated portable hammers. Faraday. 9329.
Revolving cylinder internal-combustion engines. Butler. 9339.
Heat economising in power generation. Kitchen & Von Bernuth. 9377.
Motor road vehicles. Cleaver. 9444.
Rotary pumps. Luttrell. 9449.
Automatically-controlled valves for calorifiers and radiators. Jennings. 9612.
Purification of gases produced by the carbonisation of coal. Hiby. 9632.
Apparatus for transmitting temperatures. Lucas-Girardville and Mercadier. 9817.
Automatically controlling power-driven air compressors. Bell and Graham. 9931.
Device for automatically coupling and uncoupling vehicles. Butcher. 10099.
Metallurgical treatment of oxidised ores of copper. Dewar. 10143.
Cooling gases by direct thermodynamic process. Chamberlain. 10468.
Apparatus for use in coal mines for removing dust from rough surfaces. Mavor & Coulson, Ltd., & Mavor. 10796.
Torsiometers. Denny & Edgecombe. 11174.
Fluid-pressure apparatus. Walker. 11562.
Carburetting devices for internal-combustion engines. Bullock. 12018
Operating levers applicable to gear changing devices, electrical contacts, &c. Accles. 12127.
Manufacture of fuel briquettes. Board. 12151.
Manufacture of compressed fuel. Thomas. 12196.
Method of treating copper-bearing substances. Bradley. 12304.
Construction of ships' hulls. Von Köppen. 12478.
Compressed-air engines. Sutcliffe. 12810.
Apparatus for automatically recording the percentage of carbon monoxide in gaseous mixtures. Levy. 12811.
Clutches. Price. 13555.
Metallic packings for piston rods. Simpson & Russell. 13660.
Pipe couplings. Gammenthaler and British Mannesmann Tube Company. 15187.
Hydrocarbon vaporisers for internal combustion engines. Mowbray. 16018.
Compressed-air brakes. Müller. 16598.
Lathes. Schellenbach and Lodge and Shipley Machine Tool Company. 17477.
Internal-combustion engines. Benier. 18599.
Boring and grinding. Crossley. 18612.
Apparatus for measuring applied stress for use in connection with testing machines. Wazau. 19308.
Locking nuts on bolts. Penberthy. 19623.
Bearings. Westley. 19635.
Charging blast furnaces. Aumund. 20375.
Metal packing rings. Wasson. 21425.
Means for operating and locking railway points or switches. Wood. 23285
Apparatus for loading and unloading ships. Grossmann & Neumann. 23894.
Workmen's time recorders. Kiely. 24490
Fuel feed regulation and control for internal-combustion engines. Jannette-Walen. 25830
Concrete railway sleepers. Ferguson & Buel. 25870.
Pulley blocks. Great Central Co-operative Engineering and Ship Repairing Company, and Elford. 26026.
Injectors. Geb. Korting Akt.-Ges. 26239.
Roller bearings. Carpenter. 26438
Means for securing the cylinders to the crank casings of internal combustion engines. Salmson, Canton, & Unne. 26447
Apparatus for starting up explosion motors. Mairesse. 27023
Radial drilling machines. Asquith & Asquith. 28357
Wrought-iron annealing pots. Lammine. 28406.
Apparatus for mixing and compressing fluids. Harlé et Cie. 29381.
Fluid-pressure brakes for locomotives. Westinghouse Brake Company. 29397.

1912.

Valve-seating machines. Olson. 462.
Lubrication of internal-combustion engines. Butterfield. 658.
Road locomotives. Fowler, Lalonde, & Tuer. 726.
Worm gears. Shillito & Wallwork. 1037.
Lifting gear for mines. Mansfeld'sche Kupferschiefer Bauende Gewerkschaft. 1160.
Automatic couplings for railway vehicles. Zachariä. 1679.
Rotary engines. Silvestri. 2477.
Pipe couplings. Marr. 2601.
Driving of depth indicators for winding systems. Siemens Schuckertwerke Ges. 3480.
Railroad rail. Moore. 4581.
Water-tube steam boilers. Todd. 5069.

ELECTRICAL, 1910.

Electricity meters. Johnson & Billington. 19075.

1911.

Telephone exchange systems. Jensen. 9142.
Devices for starting and protecting electric motors. Wolseley Sheep Shearing Machine Company, and Brewerton. 9176.
Electrical measuring instruments. North. 9819.
Electrical reversing apparatus for remote control. Smith, Major, and Stevens, Ltd., Major, & Kennard. 12828.
Electrically-operated signals for railways. Automatic Electric Block Signalling Company, and Brousson. 14148.
Arc lamps. Wetter. 17778.
Electric sparking apparatus for internal-combustion engines. Unterberg & Helmle. 21785.
Means for cooling the rotors of turbo-generators. Körner. 26756.

1912.

Wireless telegraphy installations. Thompson. 2769.
Telephone exchange systems. Jensen. 4983.
Couplings or joints for electrical cables. Beaver & Claremont. 5071.
Telephone exchange systems. Jensen. 5876.

METAL QUOTATIONS.

TUESDAY, MAY 7TH.

Aluminium ingot	67/-	per cwt.
„ wire, according to sizes, &c. ......from	102/-	„
„ sheets „ „ ...... „	120/-	„
Antimony .... £27/-/- to	£28/-/-	per ton
Brass, rolled	8½d.	per lb.
„ tubes (brazed)	10⅞d.	„
„ „ (solid drawn)	9d.	„
„ „ wire	8¼d.	„
Copper, Standard	£68/17/6	per ton.
Iron, Cleveland	53/6	„
„ Scotch	59/6	„
Lead, English	£16/17/6	„
„ Foreign (soft)	£16/11/3	„
Mica (in original cases), small	6d. to 2/-	per lb.
„ „ „ medium	2/6 to 4/-	„
„ „ „ large	4/6 to 8/6	„
Quicksilver	£8/5/-	per bottle.
Silver	27⅞d.	per oz.
Spelter	£25/10/-	per ton.
Tin, block	£208/-/-	„
Tin plates	14/7½	„
Zinc sheets (Silesian)	£29/-/-	„
„ (Stettin; Vieille Montagne)	£29/7/6	„

Aluminium Alloys.—A lecture on "Aluminium Alloys" was recently delivered by Dr. Rosenhain at a meeting of the Birmingham Metallurgical Society. The lecturer pointed out the importance of weight in materials of engineering construction. In bridges beyond a certain size the principal load was the weight of the structure itself, and determined the limits of size to which single-span bridges could be pushed. Similar considerations applied to roofs. In the moving parts of machinery weight was an obstacle to high speeds, while the disadvantage in trucks, motor-cars, and aeroplanes was obvious. The use of light alloys raised some difficulties. In the early days undue expectations of the power of aluminium gained currency. With the purer metals now available the corrosion of these alloys was not more than that of steel.

The Mechanical Engineer.

AN ILLUSTRATED WEEKLY JOURNAL Vol. 29, No. 747

Edited by
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Shipfoundering Fallacies.

ALTHOUGH several weeks have elapsed since the tragic disaster of the "Titanic," it still looms big in the public mind, and the incidents associated with it have provided many subjects for discussion. In view of the enquiry that is being held, it would, of course, be out of place to discuss any matter affecting the personal responsibility of those in any way responsible for the disaster, but a number of general questions relating to the foundering of steamships have been so prominently brought under notice, and are of such interest from an engineering point of view, that the present seems a convenient opportunity for referring to them, especially as they bear on certain fallacies which it is desirable though difficult to eradicate from the public mind. The belief that boilers on board ship explode when they become submerged is somewhat common, even among marine engineers, and one to which we have on previous occasions drawn attention. It is opposed to all facts as well as to scientific reasoning. Numerous steam vessels which have foundered in comparatively shallow water have been salved, but we have never yet heard of a case in which the steam boilers were found ruptured as a consequence of sudden immersion, and anyone who will take the trouble to think about the matter will realise its improbability. The belief appears to rest on the fact that when ships have foundered, explosions have been heard, and as these have been usually accompanied with the escape of considerable volumes of steam from the surface of the water, it has been assumed that the boilers have given way. This idea probably also receives some support from a mistaken impression in the minds of many engineers who ought to know better that the sudden immersion produces intense contractile strains which the plates of the boiler could not resist, that the partial vacuum created by rapid condensation would cause steam to be generated with explosive violence. These contradictory conceptions of steam generation

appear to be relics of old fallacies about boiler explosions and the danger of injecting water on to over heated furnace crowns, and which were clung to very tenaciously until practical demonstration showed their baselessness. The rush of steam, which is a common incident of ship foundering, is easily accounted for by the quenching of the fires as the water gets to them, coupled with the inevitable rupture of all kinds of steam connections when a vessel gets a serious list, and the boilers and machinery break away from their fastenings. But, it may be asked, if the boilers do not burst, to what, then, are the sounds which are heard, and of which there was distinct evidence in connection with the "Titanic," due? It is easy to understand, however, that such sounds may have readily been produced by the failure of bulkheads of water-tight compartments, which became subject, owing to depth of immersion, to a pressure so much in excess of the atmosphere which they would contain when the water-tight doors were closed that they ruptured, or, in other words, the compartments collapsed much in the same way as the copper cylinder of a kitchen range is crumpled by external pressure when a partial vacuum is created in it during frosty weather, and this brings us to consider what probably takes place when steam boilers are immersed in deep water, and subjected to great external pressure. We have stated that no boiler shell that has been salved has, so far as we know, been found ruptured, nor have we ever heard of a shell being found collapsed, but in the case of all salved ships the depth is insufficient to produce a collapsing pressure greater than almost any boiler would be able to resist. If we come to consider, however, that a pressure of 100lbs. per square inch occurs at a depth of 200ft., and would increase proportionately at greater depths, it is easy to understand what does happen when boilers become deeply submerged. The diminution of internal pressure as a result of condensation from cooling would be accompanied with steady increase of collapsing pressure which would, if the shell did not rupture and there were no openings to admit water, lead to its being crushed into a shapeless mass. The extent to which this eventuality would be reached would, of course, depend on circumstances, such as the rapidity of sinking and the area of the openings created in the course of the events we have pictured. A somewhat similar action, it will be seen, would be exerted upon the various compartments that were water-tight when the vessel began to sink, and result in their distortion until they eventually ruptured, an effect which, owing to their size and large flat surfaces, would soon be brought about. In some of the popular sensational accounts of the "Titanic" disaster it has been asserted that, owing to the enormous pressure in the sea depths where she sank, the water would be so dense that the ship would never reach the bottom. It is scarcely necessary to discuss this with anyone possessing the slightest knowledge of the physical properties of water, but, as it has been put forward in all seriousness and a large section of the unscientific public believe it, it is desirable to point out its utter absurdity. Water, it is true, is compressible, but only to so slight an extent that there would be hardly any difference between the specific gravity of water at the surface of the Atlantic and at the two miles' depth where the "Titanic" lies, while, further, when water once obtained free access to the interior compartments of the ship, which it would rapidly do in the manner we have indicated, no further distortion as a result of external pressure could take place, because internal and external pressure would then balance each other. The most potent force which would determine the final shape of the "Titanic" on the Atlantic floor would be that derived from the falling of her own mass under the action of gravity through two miles of sea, and which would probably impart in this instance a velocity double that of the fastest express train. The effect of the impact between the vessel's structure and the sea floor at this speed can be more easily conceived than described. In an instant the most imposing marine structure that man has yet conceived would be converted into a shapeless heap of scrap. In discussions of the "Titanic," as well as of other previous shipping disasters, reference is often made to the suction exerted by the vessel as she sinks beneath the surface. The popular idea is that a sort of maelstrom is created, and that anyone in the neighbourhood runs serious risk of being irretrievably sucked down. This conception again is quite wrong, and not in accordance with observed facts. To begin with, the velocity of sinking in any case is very low, and only begins when the specific gravity of the ship as a whole equals that of water. Once this point is reached, gravity comes into play, and, given depth enough, it may become very great, as we have indicated, but at the beginning the surface effect is hardly appreciable. This, we believe, has been testified by several of the "Titanic" survivors, apart from which it has been supported by direct evidence on other occasions.

SURFACE COMBUSTION AND FLAMELESS HEAT.

A LECTURE on this subject was delivered by Prof. William A. Bone before the Leeds University Cavendish Society in which he described, with an experimental demonstration, a new system of intensive flameless combustion evolved by himself and co-workers as the practical outcome of many years of scientific research upon the accelerating influence of hot solids upon gaseous combustion. This process which he had recently succeeded in working out in conjunction with Mr. C. D. McCourt at the works of Messrs. Wilson & Mathieson's, of Leeds, was applicable to all kinds of gaseous or vaporised fuels. It was characterised by the fact that a homogeneous explosive mixture of gas and air, in the proper proportions for complete combustion (or with air in slight excess thereof) was caused to burn without flame in contact with a granular incandescent solid, whereby a large proportion of the potential energy of the gas was immediately converted into radiant form. The advantages claimed for the system were: (1) The combustion was greatly accelerated by the incandescent surface, and, if so desired, might be concentrated just where the heat was required; (2) the combustion was perfect with a *minimum* excess of air; (3) the attainment of very high temperatures was possible without the aid of elaborate "regenerative" devices; and (4) owing to the large amount of radiant energy developed, transmission of heat from the seat of combustion to the object to be heated was very rapid. The resultant heating effect was, for many important purposes, not only pre-eminently economical, but also easy of control.

The process had, he said, been industrially applied in two principal forms. In the first form—diaphragm method—a homogeneous mixture of gas and air in combining proportions was passed under slight pressure through a porous diaphragm of refractory material and caused to burn without flame at the surface of the exit thereof, which was thereby maintained in a state of red-hot incandescence. In this form the actual combustion was confined within a very thin layer below the surface, and no heat was developed in any other part of the apparatus. The combustion was absolutely perfect and independent of the nature of the external atmosphere. This method was specially adapted to such operations as grilling and roasting, and also to the evaporation and concentration of liquids by means of radiant heat emitted from diaphragms fixed in a horizontal plane above the surface of the liquid.

In the second or incandescent granular bed method a homogeneous mixture of gas (or vaporised oil) and air in their combining proportions was injected, at a speed greater than the velocity of back firing, through a suitable orifice into a bed of incandescent granular refractory material which was disposed around or in proximity to the body to be heated. This method had been successfully applied to all kinds of industrial operations—as, for example, the heating of retorts, muffles, crucibles, annealing furnaces, and the like, as well as to steam raising in gas-fired boilers and the melting of metals and alloys.

Experience had proved that not only were the *maximum* temperatures obtainable by the new method (for instance, temperatures exceeding 2,000° C. or 3,600° Fah. had been obtained with coal gas) very much higher than were given by any existing method, but also that the gas consumption requisite to maintain a given temperature on the new system was only about half that required in similar furnaces fired in the ordinary way by flame contact. This had been proved in exhaustive independent trials of the system in competition with existing methods.

In multi-tubular boilers fired by gas according to the new system, as much as 94 per cent. of the net calorific power of the gas could be transmitted to the water, the rate of evaporation being about twice that of a locomotive boiler. A large boiler capable of evaporating 5,500lbs. of water an hour according to the new system, which had been erected at the Skinningrove Ironworks, Cleveland, Yorkshire, was fired with coke-oven gas from a new installation of Otto-Hilgenstock by-product ovens adjacent to the blastfurnaces. The boiler, which was made by Messrs. Richardson, Westgarth, & Co., consisted of a cylindrical drum 10ft. diameter, and only 4ft. from front to back; it was traversed by 110 tubes of 3in. internal diameter which were packed with fragments of fire-brick. It was worked under the suction of a fan, capable of producing a "suction" of 20in. water gauge. To the front of the boiler was attached a device whereby gas at 2in. water-gauge pressure from a suitable feeding chamber, together with a proper proportion of air from the outside atmosphere, was drawn (under the suction of the fan) through a short "mixing tube" into each of the 110 tubes where it was burnt without flame in contact with the incandescent granular material. The products of combustion, having traversed the 4ft. length of packed tube, passed outwards into a semi-circular chamber at the back of the boiler, and thence through a duct to a tubular feed-water heater. The fan attached to this feed-water heater sucked out the cooled products and discharged them through a short duct into the atmosphere outside the boiler house.

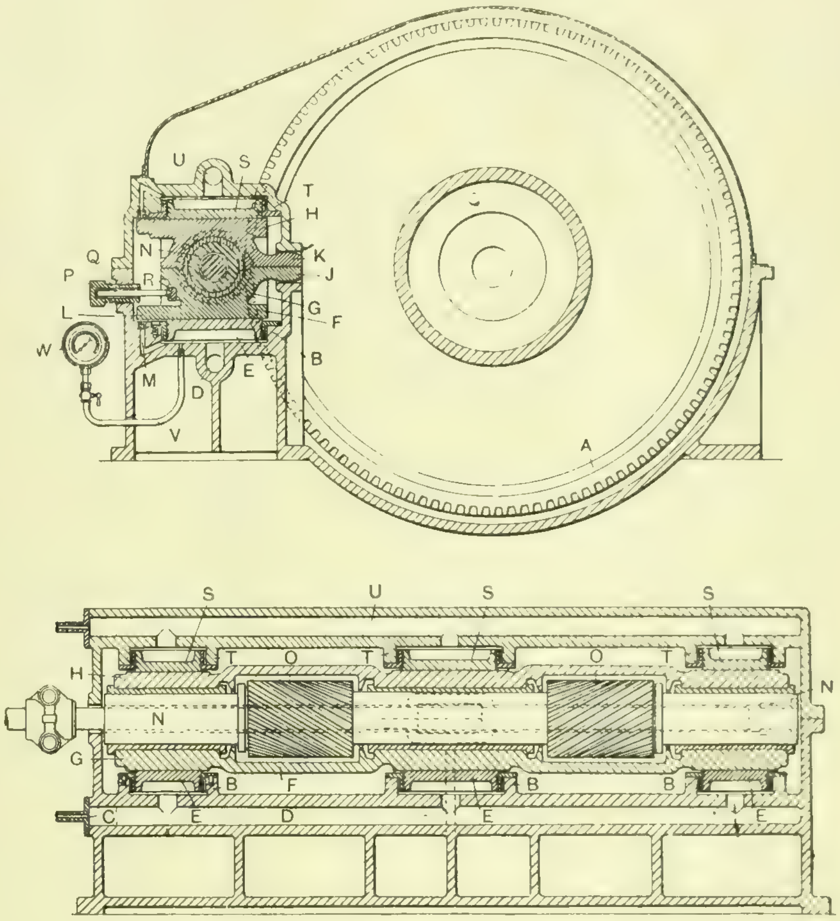
The boiler was started up on November 7th, 1911, for a month's trial run—day and night continuously—after which it was opened up for an official inspection by the representative of a boiler insurance company. The plant worked without a hitch throughout the trial, and was then taken over by the Skinningrove Iron Company. The official inspection showed the boiler tubes to be in good condition and free from scale; indeed, owing to the very rapid rate of evaporation, the scaling troubles experienced with other types of multi-tubular boilers were completely obviated, the scale being automatically shed in thin films (about one-thirtieth inch thick) from the tubes as fast as it formed. During the trial the average temperature of the waste gases leaving the feed-water heater was about 75° C.—a sufficient proof of the thermal efficiency of the plant. After the inspection the plant was re-started, and had since been in continuous operation. Despite the high rate of evaporation maintained, there was a complete absence of "priming."

By a modification of the principle employed for steam raising, lead and similar metals could be melted in bulk with a thermodynamic efficiency of 80 per cent.

Fatal Gas-cylinder Explosion.—As a result of an explosion at a shop in Govan on the 9th inst., two men were seriously injured, one of whom subsequently died. The men were engaged in bottling aerated waters. In the process a small tank or cylinder into which gas is injected was being used. The men had just finished pumping gas into this tank when the explosion occurred, and the bottom of the tank was blown out, evidently with great force. One of the men had his left leg nearly severed at the knee, which proved fatal, and the other sustained a compound fracture of the left leg below the knee. Both men also received other injuries.

WESTINGHOUSE SPEED-REDUCTION GEARING.

When reduction gearing is employed for transmitting relatively high powers from a high-speed machine to apparatus adapted to be driven at lower speeds, it is necessary to provide means whereby the pressure at the surfaces of contact between the teeth of the intermeshing gear wheels may be equalised and distributed not only in order to avoid undue wear upon the teeth and consequent losses in efficiency, but to avoid the noise and vibration accompanying such wear. It has therefore been proposed to mount one of the intermeshing wheels or one set of such wheels, when more than two wheels are employed, in a floating frame which is so supported as to permit relative angular motion between the axes of the intermeshing wheels in both a horizontal and a vertical plane, means being provided in some cases for limiting the angular movement in a horizontal plane during operation, struts or other devices being provided for this purpose. Apparatus of this description, although not limited in this respect, is primarily intended for use in systems of marine propulsion in which turbines are employed, since these machines are most efficient when run at high speed, whereas ships' propellers as at present constructed are more efficient when driven at relatively low speeds.



Westinghouse Speed-reduction Gearing.

Fluid actuated devices for supporting rotating shafts in such a manner that displacement or tilting of the shaft automatically regulates the balance of fluid pressure, whereby the shaft is restored to its normal position, are already known, and the arrangement illustrated herewith has recently been designed and patented by Mr. George Westinghouse, Westinghouse Building, Pittsburg, Pa., U.S.A., with the object of providing an improved construction of fluid actuated supporting mechanism for equalising and distributing the pressure between the intermeshing teeth of gear wheels. In this arrangement one of the intermeshing wheels or one set of such wheels where more than two wheels are employed is supported in a floating frame by means of fluid under pressure in such a manner as to permit certain relative angular motion between the gears during operation and also resilient engagement of the intermeshing teeth. Other features of the arrangement comprise means for ascertaining the amount of power transmitted by the gears during operation.

Referring to the illustrations, the apparatus consists of a base frame in which is journalled large gear wheels A which mesh with corresponding pinions carried in a floating frame. The base frame is provided with a plurality of cylinders B, which are adapted to be supplied with oil through a passage C and a channel D in the base frame which communicates with the cylinders through the ports shown. The passage

C is of relatively small area so as to restrict the rate of flow of fluid supplied to the channel D. Located in the cylinders B are pistons E adapted to support a floating frame F comprising two sections G and H secured together and having projecting portions J and K which are held in bearings in the base frame. The floating frame F rests upon the pistons E and is provided with projecting flanges L which serve to control the passage of fluid through a port M leading from the intermediate cylinder B to an outlet passage within the base frame. A shaft N is provided supported in bearings in the floating frame on which pinions O are mounted which mesh with the gear wheels A. A number of struts are provided extending through the wall of the base frame, comprising a hollow threaded member P in which is located a bar or pin Q, the inner extremities of which engage with a bearing R in the floating frame F. The member P is threaded exteriorally to engage interior threads in the wall of the base frame so that an adjustment may be made and the floating frame may be so adjusted with respect to the gear that a proper engagement of the teeth of the pinions and gear wheels will be maintained and at the same time vertical angular movement of the pinions with respect to the remaining parts will be permitted.

The operation of this form of apparatus is as follows: Fluid being pumped into the cylinders B, through the channel D, the pistons E are raised within their cylinders sufficiently to support the floating frame. If the pinions are being driven counter-clockwise so as to drive the wheels A clockwise the pressure on the teeth of the intermeshing wheels will have a tendency to seat the valve flange L so as to close the port M. The pressure in the cylinders B will therefore increase until this pressure is in excess of the pressure between the teeth of the intermeshing wheels, whereupon the pistons E will be raised slightly and the port M uncovered so that the oil will pass through this port into the overflow, from whence it may be carried back to a receptacle provided for the purpose. It will be seen that the intermediate cylinder B and its piston E are of greater diameter than the end cylinders and pistons. The intermediate piston is shown as being approximately twice the area of the end pistons, as the preponderance of pressure will be distributed at this central point. The struts P prevent horizontal angular movement of the floating frame and still permit sufficient vertical angular movement thereof.

The apparatus above described is suitable for speed-reducing mechanism in which the direction of rotation of the driving and driven wheels is constant. Under some conditions, as in systems of marine propulsion, however, where it is necessary to reverse the propeller and consequently the turbine, means must be provided for permitting reversal of the direction of rotation of the intermeshing wheels and the shafts on which they are mounted. In order to provide for cushioning or distributing the stresses set up under these conditions, a series of pistons S located in cylinders T are provided, and operating in precisely the same way as the pistons E, but through a different set of connections U. It will be apparent that when the pistons and cylinders are duplicated in this manner, the floating frame will be held between the upper and lower sets of pistons and will be supported upon a body of fluid in such a manner that the strains or stresses transmitted through the gearing will be taken up by the fluid in the respective cylinders and the pressures will be properly distributed between the different bodies of fluid in accordance with the direction of rotation of the shafts. In order to measure the amount of power transmitted by the gearing a pressure gauge W is provided connected to the channel D by a pipe V so as to measure the pressure of the fluid on which the floating frame F is supported, thus indicating the power transmitted by the gears during operation. It will thus be seen that the pinion shaft is held in place without any connection with any bearings, and any vibration due to the operation of the device will be absorbed by the fluid upon which the floating frame rests.

Steel Trolley Wire.—Steel trolley wire has been adopted on a few American electric railways, but it has not been in use for a sufficient time to determine its relative life and behaviour in service as compared with copper wire. The steel wire is hard drawn from billets in a way like that employed for copper wire. No difficulty has been experienced with steel wire in making splices or welds not exceeding ½in. in length and having a tensile strength of 80 per cent. of the wire on either side of the splice. The relative conductivity of steel and copper wire is approximately 1 to 7.

EXPERIMENTS ON BELTING.

IN an article devoted to belting for power transmission purposes by H. Kammerer, in a recent issue of "Zeitschr. Vereines Deutsch. Ing," the author states that when a leather belt is overstrained it must be frequently tightened, because the yield is large and rapid. A belt not overstrained requires tightening only to a certain degree, when it acquires a steady elastic state. This state is often acquired only after hours of work; thus belt experiments must consider the influence of time. With leather belting elastic extension is large and the permanent extension small. The ratio of tensions is more than twice as great as the frictional theory would give. This the author explains by adhesion of belt to pulley. The effective tension per inch width is 78lbs. at belt velocities between 33ft. and 98ft. per second, and 72·5lbs. at 131ft. per second. The maximum power per inch width of belt is transmitted at 164ft. per second. Double leather belts are used, the layers being in three cases fastened together throughout the entire length of the belt by bronze wire clips, leather lacing, and glue. Each of these three modes allows a high effective tension; with bronze wire clips up to 475lbs. per inch width is realised, with the others 363lbs. per inch. In double belts the effect of adhesion appears greater than that of friction, the ratio of tensions reaching 5·0. Leather link belting is better than ordinary leather belting for speeds under 65ft. per second. At higher speeds it is worse, on account of greater weight. Ratio of stresses in link belting varies according to a linear law from 2 to 3, being 2·0 at 98ft. per second, and 2·6 at 49·0ft. per second for a pulley of 49in. diam. and 180° arc of contact. When leather belts are run with the flesh side against the pulley, the tension ratio exceeds 3·0; with the hair side against the pulley this ratio does not exceed 2·0. The effective tension is 16·75lbs. per inch greater with flesh side than with hair side against pulley, and the maximum speeds allowable in the two cases are 164ft. per second and 98ft. per second respectively. The author suggests that the durability also is greater with flesh side working because the curvature of the leather is in the same direction as when on the back of the animal. Experiments on cotton, balata, and camel-hair belting show that the material is not so important as the kind of weaving employed. A smooth dense surface against the pulley face is to be recommended as more adhesive. Camel-hair belting allows 30 per cent. less effective tension when wet than when dry. A belt-fastener should be spread over as large an area as possible. The results of the experiments cannot be explained by the ordinary friction theory; adhesion occurs between belt and pulley, which varies directly as the belt speed up to 164ft. per second, and increases when the pulley surfaces are more smooth or the belt more flexible.—"Science Abstracts."

International Association for Testing Materials.—A meeting of Committee IA of this Association was held on the 8th inst., at the offices of the Iron and Steel Institute. Its object was to consider proposals for the introduction of international specifications for structural steel, steel for shipbuilding, and rails, for export, with a view to making recommendations to the sixth International Congress to be held in New York from September 3rd to 7th next. It was decided that the time was not ripe for the Sixth American Congress to entertain the matter of the international specifications in question, the Committee IA being maintained and continuing its work in the mean time.

Carnegie Gold Medal and Scholarship Awards.—At the recent annual meeting of the Iron and Steel Institute, the President (Mr. Arthur Cooper) announced that the Andrew Carnegie gold medal for the year had been awarded to Dr. Paul Goerens, of Aix-la-Chapelle. He received a Carnegie scholarship grant of £100 in 1910 to enable him to pursue his investigations on the influence of cold working on the properties of iron and steel, and it is for the results obtained in connection with this research that the gold medal has been awarded to him. Andrew Carnegie scholarships awards of £100 each have been made to Mr. Arthur Kessner, constructional engineer at the high school and lecturer in mechanical technology at the "Urania," Berlin; Mr. Eugene Nusbaumer, of Loncin-lez-Liege, Belgium, and Mr. J. Allen Pickard. A further grant of £50 has been made to Mr. John Charles Willis Humfrey, of the National Physical Laboratory, Teddington, who was the recipient of a grant of £100 in 1910.

THE PRESENT STATE OF DEVELOPMENT OF LARGE STEAM TURBINES.*

BY A. G. CHRISTIE.

Present Field of Large Steam Turbines.—Steam turbines are now being used for driving alternating-current generators, turbo-compressors, turbo-blowers, pumps and marine propellers, and, by means of gearing, to furnish power to direct-current generators, rolling mills, and the propeller shafts of steamships. Reciprocating engines were formerly used for such purposes, but recently this class of engine has seldom been installed except for rolling-mill work, non-condensing service as on heating systems, rope and belt drives, hoists, and in certain combinations with low-pressure turbines in marine work. The high economy of the piston-pumping engines and also of some types of air compressors, has

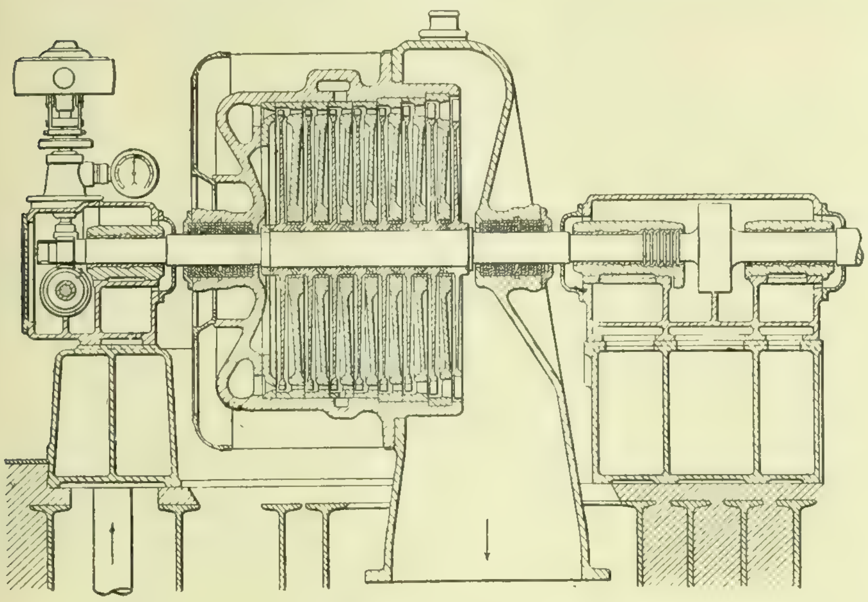


FIG. 1.—SECTION OF ZOELLY TURBINE.

continued their popularity in spite of the increasing competition of steam turbine units. The steam turbine has found favour principally on account of its low first cost of installation, its small floor space requirements, its continued good steam economy over a period of years, and its small operating and repair charges. The increased use of steam turbines in sizes up to 1,000 h.p. seems to have received at least a temporary check in Europe by the introduction of the new Stumpf direct-flow engine.

Types of Steam Turbines.—For the purpose of this paper, large commercial steam turbines will be divided into two classes: (*a*) fundamental types, and (*b*) modified or combined types. The fundamental types of turbines are as follows:—

The Parsons type, which works on the so-called "reaction" principle. In this type the heat energy of the steam is changed into kinetic energy, both in the stationary guide blades and in the moving blades. In other words, both sets of blades act as orifices expanding the steam through a small pressure drop. As nozzles and orifices usually have very high efficiencies, this turbine should, theoretically, prove the most economical of all types. The construction of the Parsons turbine is familiar to all engineers. It consists of a drum, or a number of drums, carrying the blade rows which alternate with rows in the casing. The drums carry balance pistons to equalise the end thrust.

The Curtis type, which works on the impulse principle with high-steam velocities and few stages. Each stage, however, is provided with two or more rows of revolving blades known as "velocity rows," with intermediate rows of guide blades. The steam velocity at the beginning of each stage is high. The revolving blades are carried on discs separated by diaphragms, which extend to the shaft and which carry the orifices between stages. Curtis turbines are now usually built with horizontal shafts. In American practice some sizes over 7,000 kw. still have vertical shafts.

The Rateau turbine, which consists of a number of simple impulse wheels in series on the same shaft and separated from one another by diaphragms carrying nozzles. It operates with lower steam velocities than the Curtis and consequently has many more stages. Each revolving element carries only one row of blades.

The type of turbine known as the Zoelly belongs to the same classification as the Rateau, from which it differs only in the use of higher steam velocities, in the number of stages, and in certain constructional details. Fig. 1 shows a section of a Zoelly turbine.

Each of these fundamental types is based on sound theoretical principles. In the process of manufacture and in operation, certain features have not proved entirely satisfactory, hence far-reaching modifications have been made in the design of some types of turbines. Some manufacturers have combined the characteristics of two or more types to overcome the inherent limitations of each fundamental type. A discussion of the unsatisfactory operating conditions of each type will show the reasons which led up to the changes in recent turbines, and will also aid in distinguishing the novel features of new designs.

The first rows of spindle blades in a standard Parsons turbine are placed on a drum of small diameter in order to make the blades as long as possible and to minimise the proportional leakage losses past the ends of the blades. A large number of rows are provided in order to keep the steam velocities low, as the blade velocities must be low with the small drum. The drop in pressure at each row is small, and hence the leakage is correspondingly reduced. This construction results in a turbine with a long spindle and with great distance between bearings. High-pressure steam, frequently at high temperature, is admitted to the casing. Distortion of casing and spindle are thus easily conceivable in such construction, and to allow for this contingency the clearance on the ends of all blades is usually increased. This distortion may be due either to unequal heating or to the growth of the cast-iron casings. The fluid friction losses are large in this high-pressure section, for a large number of rows of blades must be revolved in steam of high density. The leakage losses and fluid friction losses in the high-pressure section, together with the troubles due to distortion in the long shaft, have forced designers to introduce modifications in this portion of the turbine, either by new blading arrangements, by dividing the total expansion in large sizes between two cylinders, or by the introduction of impulse blading.

The low-pressure sections of Parsons turbines have always shown high efficiencies. As low steam velocities are characteristic of this type, there is no cutting away of blade material, even with very wet steam, provided no injurious properties are present in the feed water. This low-pressure section has therefore been altered only in details.

The presence of a large low-pressure balance piston in close proximity to the steam inlet has frequently been the cause of serious distortions. Many builders now place this balance piston in the exhaust end, a construction due to Fullager.

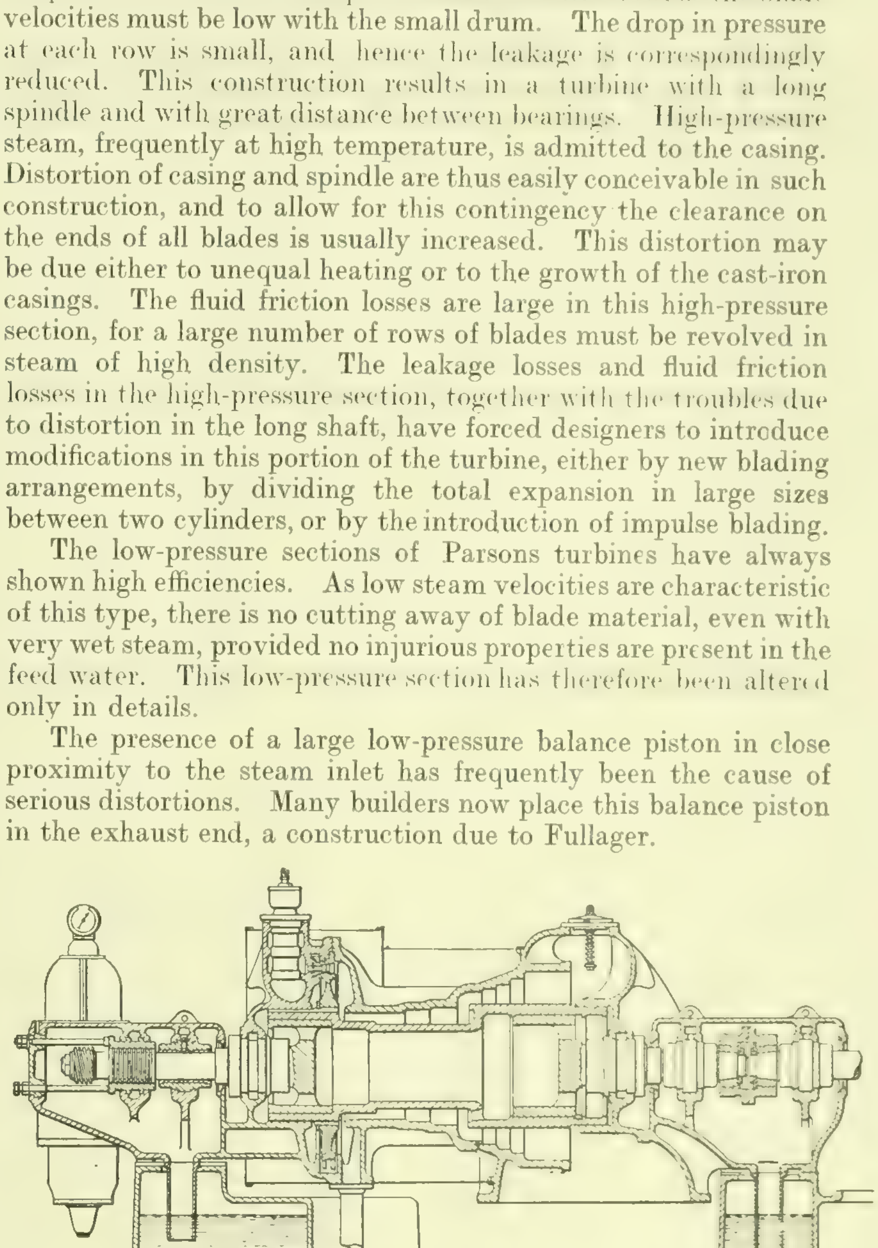


FIG. 2.—SECTION OF BROWN, BOVERI'S CURTIS-PARSONS TURBINE.

The Curtis turbine utilises high steam velocities in all stages. As steam becomes wet through expansion in the low-pressure stages, there is frequently considerable cutting of the blade material by the steam, although, contrary to first expectations, there is seldom cutting in the high-pressure blades due to the high initial velocities. The first row of velocity blades in a stage usually does the greater portion of the work, and hence the second row does not work at maximum efficiency. As the steam of the first stage is expanded very fully in the nozzles, there is no high pressure or superheat in the turbine casing or at the glands. The vertical type of unit is sometimes subject to electrical unbalancing and to other troubles peculiar to this construction. It is not as accessible in operation as the horizontal

* Paper read before the American Society of Mechanical Engineers.

machines. Recent designs have provided for horizontal units and for the replacement of the low-pressure section by sections of other types.

The Rateau turbine has high pressures on the gland at one end. There are a large number of discs revolving in dense steam at the high-pressure end. It has lower steam velocities throughout than the Curtis, and consequently has no blade-cutting effects in the low-pressure section. The clearances around the blade are large, but the shaft clearances of the diaphragms must be kept small. Some builders of this and the Curtis type have

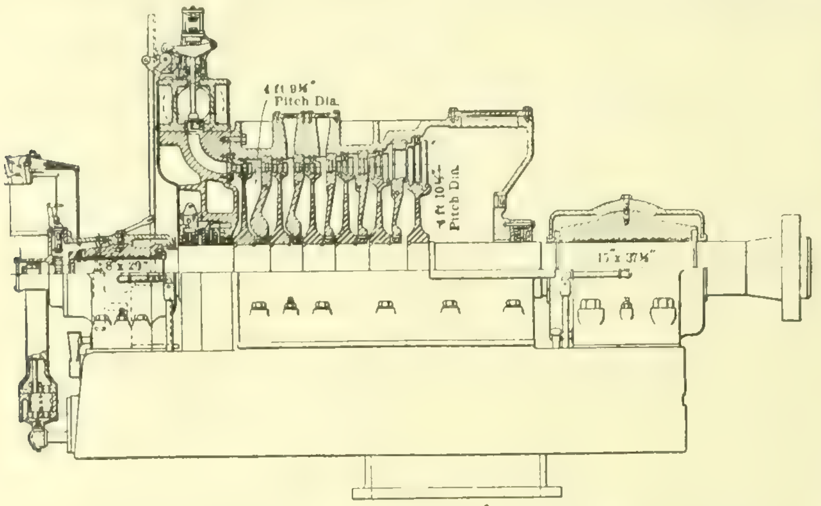


FIG. 3. HORIZONTAL CURTIS STEAM TURBINE. 7,000 KW., 1,800 R.P.M., SIX-STAGE.

brought out new designs which employ the high-pressure section of the Curtis with the low-pressure section of the Rateau. These represent a compromise between efficiency and manufacturing costs.

Under the classification of modified or combined types, there are turbines with modified Parsons, Curtis, and Rateau construction, and turbines with combinations of Curtis-Parsons, Rateau-Parsons, Curtis-Rateau, and Curtis-Zoelly construction, with a few special combinations. Some typical turbines of these classes are described in the following paragraphs.

The Allis-Chalmers Company manufacture a turbine of the modified Parsons type. High peripheral speeds are employed with a decreased number of rows. A portion of the theoretical efficiency in the high-pressure end has been sacrified by the use of fewer blade rows. Also a smaller proportion of work is done in this section than is usual in Parsons turbines. The blades

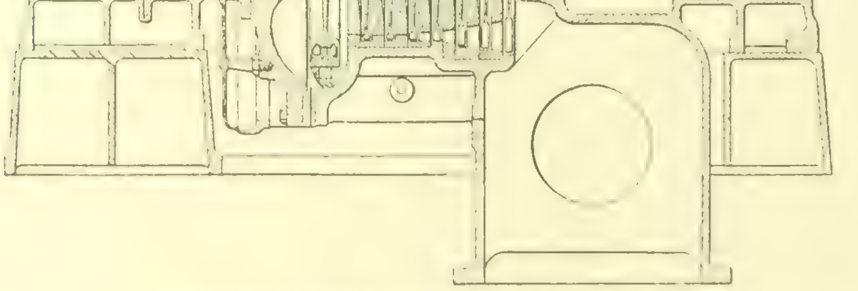


FIG. 4.—SECTION OF BERGMANN CURTIS-RATEAU TURBINE.

are all provided with a channel-shaped shroud. European experimenters have pointed out that better efficiencies are obtained with shrouded than with plain blades, as the so-called spilling over at the ends is prevented. Wing blades are fitted in the last pressure rows to take care of the large volumes of low pressure steam. The spindle is much shorter and stiffer than the standard Parsons, and hence smaller clearances can be provided. The Fullager low pressure balance piston is also used. The outstanding features of this design are—reaction principle with drum construction, few rows of blades with high steam velocities, short spindle construction, and employment of wing blades for high vacuum. The steam consumptions obtained on this type show improved efficiency over standard construction.

A number of Parsons turbines have been built in which the total expansion is divided between two cylinders. One of the best-known units of this type is installed at Dunstan Power Station, England. This was built by Richardsons, Westgarth, and Co., on Brown-Boveri designs. This unit, however, employs a modified double-flow Parsons construction in the low-pressure cylinder.

C. A. Parsons & Co. have used cast-steel cylinders for the high-pressure portion of their turbines so as to overcome the troubles due to deformation and growth of metal under high pressures and superheat experienced with cast-iron casings.

The Westinghouse Machine Company have developed a double-flow machine which employs a Curtis high-pressure stage with Parsons intermediate and double-flow low-pressure sections. There is only one balance piston in this machine next to the Curtis ring. These turbines run at high speeds, have short shafts and small clearances. The steam is expanded in the nozzles and hence there are no high pressures or temperatures in the casing. By providing two low-pressure sections, high vacuum can be economically utilised.

European builders of Parsons turbines, among whom are Brown, Boveri, & Co., C. A. Parsons & Co., Franco Tosi, Sulzers, Willans & Robinson, and Erste Brunner, have replaced the high-pressure sections of their Parsons turbines by a Curtis wheel with two or more velocity rows, but have retained the single-flow Parsons drum construction for the remaining portions.

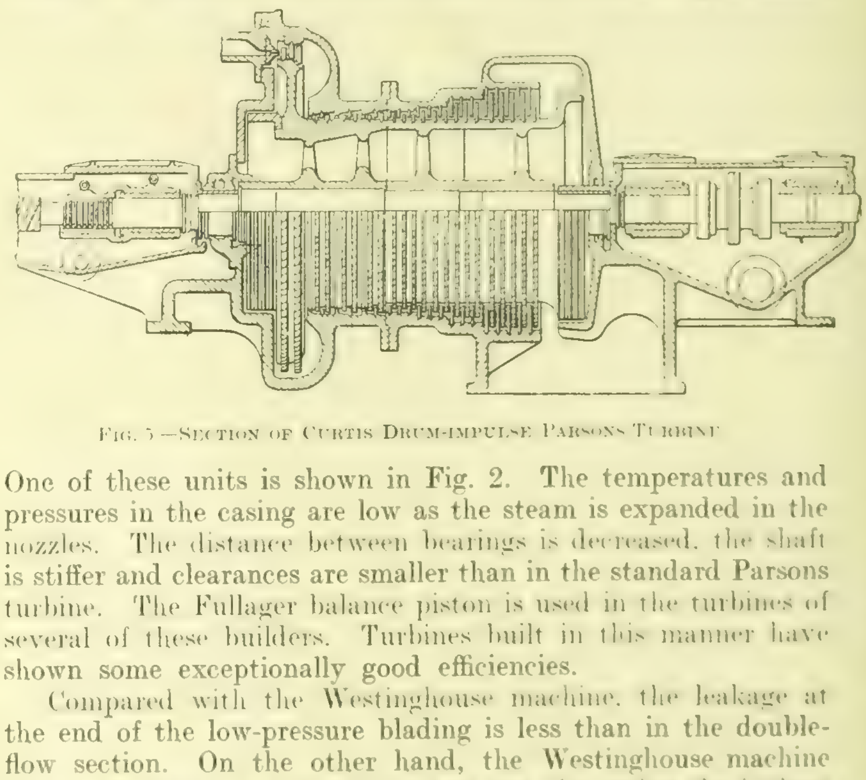


FIG. 5.—SECTION OF CURTIS DRUM-IMPULSE PARSONS TURBINE.

One of these units is shown in Fig. 2. The temperatures and pressures in the casing are low as the steam is expanded in the nozzles. The distance between bearings is decreased, the shaft is stiffer and clearances are smaller than in the standard Parsons turbine. The Fullager balance piston is used in the turbines of several of these builders. Turbines built in this manner have shown some exceptionally good efficiencies.

Compared with the Westinghouse machine, the leakage at the end of the low-pressure blading is less than in the double-flow section. On the other hand, the Westinghouse machine has smaller balance piston losses and can also utilise the highest vacuum at better efficiency.

Melms and Pfenniger employ a drum impulse section of about five stages instead of a Curtis ring on some of their large turbines. They claim improved efficiency from this construction, though high-pressure and high-temperature steam are introduced into the casing.

The General Electric Company now manufacture a horizontal type Curtis turbine in all sizes up to 7,000 kw., a section of which is shown in Fig. 3. This embodies all the essential features of the Curtis design. Compared with the vertical type, this design provides easier access to all working parts such as governor, bearings, valves, &c., and allows a better survey of the unit. The machine can also be dismantled and its internal parts examined with less trouble. The oiling problem is very simple compared with the vertical units, as there is no step bearing to provide for. It is possible that only horizontal units of all sizes will be built in the near future. The A.E.G. also builds similar turbines up to 1,000 kw. capacity.

Many manufacturers in Europe are now building a turbine of the type shown in Fig. 4. This consists of a Curtis high pressure with Rateau or Zoelly low pressure sections, the number of stages

depending on the size of the machine, the speed, and the steam conditions. The pressure and temperature in the casing are low, as a consequence of the expansion of the steam in the nozzles. The steam velocity is moderate in the low-pressure section. This machine is longer than the simple Curtis but shorter than the Rateau. Its builders claim improved efficiencies over either of the fundamental types.

Belliss & Morcom, of Birmingham, have introduced a turbine consisting of a high-pressure Curtis stage with a low-pressure drum construction like Parsons, but fitted with impulse blading on the spindle and blades forming expansion parallel wall nozzles in the casing. All other impulse turbines employ diaphragms extending to the shaft. There are a greater number of rows in a Belliss turbine than in a corresponding Rateau turbine, and hence a lesser pressure drop through each set of guide blades. The net leakage loss may thus be lower than the Rateau, even though the leakage area is greater. This turbine is essentially a Curtis-Parsons construction, with few rows of blades and with the expansion taking place in the stationary blades only.

A turbine shown in Fig. 5 has recently been patented in England, which has some features of unusual interest. The high-pressure steam is Curtis, the intermediate section is of a drum impulse type with three stages, while the low-pressure portion Parsons, which may be also double-flow. This combines features of all three fundamental types, and it will be interesting to see what results are obtained in practice by such an arrangement.

(To be continued.)

DENNY & EDGECOMBE'S TORSIOMETER.

ELECTRICAL torsiometers, while they have the advantage that the indicating instrument employed with them may be placed in any convenient position, as its connection with the shaft in which torque is being measured is electrical, have the disadvantage of great delicacy in their parts, particularly if they be adapted for wide readings of small amounts. Mechanical torsiometers, while they avoid the disabilities of delicate construction, suffer from the fact that their indicating or recording mechanism is in mechanical connection and must of necessity be close to that part of the shaft where torque is measured— that is to say, in the shaft tunnel or beneath the floor plates of a ship—and very often difficult of access. With a view to obtain the advantages of both systems and avoid their disadvantages, Mr. Archibald Denny, of William Denny and Brothers, Leven Shipyard, Dumbarton, and F. T. Edgecombe have designed and patented the arrangement of torsiometer shown in the accompanying illustrations, and which comprises essentially a mechanical torque measuring device and an electrical device operated thereby and indicating or recording that measurement at any convenient point distant, it may be, from the mechanical device. The apparatus may further comprise a plurality of electrical devices of different calibre, so that torque may be read either upon a wide scale for small measures, or a close scale for greater measures. The mechanical torque measuring device is of the type in which means are provided for multiplying the relative motion of the two parts, and the electrical indicating device consists of a rheostat, the moving contact of which is operated by one of those parts in that mechanical device to which is transmitted a multiplication of the torque movement.

In the mechanical torsiometer referred to there is a drum rotated by multiplying gearing and magnifying the torque movements of the shaft being tested. In the arrangement shown in Fig. 1 there is substituted for this drum a balanced arm A driven by the usual train of wheels B from the arc of teeth on the member C moving under torque relatively to the member D upon a bracket E on which wheel train and arm A are carried. The arm A is adjustable for zero setting and carries a contact piece F making contact with an arc of resistance G which is built up, as shown in Fig. 2, of closely adjacent zig-zags of metallic ribbon H between the folds of which are inserted strips J of insulating material. This arc of resistance is held in a channel in a disc K secured to the bracket L carrying the multiplying gear. Thus it does not rotate upon its own axis, but only bodily with the bracket L which in turn is carried by the bracket E. Within a central drum on this disc K is arranged a coil spring M connected at one end to the drum and at the other end to the multiplying gear spindle upon which is carried the contact-bearing arm A. This spring serves in the first place to take up "backlash" in the gear, and in the second place to electrically earth, through the apparatus to the metallic structure of the ship, the contact piece F.

As shown in Figs. 1 and 3, current from an accumulator or other source is led by wires N O (indicated diagrammatically) and brushes to slip rings P Q and thence to each end of the arc of resistance G. The contact arm A being earthed, there is thus provided a separate circuit through each slip ring—one circuit for "ahead" running, the other for "astern." In each of these circuits is a balancing resistance R S for testing purposes and which can be cut out or in by the operation of switches T U, while in the earth connection is also a switch V, so that circuit may be broken when no reading is desired. In the earth connection is also a rheostat and travelling contact W by which the instrument used for indicating (or recording) may be adjusted, the two circuits N O and the earth connection finally terminating in the three terminals Y Z X, of differentially wound duplex ammeter or other equivalent instrument having a scale calibrated in torque units. The ammeter or other instrument used may be provided with devices recording upon a chart in the usual manner.

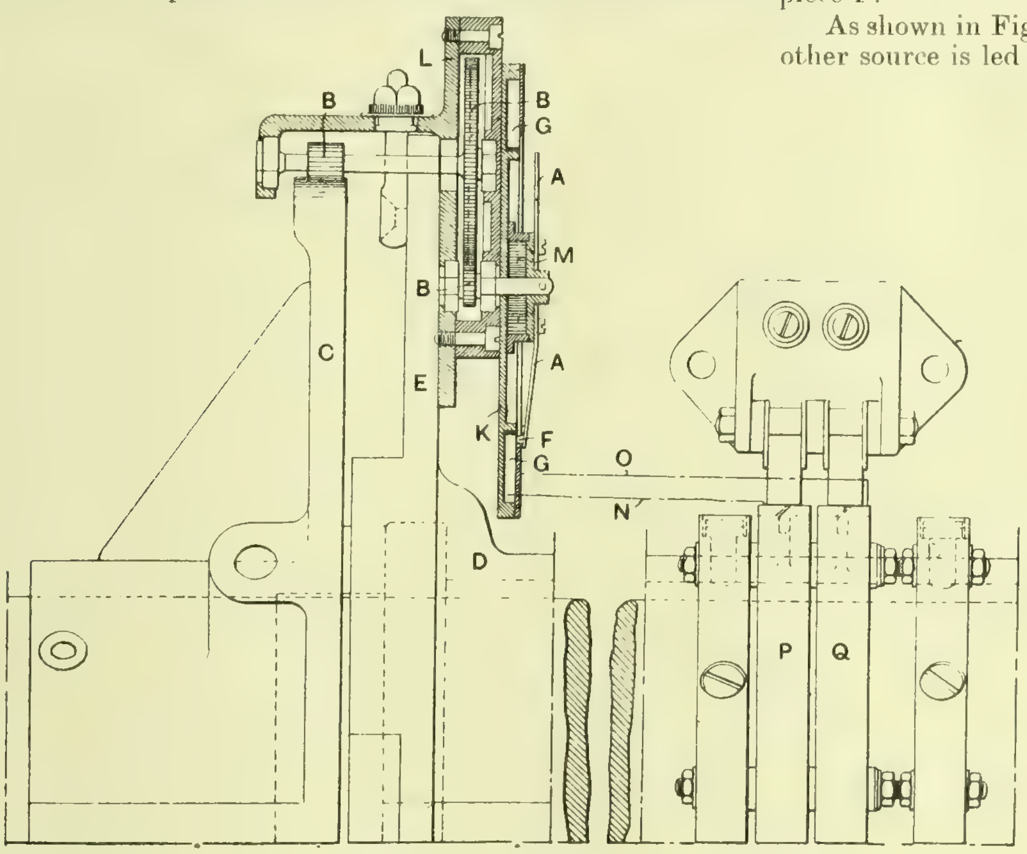


FIG. 1.

FIG. 2

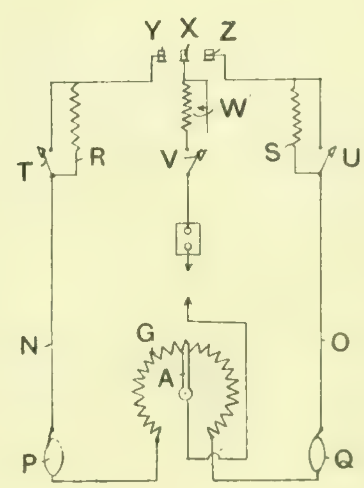


FIG. 3.

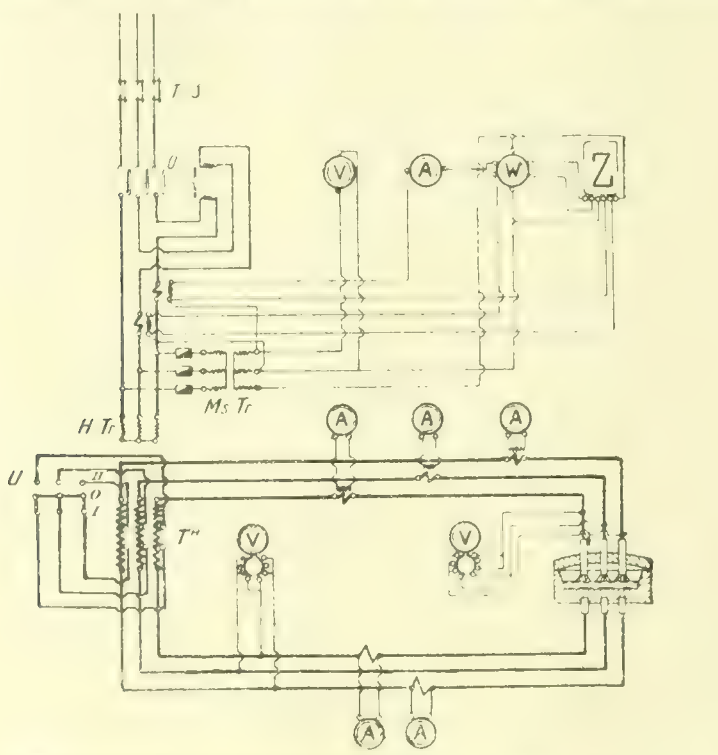
DENNY & EDGECOMBE'S TORSIOMETER.

IMPROVEMENTS IN ELECTRIC FURNACES AND THEIR APPLICATION IN THE MANUFACTURE OF STEEL.*

BY HANS NATHUSIUS, DR.ING.

(*Concluded from page 597*).

THE lining of the Nathusius furnace may be either basic or acid, and the roof is built of silica bricks. In a basic furnace the bottom and the side walls are lined with dolomite and tar rammed



Switch in O position = zero point in the bath.
,, I. ,, = zero point in transformer with low tension in hearth electrodes.
,, II. ,, = zero point in transformer with high tension in hearth electrodes.
Z = Meter, U = Switch, A = Amperemeter, V = Voltmeter, W = Wattmeter, TH = Main Transformer, Tr. S. = Separating Switch, O.S. = Oil Switch, Ms. Tr. = Measuring Transformer, H. Tr. = Booster transformer.
FIG. 2.—WIRING DIAGRAM FOR NATHUSIUS FURNACE, ARRANGED FOR WORKING WITH HIGH TENSION ALTERNATING CURRENT, AND TRANSFORMER WITHOUT NEUTRAL.

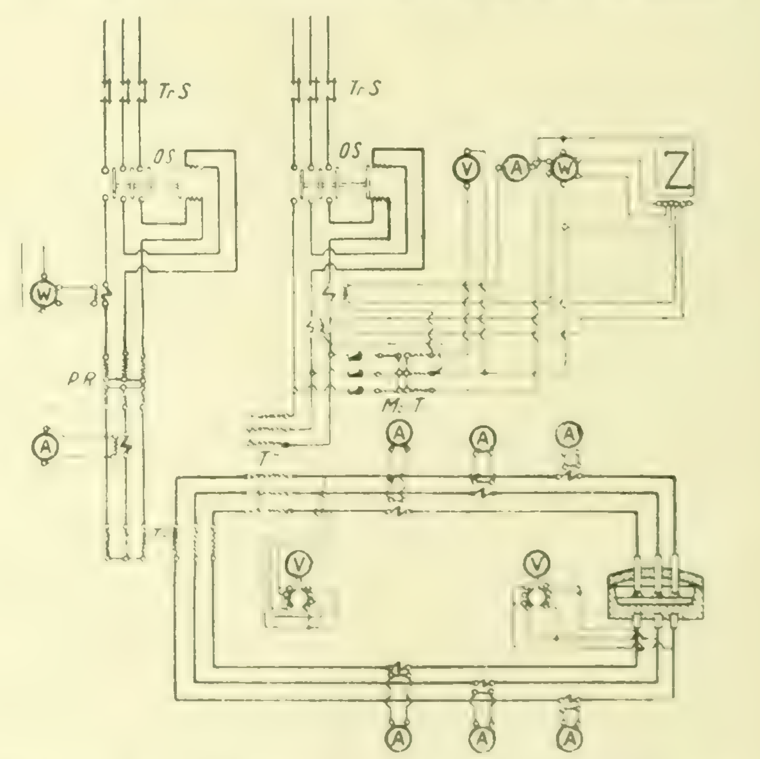
in the usual way. It is a good practice to lay a few courses of magnesite bricks where the roof and side walls meet. The required repairs to the side walls when renewing the roof can then be done very quickly. In the furnace under consideration, owing to the good distribution of the arcs, and their reduced intensity, the local overheating of the surface is not so great. When it is required to renew the arch the side walls must also in most cases be repaired, as the roof and the sides bind together. Approximately, 100 heats may be obtained under one roof when only cold metal is charged, and nearly double that number when hot metal is charged. The fact of the current flowing through the bottom increases its durability considerably, for it is well known that a thorough burning at high temperature is the best security for a high degree of refractoriness. As the bottom itself is heated to a high temperature it becomes burnt automatically. For the same reason repairs can easily be made, because the dry dolomite mass when thrown on the bottom is immediately burnt on. Any holes retaining puddles of liquid metal, which might prevent the burning of dolomite, are emptied to the last drop by tipping the furnace to a sufficiently steep angle. Slight repairs to the furnace can conveniently be done during the interval between two charges. Heavy repairs to the bottom are never required.

Coming now to the electric installation of the furnace, the current employed is a 3-phase alternating current of any convenient frequency. This kind of current is the most convenient for metallurgical work, and in its application economical as well as electrical and thermo-technical advantages are involved. A 3-phase current of any frequency may be used. Even in the case of melting down cold charges it is not required to put down a motor generator or a separate generator. The furnace can be connected direct to a step-down oil transformer, which reduces the voltage of the mains to that of the furnace (110 volts). The saving in first cost, as well as in working expenses, has already been commented on. Different systems of connection are employed according to the particular requirements of the furnace. The simplest and most useful connection when working with

* [illegible]

fluid charges is shown in Fig. 2. It will be seen that there are three surface carbon electrodes which are connected to the outer terminals of the secondary windings of the furnace transformer, and three bottom electrodes connected to the three inner terminals of the secondary coil. The three inner terminals of the transformer are obtained by separating the windings at the neutral point where the three secondary windings of an ordinary 3-phase transformer are connected. By this means the neutral zone—if it is permissible for the sake of a clearer understanding thus to represent the electric conditions—is transferred to the bath itself, and the current must gravitate from all points of supply towards this neutral zone. In other words, the current, though supplied from a single source only, is forced to flow not only between the upper and bottom electrodes, but also between any upper electrode and any bottom electrode. It is thus possible with a single source of current, to heat the charge in all parts, provided that its resistance is sufficiently high, or that the current is strong enough to produce sufficient heat in the charge when the resistance is low.

Experts have expressed doubt as to whether any current flows through the bottom electrodes or even between the bottom electrodes of this furnace. In Fig. 4, in which (in two phases) the course of the current, flowing from the outer terminal (1) of the secondary winding of phase I., is indicated by arrows and numbers, it may clearly be seen that it is impossible for the current to return to the starting point if it passes only between the surface electrodes. Hence, with this connection, no closed circuit can be established through the surface electrodes only. Since the neutral point is disconnected and transferred to the bath, a circuit can only be established when an equalising current flows through the bottom electrodes as well as through the upper electrodes towards the neutral zone in the bath. According to the first law of Kirchhoff, the sum of the currents entering the surface electrodes must be exactly equal to the sum of the currents leaving the bottom electrodes. This proves, without doubt, that there must be a passage of current between the bottom electrodes when current passes between the surface electrodes. Otherwise, the sum of the currents in the conductors of the surface electrodes could not be equal to that in the conductors of the bottom electrodes. It



A = Amperemeter, V = Voltmeter, W = Wattmeter, Z = Meter, TH = Main transformer with [illegible] F.R. [illegible] transformer, Tr. S. = Separating Switch, O.S. = Oil Transformer, Ms. Tr. = Measuring transformer.
FIG. [illegible]—WIRING DIAGRAM FOR NATHUSIUS FURNACE, WITH [illegible] ALTERNATING CURRENT, MAIN TRANSFORMER WITH [illegible] NEUTRAL AND [illegible] REGULATOR FOR VARIABLE HEARTH HEATING.

might be said that the currents are only flowing between the surface electrodes and the bottom electrodes without also flowing between the individual surface electrodes and the individual bottom electrodes. This is, however, impossible, as the current must flow between two points between which there is potential gradient and a conductive connection. Since there is a fall of potential between any two electrodes, and since the

electrodes are all mutually in conductive connection through the metal bath, there must be a flow of electricity between the upper electrodes and also between the bottom electrodes. To obtain a clear conception of the electric conditions, it will be well to consider the various resistances and tensions in the furnace. In a 5-ton Nathusius furnace the tensions are, under normal conditions, as follows :—

Between the upper electrodes	110 volts.
Between the lower electrodes	10 ,,
Between the upper and lower electrodes ..	61 ,,

The resistances are :—

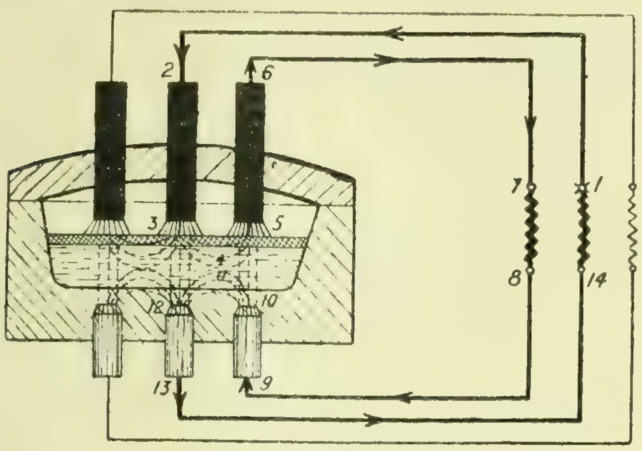


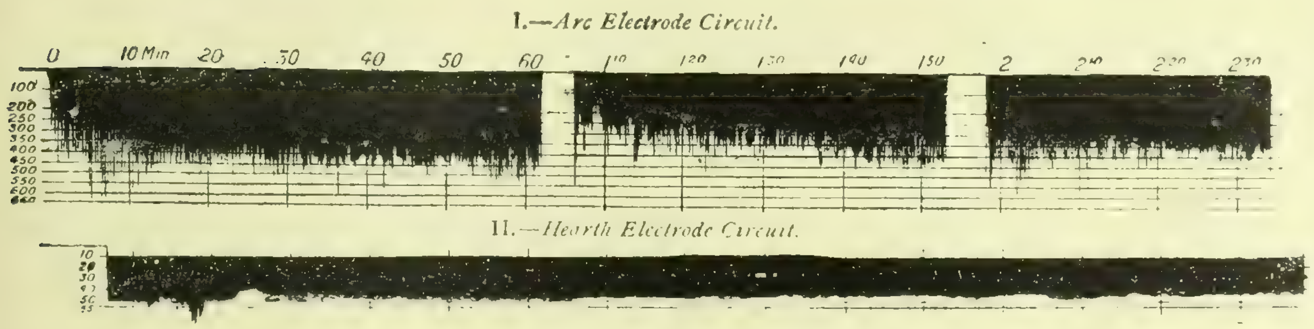
FIG. 1.

A. Between the upper electrodes :—
- (1) Resistances of two air spaces.
- (2) Resistance of two layers of slag.
- (3) Resistance of the bath or charge.
- (4) Contact resistance between slag and metal bath.

B. Resistance between the bottom electrodes :—

I. Covered bottom electrodes :—
- (1) Resistance between two layers of hearth material.
- (2) Resistance of the bath or charge.
- (3) Contact resistance between bottom electrode and hearth material.
- (4) Contact resistance between hearth material and bath.

II. Exposed bottom electrodes :—
- (1) Resistance of the metal bath or charge.
- (2) Contact resistance between bottom electrode and metal bath.



Heat No. 1067. August 19, 1911.

Charge	5620 kg. liquid basic steel.
Yield..	5950 kg. material higher in silicon.
Length of heat	2 hours 35 minutes.
Total energy consumed (including transformer losses) ..	1300 kilowatt-hours.

FIG. 5. LOAD CURVES OF A 5 6 TON NATHUSIUS FURNACE. (Exposed hearth electrodes. Curves taken on secondary circuit.)

C. Resistance between a surface electrode and a bottom electrode :

I. With covered electrodes :
- (1) Resistance of one air space.
- (2) Resistance of one layer of slag.
- (3) Resistance of the metal bath.
- (4) Resistance of the hearth material.
- (5) Contact resistance between slag and metal bath.
- (6) Contact resistance between metal bath, or charge, and hearth.
- (7) Contact resistance between hearth material and bottom electrode.

II. Exposed bottom electrodes :—
- (1) Resistance of one air space.
- (2) Resistance of metal bath.
- (3) Contact resistance between slag and metal bath.
- (4) Contact resistance between metal bath and bottom electrode.

The tension between the upper electrodes and between the upper and the bottom electrodes is constant, whereas the tension between the bottom electrodes depends on the resistance between the bottom electrodes. It is now theoretically possible that in the case of covered bottom electrodes, and with a cold hearth at the beginning of a run, the tension at the bottom may also reach 110 volts, under which condition no current could flow between the electrodes. Such a condition, however, does not occur in practice, because, as with an open-hearth furnace or a converter, a relined electric furnace must be heated before it can be started. The bottom will therefore soon become a good conductor ; its resistance will diminish gradually as the furnace becomes warmer, and the tension will fall to 10 to 15 volts.

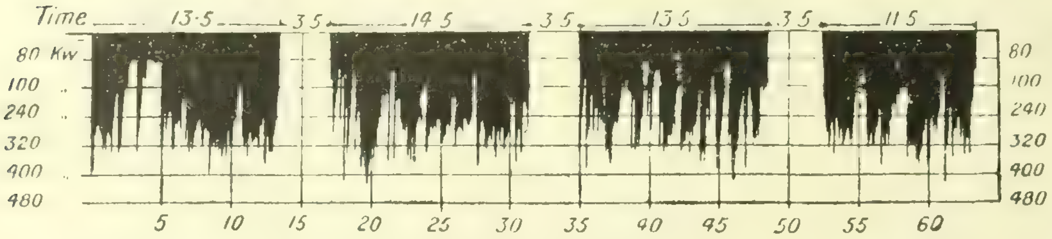
It is evident that the distribution of the current will be considerably influenced by any alteration of the air spaces, and of the resistance of the layer of slag or of the bottom material. If the charge consists of ore or of scrap iron with large air spaces, then the electric resistance of the charge is quite high enough to generate a sufficient heat in the charge, with the usual current of 3,000 to 4,000 amperes.

A better contact with the charge is obtained with exposed electrodes. These are made of mild steel, and, to prevent their melting it is necessary to cool the portions outside the furnace with water. If the charge consists of fluid metal, such as mild steel, then the heat in the bath may be increased by employing bottom electrodes covered with a layer of the hearth material, as shown in Fig. 1. This material will then act as a heating resistance, and the comparatively low resistance of the bath can be increased by taking advantage of contact resistance, hysteresis, eddies, or skin effect.

If this increase of resistance does not suffice to produce the necessary heat effect in the charge, then the current flowing between the bottom electrodes may be strengthened by inserting a booster transformer in the circuit of the electrodes, as shown in Fig. 3. By this means the heat produced by the bottom electrodes may be regulated from zero to any desired maximum, just as the arc heat may be regulated by lifting or lowering the carbon electrodes. By using the booster transformer in connection with a tension regulator (see diagram of connections, Fig. 3), the energy delivered at the upper as well as at the lower electrodes can be regulated to any desired degree. The regulation is based on changing the voltage, is independent of the actual resistance of the current, and is effected by the use of a double push-button without disturbing the working of the furnace and without switching the transformer out ; it is also independent of the main transformer. The tension regulator is worked by a small auxiliary motor, supplied with energy by a small low-tension 3-phase transformer. The circuit of the auxiliary motor is closed by manipulating one or the other push-button, and by means of a worm gear the motor turns the tension regulator in either direction, whereby the tension of the transformers is either augmented or decreased. On the release of the push-button the motor and the tension regulator stop in the desired position. By means of a contact relay the regulation of the tension may be done automatically. The same operation may, of course, be carried out without the booster transformer. The main transformer must then have an adjustable neutral, whose position may be adjusted so as to increase the supply of energy to the arc-circuit or to the

bottom circuit as required. A connection of this type is shown in Fig. 4.

The electric current can thus be compelled to flow through the bottom lining and the bath or charge, as well as through the slag, and a comparatively large resistance is brought into the electric circuit. The resistance acts as an electric buffer by diminishing the unavoidable jumps in the arc current, and thus enables the furnace to be worked either direct from the supply mains (if 110 volts is available), or on the circuit of an ordinary static transformer. The installation of an expensive motor-generator and complicated choking coils is saved. The furnaces which have been in continuous work for many years at Friedenshütte bear out these statements. Both the 5–6-ton furnace and the 2–3-ton furnace are connected direct to the supply mains, and have never caused trouble at the generating station.



The weekly average of 21 successive working weeks with this furnace was as follows:

Ferro manganese treated	29,150 kg.
Energy consumption (including transformer and conductor losses) ..	24,700 kw. hours.
Energy consumption per ton of ferro manganese melted	841 kw. hours.

Fig. 6. Load Curves of a Nathusius Furnace, Specially Arranged for Melting Ferro-manganese with Moderate Bottom Heating. (Rammed hearth electrodes.)

The accompanying load-curves also show that the favourable methods of connection adopted by the author eliminate the violent fluctuations in the arc current. The curves have been determined by means of a registering wattmeter with unequally loaded phases, whereby the effects of the self-induction in both circuits (arc and bottom) are eliminated.

As may be seen from Fig. 5 in recording the measurements taken on the 5–6-ton furnace, the total working period of each heat is divided into two or three stages, each marked by adding new slag either once or twice. Small discrepancies in the curves are not caused by unsteadiness of the arc-current, but are due to fluctuations of the primary tension or to manipulations of the furnace.

It will be plainly observed that the state of the bath influences to a certain extent the fluctuations which occur shortly before slagging off, that is, when the bath is particularly hot and boils while giving off gases; the fluctuations are also considerable after adding slag, because then the strongest reaction takes place.

The curves show that, at an average load of 350 kw. at the arc electrodes, an average load of 60 to 65 kw. is available at the bottom electrodes (Fig. 9). When the electrodes are bare the power in the bottom electrode circuit is reduced to 12 kw. (Figs. 5 and 10). The curve in Fig. 6 is the secondary load curve of the arc circuit of the 2-ton ferro manganese furnace when melting down cold charges.

Fig. 7 shows a load curve from the primary side of the transformer for the 5–6-ton electric steel furnace with fluid charge. The curve shows the fluctuations in the load, which is of importance to the generating station, and indicates that the furnace causes considerably less fluctuation of the current than a simple arc furnace, although it is only on the circuit of a simple transformer.

The curve in Fig. 8 clearly shows the difference in the fluctuations in the case of a simple arc furnace and those of a combined arc resistance furnace. The Nathusius connection is applied in Diagram I., and that of a simple arc furnace in Diagram II.

The cause of these differences will be understood on considering the tension diagram. When the neutral point of the main transformer in the Nathusius connection is removed to the bath, the tension between the bottom electrodes is a function of the current flowing in the arc circuit, *i.e.*, certain tension fluctuations will be measurable at the bottom electrodes when great oscillations occur in the arc circuit. Since the secondary phase tension is at constant primary tension, the tension at the arc electrodes must drop when the electrodes are short circuited. Thus the oscillations due to short circuiting of the arcs are damped, and this has a greater effect than the increase of the energy supplied through the bottom electrodes.

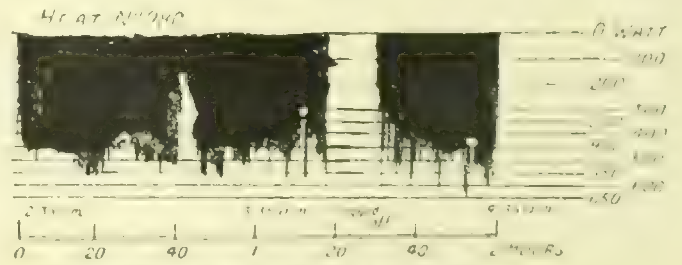
The putting in of a booster transformer does not alter these conditions, and it is therefore to be observed on the curves, Figs. 8 and 9, that each load peak in the arc circuit corresponds to a load peak in the circuit of the bottom electrodes.

The lines of force traversing the molten steel bath produce a rotary magnetic field which causes a rotation of the material. In the author's furnace a moderate rotation of the bath is attained by leading the current through the large cross-section of the bath and in different directions. It is also obvious that by distributing the current in the depth of the bath as well as on the surface the rotary magnetic field is produced throughout the entire bath. In this way not only a very uniform heating of the bath is obtained, but also an extremely homogeneous product. This advantage is especially important in producing alloyed steels.

The question is now, How can an arc-resistance furnace be economically applied in metallurgy? To give a general answer is of course impossible, as it depends entirely on individual or local conditions as to how the electric furnace can be applied to the best advantage.

Taking the case of large blastfurnaces and steelworks where there is available blastfurnace gas, and therefore also comparatively cheap current and liquid steel either from a converter or an open-hearth furnace, and where the required grades of steel are not tool steel, but ordinary steel such as hard material for rails, structural steel, projectiles, or soft material for tubes, plates, hydrogen flasks, &c., in large quantities, an electric furnace of the same capacity as the converters or the open-hearth furnaces is the most suitable, as undivided and partially refined charges can then be used. Whether this is possible depends upon whether there is a sufficiently good market for the grade of steel to be produced in the electric furnace. At Friedenshütte, however, a 5–6-ton furnace had to suffice, and this was in continuous work for more than two years in combination with basic steel works. The converters there have a capacity of 12 to 15 tons, of which 5 to 6 tons are charged into the electric furnace, and the remainder is cast into ingots.

One question arises, whether it would not be possible under certain circumstances to work the electric furnace economically in direct connection with the blastfurnace or mixer and thus dispense with the converter or the open-hearth furnace altogether. In the present state of the electric furnace the author is of opinion that such a step would be premature.



Heat No. 980. (Rammed hearth electrodes.)

Charge	5460 kilogrammes liquid basic steel
Yield	6230 kilogrammes material high in silicon.
Energy consumed (including losses in transformer and secondary conductors . . . .)	1100 kilowatt-hours.

Fig. 7. Load Curve of a 5–6-ton Nathusius Furnace. Primary circuit with combined surface and bottom heating.

In large metallurgical works cheap producer coal is generally available. In such cases gas firing is always a cheaper heating agent than the electric current, even when the latter is generated by blastfurnace gas engines. There is no object in performing operations in an electric furnace which can be done sufficiently well in a cheaper gas-fired furnace.

But even if coal is expensive and electric power very cheap, say at 0·07 of a penny per kilowatt-hour, the question must still be answered in the negative. In working up direct metal in an electric furnace by a process similar to the ore process in

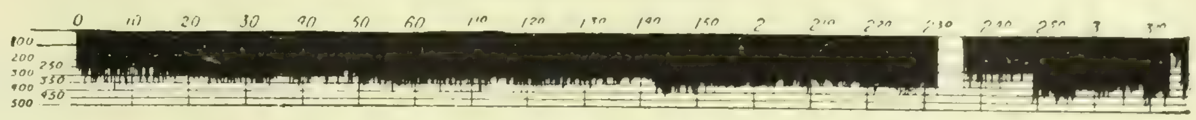
the open-hearth furnace, the refining would take too long a time, on account of the large quantities of ore and slag which would be required in the neutral atmosphere. The control of the large quantity of slag by heating from above with arcs would no doubt be a most difficult problem, and the refining would be indefinitely prolonged. Even with the cheapest possible power supply the cost of transformation would unquestionably be higher than that of heating an ordinary tilting open-hearth furnace.

The author is of opinion that the conversion of pig iron by electric means may economically be performed in a heated mixer or tilting open-hearth furnace. When an open-hearth furnace is charged with hot iron either direct from the blast-furnace or from a hot mixer it is a well-known disadvantage that the whole bath must be kept unnecessarily hot for a long time after adding the cold slag additions before an energetic reaction can take place between the metal and the still unfused slag.

The slag additions might, however, with advantage be melted in a separate furnace, and for this purpose the electric furnace, and particularly the combined arc-resistance furnace is better suited than any other because of the high temperature attainable and the high resistance of the charge. The fluid slag of the proper composition can then be charged direct on to the metal bath. A violent reaction and disturbance will then take place in the bath, and the refining will be completed in a very short time. In large steelworks, with a row of open-hearth furnaces at work and where the demand for fluid slag is continuous, the electric furnace may be arranged as a kind of slag mixer, which can always deliver slag capable of reaction. This method might perhaps be usefully applied in the Talbot, Bertrand-Thiel, or Hoesch processes.

In any case, the time of the refining process would be considerably shortened, while it is evident that the two molten masses can react more rapidly on each other. The reaction is also certain to be more complete than when the slag is charged cold. Under these conditions it may become possible to convert direct metal into mild steel in an electric furnace, assuming the electric energy is generated by means of blastfurnace gas.

Connections according to Diagram I.



Connections according to Diagram II.

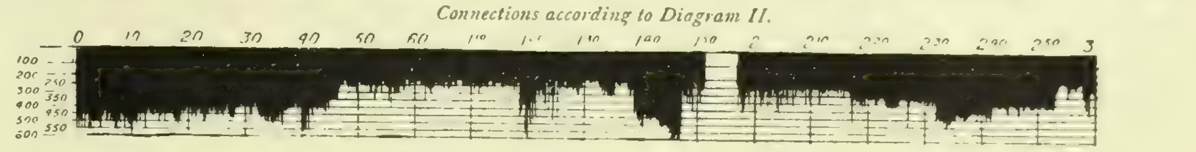
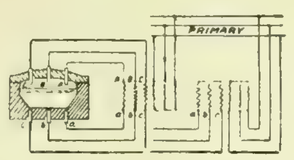


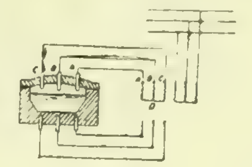
DIAGRAM I.



Heat No. 1025. July 21, 1911.

Charge . . . . 5800 kilogrammes liquid basic steel.
Yield . . . . 6000 kilogrammes low silicon material.
Energy consumed (including losses in transformers and secondary conductors . .) 1400 kilowatt-hours.
Bare hearth electrodes.

DIAGRAM II.



Heat No. 1056. August 15, 1911.

Charge . . . . 5570 kilogrammes liquid basic steel.
Yield . . . . 5890 kilogrammes material higher in silicon.
Energy consumed (including losses in transformer and secondary conductors) . . 1300 kilowatt-hours.
Exposed half electrodes.

FIG. 8.—LOAD CURVES OF A 5-6-TON NATHUSIUS FURNACE.
(Arc electrode circuit-secondary.)

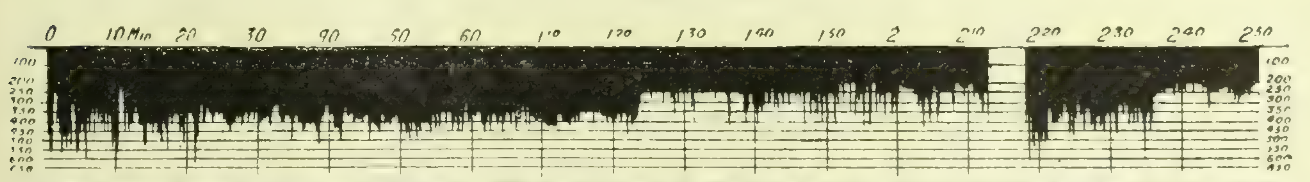
liminary refining in the two furnaces C and B. For the removal of the remainder of the impurities the hearth is charged with a highly oxidic slag (1). Furnace B contains pig iron (medium metal II.), which has already been partially refined in a mixer (furnace C). The further refining is effected by slag 2, now lower in oxygen, from furnace A.

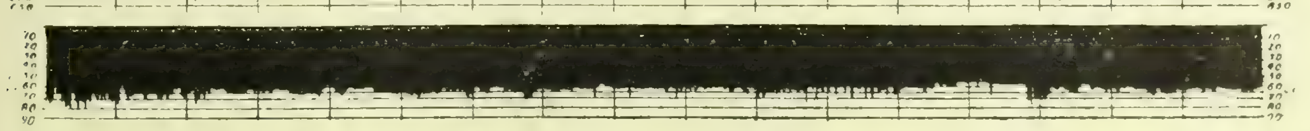
When the reaction is finished in furnace B the metal (II.) the refinement of which is now fairly advanced, is charged into furnace A, while the pig iron bath I. is treated in furnace C with slag 3, now comparatively low in oxygen. The slag in furnace C is then poured off, and is a most valuable one if the pig iron used is phosphoric. At the finish the slag consists chiefly of lime, silicic acid, and phosphoric acid.

This method possesses many advantages. First, the phosphorus contained in the pig iron, and valuable in the slag, is not lost. Secondly, all the iron in the slag is reduced, and the yield can thus be increased. Thirdly, very little or no worthless slag need be produced, which saves the expense of transport to the waste heap. Lastly, the refining of the metal can be carried practically to perfection.

For the melting down of ferro-alloys electric furnaces may also prove highly useful in large iron and steelworks. For this purpose the arc-resistance furnace has special advantages. In order to melt down the expensive alloys quickly and without waste or evaporation losses, the heating must be as uniform as possible—conditions which can be realised fully with an arc-resistance furnace. The West German Thomasphosphate Works have a method for melting down and working these ferro-alloys in which the material, such as ferro-manganese, is to some extent overheated, is kept molten for some time in a mixer under the one slag, and is overheated somewhat without loss of manganese through burning or evaporation.

I. *Arc Electrode Circuit.*





II. *Hearth Electrode Circuit.*

Heat No. 1248. October 31, 1911.

Charge ...	1860 kg. liquid basic steel.
Yield ...	5150 kg. material higher in silicon
Length of heat ...	2 hours 51 minutes.
Total energy consumed, including transformer losses	1100 kilowatt-hours.

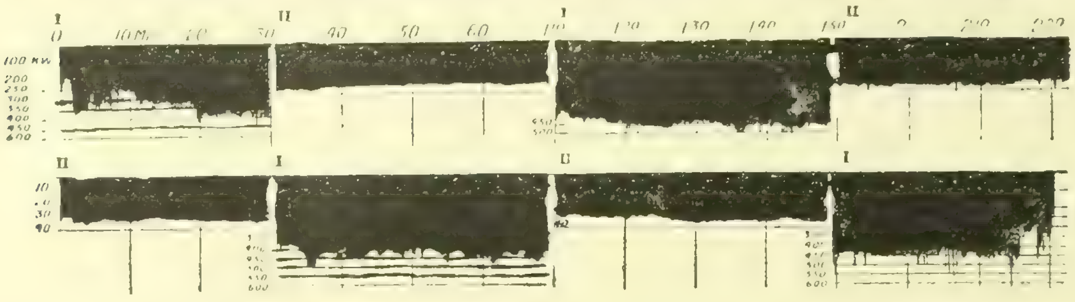
FIG. 9.—LOAD CURVES OF A 5-6-TON NATHUSIUS FURNACE. (Rammed hearth electrodes. Curves taken on secondary circuit.

The same method may also be used with advantage in combination with a heated mixer and a tilting open-hearth furnace. A third furnace—an arc-resistance furnace—may be added with advantage. Such a combination of furnaces is shown in Fig. 11. It will be seen that there are three furnaces. Furnace C represents the hot mixer, B the tipping open-hearth furnace, and A the arc-resistance furnace. The three furnaces are intended to work together in such a manner that furnace A contains steel (refined metal III.) which has undergone a preliminary refining in the two furnaces C and B.

This process has been used for more than a year at Friedenshütte in Upper Silesia, using an arc-resistance furnace of 2 to 3 tons. The furnace is in continuous operation, and is employed to melt down ferro-manganese for use in the basic Bessemer converter. The gain obtained by this process amounts generally to 0·35 shilling net per ton of steel, and has at times risen to over 0·4 shilling. It is based on the saving of ferro-manganese, which amounts to about 30 per cent. of the former consumption when

using cold ferro-manganese. The saving is effected by the taking up of all the molten ferro-manganese into the bath, and the losses in the slag are eliminated. The molten ferro-manganese reacts much more vigorously, and a smaller quantity is therefore required to produce the same reducing effect as a larger quantity of cold ferro-manganese. Lastly, ferro-manganese which has crumbled to powder through storage for a long time may be used without disadvantage, whereas formerly it was considered valueless.

Even if the costs of current, ferro-manganese, and other items were such that there would be no net saving, it would nevertheless be of advantage to erect an electric furnace for the process. By the use of molten and somewhat overheated ferro-manganese important improvements are obtained in the quality of steel, and the working is facilitated.



I. *Arc Electrode Circuit.* II. *Hearth Electrode Circuit.*

NOTE.—The two curves were taken with two Wattmeters in exact agreement with each other, which were simultaneously reversed. Heat No. 1238. October 27, 1911.

Charge	5330 kg. liquid basic steel.
Yield	5630 kg. material higher in silicon.
Length of heat	2 hours 21 minutes.
Total energy consumed, including transformer losses ..	1200 kilowatt-hours.

FIG. 10.—LOAD CURVES OF A 5-6-TON NATHUSIUS FURNACE. (Exposed electrodes in the hearth. Curves taken on secondary circuit.)

The speed of diffusion with molten and slightly overheated ferro-manganese is of course much greater than that of cold ferro-manganese, the reason being that the reactive capacity of the molten ferro-manganese is much greater, and the deoxidation of the steel is consequently much more thorough. This is proved by the fact that overblown charges can easily be remedied with molten ferro-manganese. Further, material containing 0·25 to 0·3 per cent. of manganese can be easily rolled without cracking when the charge has been reduced by molten ferro-manganese, while the material from similar charges reduced with cold ferro-manganese containing up to 0·3 to 0·4 per cent. have broken in the rolling mill.

Further—what is very important in the manufacture of rails—the portion of the molten ferro-manganese which is required to alloy with the steel distributes itself much more regularly in the iron, as the alloying capacity of the molten ferro-manganese is much greater than that of the cold ferro-manganese. The segregation of the manganese, which otherwise easily occurs, is thus eliminated. Also the reducing back of phosphorus from the slag into the bath when cold ferro-manganese is used, is avoided. The molten ferro-manganese does not come into contact at all with the slag of the steel charge, because it is poured straight into the clean stream of metal while the converter is being poured. The result is that the desired chemical composition of the final product is obtained with much greater certainty and spoiled charges are avoided. Since the adoption of the molten ferro-manganese process at Friedenshutte, the analysis of the converter charges have shown a much greater uniformity.

The foregoing clearly shows that the melting down of ferro-manganese in an electric furnace, and its application all at once in the liquid state for the deoxidation of basic steel charges, is an important metallurgical improvement on the Bessemer process. The technical progress of the latter method has of late years been more in a purely constructive direction, such as an improved arrangement of converters or transport of materials. In the metallurgical sense, a certain stagnation seems to have set in which, rightly or wrongly, has brought the old process into discredit. The author hopes that this new method of reduction will serve the purpose of restoring its former credit. Among basic steelworks in Germany which have adopted the new process may be mentioned the Friedenshütte Works and the Hasper Works.

It is obvious that the same process may be applied to the basic open-hearth furnace or the Talbot process, when a large number of these furnaces are working continuously. The saving in ferro-manganese will probably be as great in these cases, and an improvement in the quality of steel would result. The new method would also prove of great advantage in cases where reduction must take place in the ladle, as in the Talbot process. Instead of ferro-manganese alone, one might also melt down mixtures of ferro-manganese and ferro-silicon or aluminium, according to requirements. The result is always the same, namely, improved qualities and saving of expensive flux. The author believes that steel alloys of tungsten, chromium, molybdenum, &c., as used for ordnance and armour plates, may with advantage be melted down in a small electric furnace and charged in a molten condition. This method ought also to be useful in the production of high silicon steels and high manganese steels.

In conclusion, the author must not omit to refer to the following applications of the electric furnace: There is a great deal of waste at large tool-steel works of valuable steel alloys, such as turnings of nickel, chromium steels, tungsten steels, or high silicon steels. This waste cannot be melted down with advantage in an open-hearth furnace or in a crucible furnace. The reducing slag and the oxygen of the open-hearth furnace gases would cause a great waste of valuable material. In a crucible furnace the material may absorb carbon from the crucible, and, being too open, it is not suitable for charging crucibles. The crucible furnace is also too expensive.

In the electric furnace the material may be melted down under a neutral slag and in a neutral atmosphere, practically without any waste and without changing the chemical composition of the charge. The electric furnace is also more suitable for open material on account of the easy access and its greater capacity compared with the crucible.

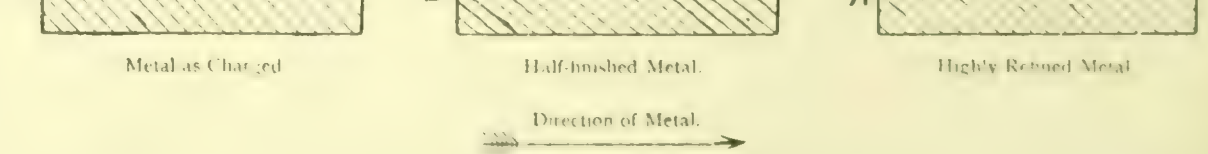


FIG. 11.

There is hardly any metallurgist who will deny that the electric furnace is more perfect than any other furnace of the present day. If, nevertheless, the results in many cases have not been so good as might have been expected in the hands of an experienced metallurgist, then the reason is—as has often been the case in the past—that the development has advanced at a greater speed than the requirements.

Sir W. G. Armstrong, Whitworth, & Co., Ltd.—The directors of this company have appointed a Works Board which will deal with departmental questions. The members of the new board will be styled local directors; they have had long service with the company, and the new arrangement is expected to work well.

TRIALS OF THE OIL-ENGINED VESSEL "JUTLANDIA."

THE twin-screw motor vessel "Jutlandia," the first large oil-engined ship built on the Clyde, has passed successfully through all the trials stipulated in the contract, and is now practically ready for sea. The trials, which were of an exhaustive kind, occupied three days. The speed of the vessel on service is to be from $10\frac{1}{2}$ to 11 knots. On the measured mile at Skelmorlie the mean speed attained was 12 knots on a horse-power of 2,700 indicated, and with the engines running at 135 revs.—five revolutions less than the number designed for the service speed. The fuel used was oil of a specific gravity of ·855, but the engines are capable of being run on fuel of a considerably higher specific gravity. The exact fuel consumption per horse-power was not obtainable, as the figures had not been worked out fully, but the builders estimate that in regular service the amount necessary will be about 10 tons for each day of 24 hours' continuous running. The starting, stopping, reversing, and manœuvring tests were equally satisfactory.

The vessel is of 5,300 tons gross and 7,400 tons carrying capacity, 570ft. in length between perpendiculars, 53ft. in beam, and 30ft. in moulded depth. She is a sister-ship to the "Selandia," launched last year by Messrs. Burmeister and Wain, Copenhagen, for the same owners. Her engines—of the Burmeister & Wain-Diesel type—are designed to work on the 4-cycle principle, and each shaft is driven by eight cylinders, the diameter of the cylinders being 20·87in. and the stroke 28·74in. The engines are started and reversed by means of compresed air at a pressure of 300lbs. In connection with the compressors there are two sets of auxiliary oil engines, each having four cylinders, and developing 250 i.h.p. at 230 revs. Each set includes an electric generator for providing current for working the other auxiliaries, and a 2-stage air compressor designed to compress air up to 300lbs. per square inch. The air, which is stored in four large reservoirs, is used at this pressure for starting and reversing the main engines and for other purposes. The arrangement of the starting and reversing gear is the same in the "Jutlandia" and the "Selandia." The air admission, exhaust, fuel oil, and starting valves are placed on the top of the cylinder, and are operated by eight cams—four for going ahead and four for going astern—the distance between the ahead and the astern cams in each case being about 2in. The cam shaft is operated from the main crank shaft, and to ensure reversal all that is necessary is to move the cam shaft longitudinally to the extent of about 2in. after the cam rollers have been raised. This change was made during the trials—from full ahead to full astern—in 12 secs. There is one main starting lever, which has to be drawn to one extremity of its motion before the reversing engine can be started. In this position both the compressed air and the oil fuel are cut off from the main engines. The small reversing engine, of the reciprocating type, is then started, and its action shifts the cam shaft into the required position, ahead or astern, as the case may be, and afterwards lowers the cam levers back into their working places. When the engine has been got under way by means of compressed air, the main lever is pushed still further over into the oil-fuel position, and the engine is thus started running under ordinary conditions.

ELECTRIC TRACTION FOR CITY AND SUBURBAN PASSENGER TRANSPORT.

A MEETING of the Society of Engineers was held on the 6th inst., when a paper on "Intermittency: Its Effect in Limiting Electric Traction for City and Suburban Passenger Transport" was read by Mr. Wm. Y. Lewis. Recent reports on the traffic problems of London and other great cities, he said, showed that cheap and effectively rapid transit was of supreme importance to the community, and was an essential in all industrial, commercial, and professional activity, since it affected wages, cost of living, rents, rates and taxes, value of property and land, and other matters touching individual welfare. Costly efforts had been made to furnish facilities, but the results left much to be desired in respect of effective speed, cost, and comfort. There was no finality (nor should there be, if prosperity was to continue) in the growth of the travelling habit—a direct outcome of the provision of facilities.

Progress so far, however, had, he observed, been wrongly directed in the endeavour to solve the city and suburban passenger transport problem. The character of the traffic was that of a continuous stream of varying volume; yet all attempts to meet its requirements had been made on the distinctly intermittent plan of operation. This involved a series of delays, resulting in low average speed, whilst to provide a service of sufficiently commodious and numerous trains to deal with dense traffic streams necessitated heavy capital expenditure and operating costs. Even then the electric train system could not secure the preponderating and most lucrative "short haul" traffic.

These limitations were, he considered, due to "Intermittency," which demanded heavy and bulky trains, with correspondingly long stations and spacious tunnels. The rolling stock must be substantial to withstand the severe stresses due to the accelerations essential and to carry the necessarily heavy equipment. Consequently the permanent way had to be heavily constructed with duplicate feeder rails, the tracks being further complicated by elaborate signalling apparatus. The trains required costly labour for their operation, and consumed much energy, of which about half was wasted at the brake blocks, resulting in high maintenance charges. The minimum distance between stations was limited to about half a mile, though twice as many per mile was desirable, whilst the maximum schedule speed was only 15 to 16 miles per hour. A greater amount of rolling stock than would suffice at higher speeds had to be provided, requiring spacious car sheds and yards. Extensive lighting, ventilating, and other apparatus was required, entailing further heavy energy consumption. The equipment comprised a very complicated fourfold power plant in several distinct classes, one being mounted on and hauled by the trains. The aggregate plant capacity required for a maximum of 12,000 seats per hour in each direction was about 12,000 kw. per route mile.

The overall efficiency of the system was so low that of every thousand tons of fuel delivered to power house bunkers for propulsion purposes alone, only one ton was due to the weight of passengers carried. Some 19 tons could be apportioned to hauling rolling stock, but the rest was lost in brakes, equipment, transmission, and conversion losses. The cost of the subway train system was about £600,000 per mile, and the operating cost, including fixed charges, worked out at between 0·18d. and 0·2d. per seat mile. Consequently, even at prevailing high fare rates of 0·6d. per passenger mile, the receipts did not balance the costs, and further developments were held up in all directions. The paper set forth complete calculations, based on actual results, leading to the above conclusions, and was illustrated by 20 diagrams. The author presented his paper as a protest against "Intermittency," especially the present tendency towards the multiplication of small self-propelled and individually controlled street surface units, and in conclusion pointed to the necessity of recourse to the more sensible continuous plan for the better solution of the problem.

Water Power in Scotland.—Mr. A. Newlands, in a paper read before the Inverness Scientific Society, estimates that in Scotland 1,000,000 h.p. could be developed from water, and points out that even if the figure be halved it would still represent, on a 10-hour working day basis throughout the year, an amount of power equal to that obtained from $3\frac{1}{2}$ million tons of coal. There are, he observes, over 40 localities where water power is available in amounts ranging from 400 h.p. up to 20,000 h.p. In regard to Inverness, he points out that if the rainfall in the 700 sq. miles that drain into the river Ness were retained in Loch Ness by controlling the overflow into the river, it would be possible by employing the Caledonian Canal as a flume or conduit to convey the stored water to the town and utilise it there for the development of 3,000 h.p. during the working days of the year, while yet supplying sufficient water to the river to maintain the normal summer flow. Another attractive drainage area for power purposes is that of Loch Luichart, having an area of 149 sq. miles. The river flows out of the loch in a series of cascades, and falls 125ft. in a length of 850 yards. On a 75 per cent. efficiency, and dealing with half of a 42in. rainfall as available for power, 1,580 h.p. on a 24-hour power day could be developed. This would be fully 3,000 h.p. per working day.

THE POSSIBILITIES OF FLUE GAS ECONOMISERS ON BOARD SHIP.*

BY R. ROYDS, M.SC., AND J. W. CAMPBELL, M.SC.

MANY endeavours are being made to introduce internal-combustion engines for the propulsion of ships. Whether the steam engine will be superseded eventually or not is much a matter of individual opinion or conjecture, but, in any case, the competition is certain to lead to a still more earnest consideration of the efficiency of the steam plant on board ship, and of any proposals which have for their object the increase in the efficiency of such plant. Whilst great improvements have been made in the steam engine, little has been done to improve materially the thermal efficiency of the ordinary boilers on board ship. It is well known that, at the present day, something like 20 per cent. of the total heat in the fuel is carried away by the flue or furnace gases, and many engineers are looking into the problems involved in the recovery of some of this heat. Mr. Hall-Brown, in his presidential address to this Institution, voiced the general desire for some enquiry into this intricate problem. It appeared, therefore, to the authors of this paper that the possibilities of the recovery of the waste heat from the furnace gases are ripe for thorough discussion.

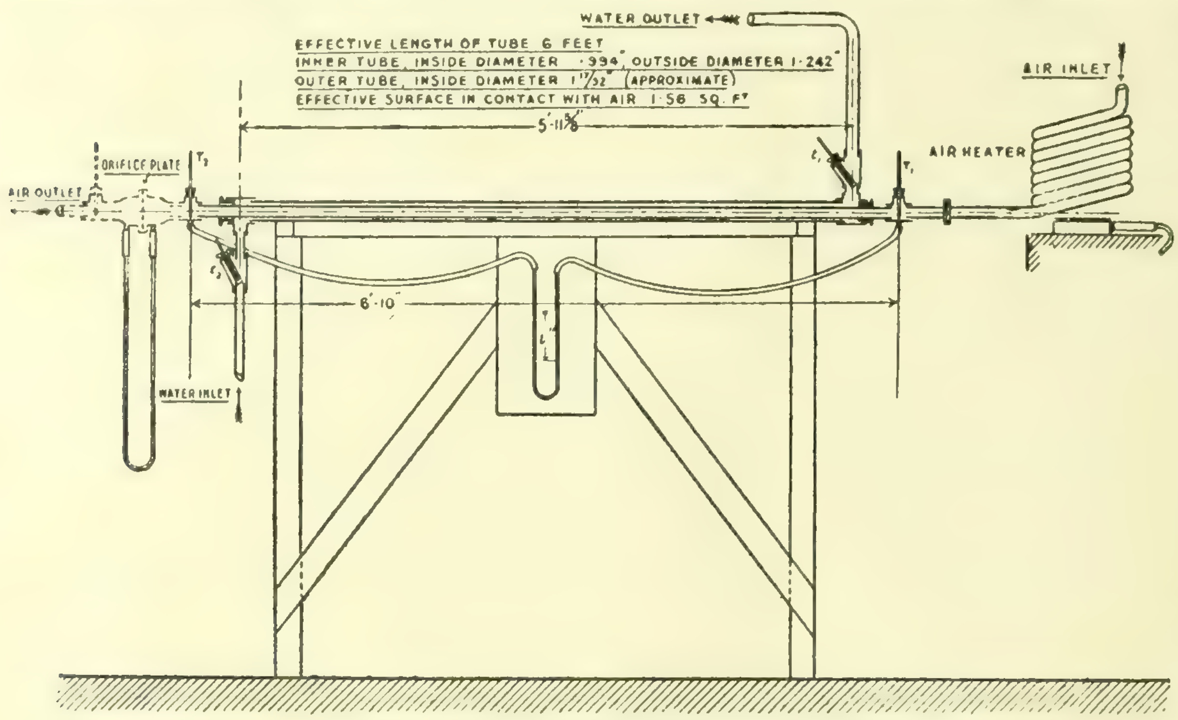


FIG. 1.

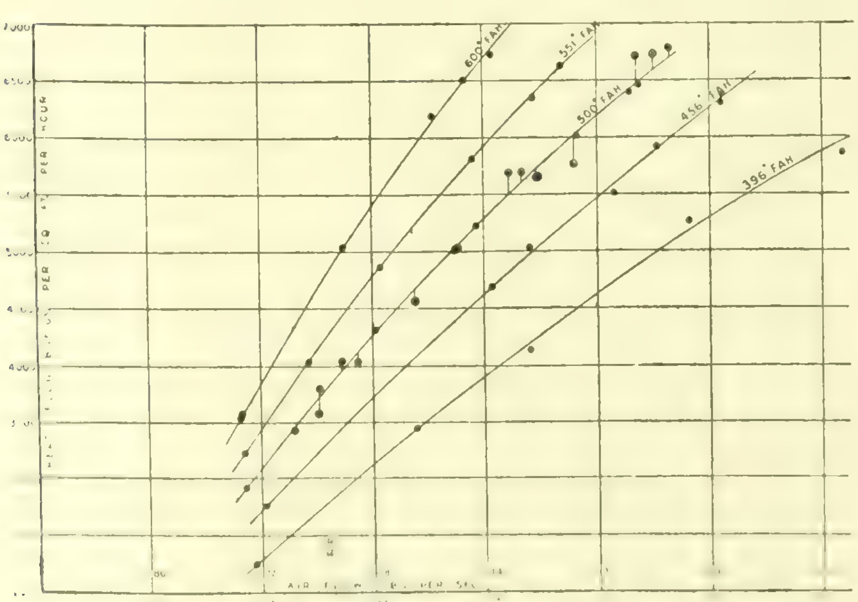


FIG. 2.

As far back as 1888, and even before that date, Mr. Ebenezer Kemp introduced flue gas feed heaters on board ship. In his first arrangement the feed heater had only about $\frac{1}{26}$th of the heating surface of the boilers, and he only got a rise of about 15° Fah. in the feed water. Gradually increasing this ratio in different vessels, he eventually succeeded in obtaining a rise of the feed temperature of about 150° Fah. with a ratio of feed-heating surface to boiler-heating surface slightly greater than 2 to 1, and he claimed to obtain about 15 per cent. increase of overall efficiency. Some difficulties were experienced, largely due to excessive corrosion of some parts of the feed-heater tubes, and since Mr. Kemp's decease little has been done with regard to such heaters, at anyrate in connection with ordinary return-tube marine boilers. It will be noticed that the large extent of feed-heating surface which he eventually adopted produced a very heavy and bulky arrangement, and this, together with the increased adoption of steam feed heaters, has probably militated against the reintroduction of flue-gas feed heaters.

Within recent years feed-water heating seems to have become a practical possibility on locomotives, and, as the problem in the locomotive has much in common with the same problem on board ship, a brief description of some results of practical experiments on locomotives will not be out of place. In the Trevithick system of feed heating, as used on the Egyptian State Railways, the feed water is heated to near 212° Fah. in an exhaust-steam surface heater, using a comparatively high velocity of the feed water to obviate salt deposits from hard water and the undue corrosion of the tubes. The water then passes into a smokebox heater having small diameter tubes, and the feed is here raised to between 270° Fah. and 280° Fah. under express service conditions. After elaborate experiments under service conditions, the overall increase in the efficiency of the locomotives fitted with heaters is over 20 per cent. as compared with sister engines without heaters and in the same service. No doubt, part of this increase of efficiency is due to the easier steaming of the boilers with hot feed, and to the lower rate of coal consumption at the same train loads.

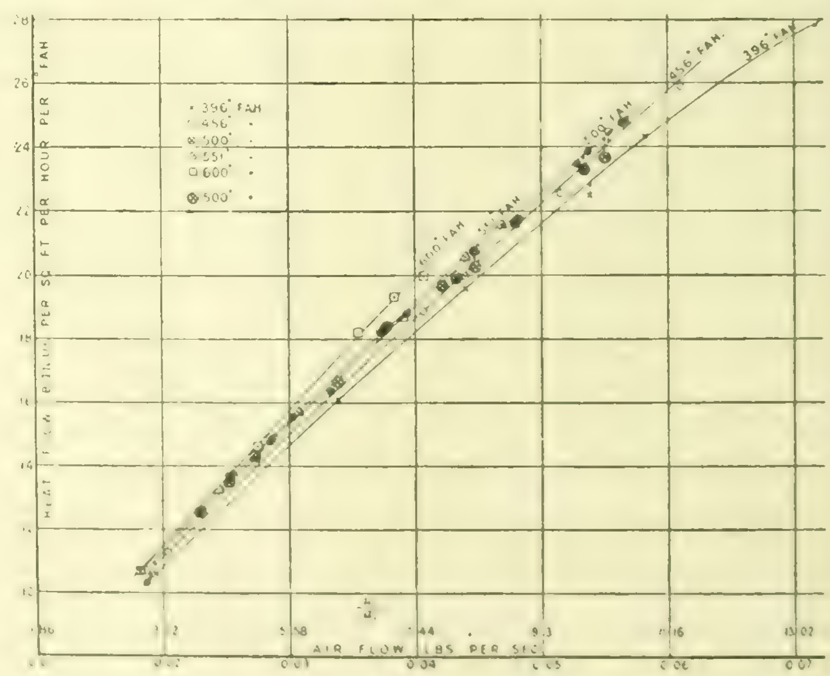


FIG. 3

It may be said that the most desirable features of a flue-gas feed heater on board ship are (1) the smallest possible weight and bulk consistent with a reasonable increase of the feed temperature, and (2) simplicity, reliability, and ease of working under ordinary conditions. The authors have made some experiments, at the Glasgow and West of Scotland

* Abstract of paper read before the Institution of Engineers and Shipbuilders in Scotland, January 23rd, 1912.

Technical College, bearing chiefly upon the first-mentioned feature, which it is now proposed to describe. A solid drawn steel tube, of ·994in. inside and 1·242in. outside diameter, was enclosed in a tube of $1\frac{7}{32}$in. inside diameter, the lengths and arrangement of the apparatus being as shown in Fig. 1. Air under a small pressure was passed through the gas heater and then allowed to flow through the tube, the inlet and outlet temperatures being measured by mercury thermometers inserted with the bulbs in direct contact with the air. Water passed from the town's main through the annular space between the tubes, and the inlet and outlet temperatures were measured by mercury thermometers inserted in deep pockets. The weight of water passing through was obtained by tanks on weighing machines, and the heat taken up by the water could thus be obtained. This was equated to the heat lost by the air, neglecting external losses, and using ·24 as the specific heat of the air, the weight of air-flow was calculated. All the parts of the apparatus were well insulated by asbestos cement and felt covering. An orifice outlet was arranged, as shown dotted in Fig. 1, by which it was hoped to get an estimate of the air-flow, but this was not successful, owing to the velocity of approach to the orifice being excessive, and its value unknown. This orifice was afterwards discarded, and replaced by a divergent mouthpiece having several modifications represented in Table I. In designing the apparatus the authors chose to let the air flow through the inner tube and the water outside, for the particular reasons that the external losses of heat would be reduced to a minimum, and that it was hoped to convert some of the kinetic energy of the leaving air into the form of pressure energy, whereas, had the water been sent through the tube, and the air through the annular space, no recovery of the kinetic energy of the leaving air could be expected.

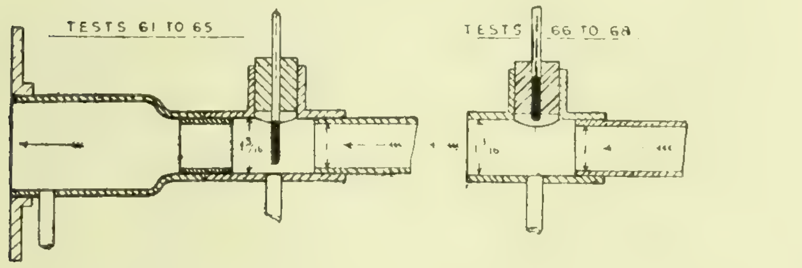
The results of some of these experiments are given in Table I. and in the graphs, Figs. 2 to 5. Fig. 2 refers to the tests made with different rates of air flow, and at different air inlet temperatures, ranging from 400° Fah. to 600° Fah. Fig. 3 shows that the heat transmission per square foot per degree Fah. between the air and water varies with the weight of air flow and with the inlet temperature, from which it is seen that the inlet temperature of the air had only a minor influence on the rate of heat transmission per degree Fah. difference. In all cases the mean air and water temperatures refer to the arithmetic means between the inlet and outlet, which, though not the true means, are subject to simple calculation.

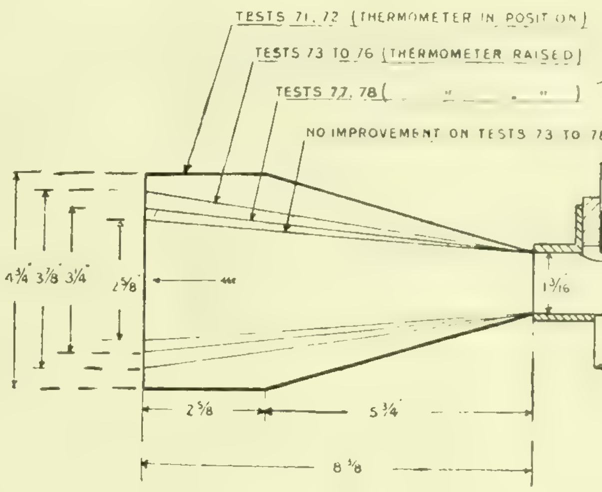
Fig. 4 refers to the tests made under nearly constant conditions as regards weight of air flow, the weight of water flow being varied with different constant temperatures of the inlet air. The series of points indicated by the small circles, crosses, &c., are the values as corrected divided by the difference of the arithmetic mean temperatures of the air and water, from which it will be observed that the results, though somewhat erratic, can be assumed to be nearly constant between the rates of water flow used in these experiments.

TABLE I.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
		Water Temperatures.			Air Temperatures.				Air Press. at Outlet Thermometer.						
No. of Test.	Water-flow lbs. per sec.	Inlet. °Fah.	Outlet. °Fah.	Heat-flow B.Th. U.'s per sq. ft. per hour.	Inlet °Fah.	Outlet °Fah.	Air-flow lbs per sec.	Air-Pressure drop through tube ins. of water	Above atmos. ins. of water.	Absolute lbs. per sq. in.	Air velocity at tube outlet ft. per sec.	Kinetic energy per lb. at outlet ft. lbs.	Pressure change corresponding to kinetic energy (no loss) ins. of water	Column 10 / Column 14	Remarks.
61	·0262	64·9	148·1	5040	500·5	260·2	·0378	6·67	0·51	14·8	126·5	249	2·66	—	See dimensions given below
62	·0245	64·0	164·1	5660	501	272	·0447	9·33	0·9	14·81	152·0	359	−3·78		
63	·0271	61·6	173·2	6780	501·2	284	·0565	14·84	1·46	14·84	195·5	594	6·15		,, ,,
64	·0252	64·6	134·1	4040	499	243·7	·0286	3·85	0·4	14·8	93·7	136·5	1·49	—	
65	·0276	64·7	118·6	3430	500	230	·0230	2·47	0·3	14·8	73·7	84·4	0·91		
66	·0273	59·4	119·6	3800	502	231	·0253	2·54	0	14·62	81·3	103	1·15	0	
67	·023	58·9	153·5	5020	502·5	260	·0374	5·62	−0·1	14·62	125	243	−2·6	·039	,, ,,
68	·0188	60·2	193·5	5770	501·5	284·5	·0480	9·61	−0·6	14·65	166	442	−4·57	·131	
71	·0412	58·5	118·4	5700	500	255·5	·0422	6·15	− ·22	14·38	140	307	−3·3	—	,, ,,
72	·035	58·0	141·2	6720	502	274·5	·0534	10·54	− ·42	14·38	182	515	5·4	—	
73	·0185	66·7	150·5	3580	502	245·3	·0252	2·91	− ·45	14·49	82·4	105	−1·15	·392	
74	·0222	63·5	152·8	4560	504	260·5	·0339	5·04	− ·79	14·49	113·5	200	−2·14	·369	,, ,,
75	·0262	61·3	154·5	5670	501·4	272·7	·0448	8·58	−1·44	14·45	152	361	−3·79	·38	
76	·0302	60·8	157·6	6740	504	282·5	·0550	12·40	−2·16	14·41	189·5	559	−5·8	·375	
77	·0246	52·1	123·4	4050	505·5	237·5	·0273	3·07	−0·5	14·6	90	126	−1·37	·365	,, ,,
78	·026	52·5	147·5	5700	504·5	267·0	·0433	7·73	−1·51	14·58	119	356	−3·7	·408	

NOTE.—In tests 61 to 65 and in 71 and 72 values given in column 10 were obtained with outlet thermometer in position.
In tests 66 to 68 and in 73 to 78 values given in column 10 were obtained with outlet thermometer raised out of air current.





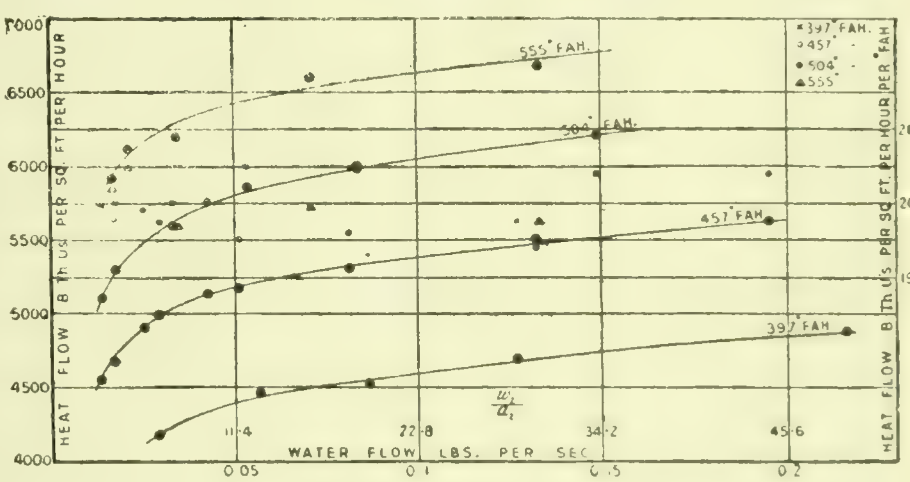


FIG. 4.

This shows that the influence of the velocity of the water on the rate of heat transmission is practically negligible when compared with the influence of the air velocity. Thus it is that no particular care was really necessary to adjust the rate of water flow to precise conditions when the flow of air was varied from test to test.

The resistance to the flow of air through the tube was measured by a water gauge connected, as represented in Fig. 1, where the points of connection were opposite the thermometers at inlet and outlet. It was assumed that the conditions were similar at the two points of connection, and that the readings taken with the thermometers in position were a measure of the resistance of the tube.

The tests 61 to 65 were made with the orifice plate detached, so that the air discharged directly to the atmosphere from the expanded end, and it would be seen from Table I. that the pressure at the outlet thermometer was above atmospheric pressure in tests 61 to 65 with the thermometer in position, showing that there was little or no recovery of the kinetic energy at the outlet. The expanded outlet was therefore detached as represented in Table I., and in tests 66 to 68, the recorded pressures at the outlet thermometer were still slightly above atmosphere with the thermometer in position, but with the thermometer raised out of the current of air a slight vacuum was obtained, showing that some of the kinetic energy was recoverable. An expanding outlet nozzle was then tried with better results, but from tests 73 to 78 the various modifications showed little difference in the amount of kinetic energy converted to pressure energy. It will be noticed that nearly ·4 of the kinetic energy at exit was

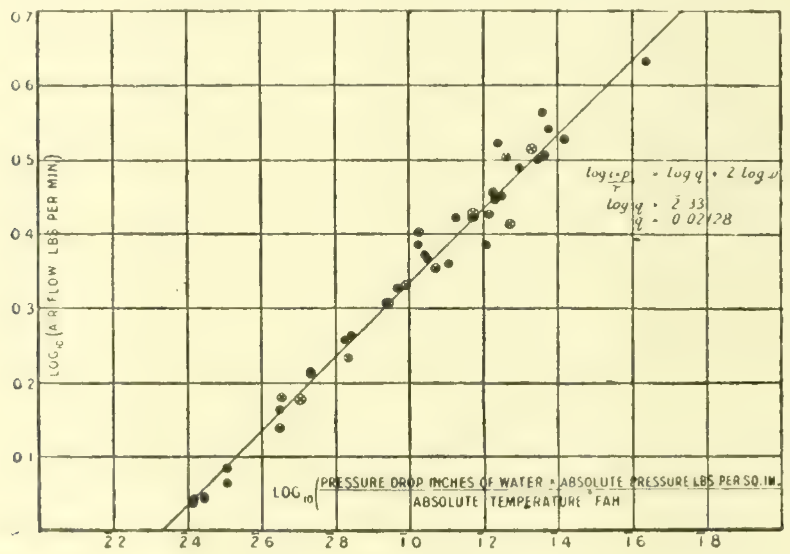


FIG. 5.

recovered, the probable reason for this low value being the nature of the flow, that is, the critical velocity being exceeded in the tube, the air flow would be of an eddying nature, and this would make recovery of the directional kinetic energy difficult. A comparison with Messrs. Heenan and Gilbert's* experiments on expanding chimneys on the air-delivery side of fans show a fairly good agreement with the above value ·4, considering the difference in the conditions. In a high-speed plant even this proportion of the outlet energy recovered is appreciable, as a perusal of columns 9 and 10 in Table I. will show, from which it follows that in the design of such plant care should be taken with the form of the outlet connections.

The total resistance to the flow of gases given by Prof. Nicolson† from boiler experiments seems to be rather greater than the total resistance obtained in the authors' experiments, but this can be partly accounted for by the fact that in his experiments the gases were outside the tubes and the water inside, with the result that practically all the kinetic energy at the outlet was lost, the end resistance at the inlet would be excessive, and the average path of the gases probably exceeded the length of the tubes. In the authors' calculations of the total resistance any small loss of energy at the inlet end was neglected.

In any flue gas economiser on board ship the gas flow would need to be high, whereas, as shown by these experiments, the velocity of the water need not have more than a moderate value. The authors recommend that the increased air pressure be obtained by increasing the blade speed of the fans. Roughly speaking, for a given fan, the weight of air discharged varies as the speed, the pressure difference between inlet and outlet varies as the square of the speed, and the power as the cube of the speed. Therefore, for a given weight of air, the number of fans required is inversely proportional to the blade speed, with blades of given angles, from which it follows that the power and steam consumption would be roughly proportional to the difference of pressure between the inlet and outlet at the fan.

There is reason to expect that the corrosion of the feed heater tubes and the deposit of salts on these tubes would be negligible provided the water was not allowed to stagnate during heating, and that soot and dirt would not accumulate on the gas side of the tubes on account of the high speed of the gases. What corrosion or salt deposit did take place would no doubt save the corresponding effects in the boilers. The increase of weight due to the feed heaters would be compensated by the saving in weight of the boilers, and by the smaller weight of fuel necessarily carried. The authors feel convinced that the use of flue-gas feed heaters on the lines suggested in the paper could be made to result in a substantial increase of overall efficiency.

* Proc. Institution of Civil Engineers, Vol. CXXIII., p. 272.

† "Boiler Economies and the Use of High Gas Speeds," Transactions of the Institution, Vol. LIV., p. 125.

LOCOMOTIVE FAILURES.*

BY N. OSGAARD.

ONE of the worst troubles that can occur to a locomotive and requires patience and skill on the part of the engineer and fireman to get along with consists in leaky flues and stay bolts. Flues will start leaking at times because of not carrying a bright, even fire, or by allowing banks to form in the firebox, causing temperature to rise and fall which creates expansion and contraction on flues and sheets. Short firing allows too much cold air to be drawn in near the flue sheet, with same results as above stated, which is also true when the fire door is allowed to remain open too long when firing. Nothing will help these troubles more than intelligent work on the part of the engineer and the fireman. Much good can be done in overcoming these troubles by teaching the enginemen how detrimental such conditions are to the boiler, and the engineer, if he has interest in his work, will watch his fireman and see that he carries out such instructions.

Other causes of leaky flues are careless and irregular boiler feeding; engineers must be taught to understand and practise such boiler feeding as will maintain as even a pressure as possible on the boiler. Working an engine harder than necessary to haul the train at the desired speed very soon tells on the boiler and should be prevented. Some waters which are used will cause flues to leak, while others will sometimes help to dry them up again. The avoiding such water as gives the most trouble from leaking will help to avoid failures. The condition of the flues, as regards keeping them clean, is one of the most important items governing the steaming of an engine, and any railway that has over 10 engines leaving a roundhouse daily will make money by keeping a man to clean out flues and do it properly. The grates should also be kept in good working order. There is nothing that will play a fireman out more quickly than hard working grates, and with such grates we usually have dirty fires with results as formerly stated. Poor workmanship on part of the boiler makers in caulking flues or in applying them is often the cause of leaky flues.

Improper steaming is often the cause of failure and may be due to various reasons, but most frequently is due to leaky joints in either the steam pipes or the exhaust pipes in the front end. The heavy service that locomotives sometimes are called on to perform and the shocks that they are subjected to throws a hard strain on the cylinder saddles and the flues, causing movements of these joints which will result in leaks. It takes only a very slight leak at this point to injure the steaming capacity of an engine. Engines are often allowed to run too long in such condition before they are given the proper test and repaired. The reason for this is that the leak at first being slight, it is hard for the engineer to determine the trouble and he does not want to make a report of it until he feels sure about it. The roundhouse foreman also dislikes to make such tests for the reason that if these joints are found to be leaking it is quite a job to fix them, and usually results in a case of holding the engine in for several days just when he may

* Abstract of paper read before the Northern Railway Club.

be short of power, so he takes a chance, and the result is failure. It pays to test steam pipes when an engine is lacking for steam even if the trouble is not found to be there.

Draught appliances may not be set just right and this affects the engine's steaming. There is no fixed rule stating just how these appliances should be set to give the best results. The adjustments can be approximated very closely, but in most cases it is necessary to experiment with them until the best results are obtained. What will do on one engine may not do at all on another, even though the engines be of the same class. The man that has charge of the draught appliances and front end nettings should observe them carefully and see that they are in good condition. Blow pipes should also be inspected occasionally as they sometimes burn off in the front end and failures have resulted on this account. Locomotive boilers are at present taxed heavily for steam, especially when the power is only heavy enough to just handle the train and make the time as on a passenger run.

Hot bearings at times are the cause of engine failures. The worst of these are hot driving boxes. It usually takes so much time to fix them up that on a passenger run, when a box gets hot and needs to be packed on the road, the time lost is seldom made up. There are times when the best of care will not overcome this trouble, and it is then necessary to relieve the box affected of some of its weight. This throws the weight on the nearest adjoining boxes and is apt to cause them to run hot. Close watching on the part of the engineer is necessary to see that there is enough lubricant in the boxes for the engine to make her next trip without running short; if not, he should report it for packing. There have been failures due to neglect in reporting this, especially when engines are handled in pool. The men performing the duties of packing these boxes at roundhouses are sometimes negligent in giving this the proper care, and there is no doubt that we have had failures due to such negligence. Such failures, however, are diminishing.

The Stephenson link motion has been the source of numerous failures due to hot eccentrics, frequently causing the straps to break. The cause of these getting hot can be attributed to the fact that the eccentrics are located underneath the engine and are hard to get at to oil when the engine stops in certain positions, and as the engineer usually is in a hurry he is prompted to take a chance on them. The stock or material in an eccentric strap is light, and at times the straps break from hard jolts. They are also inconvenient to inspect and bolts in them may come loose and cause them to break. They may be closed too tightly and this causes friction and heating, breakage being the usual result. Close watching and careful attention regarding oiling is essential with this motion. The Walschaert valve motion now coming into general use never gives any trouble in this respect and is more reliable. We have had failures from cylinder heads being knocked out. In some cases they may have been unavoidable, but there are cases of this kind that have occurred which, had the engineer been alert, might have been prevented. Our practice now is to rivet the follower head to the spider so they can't get loose, or to use a solid head, so this trouble is now practically a thing of the past.

Driving springs or hangers breaking on the road may be due in some cases to the improper inspection of the engine when at the terminal. By close inspection the fracture might have been discovered and repaired before the engine went out, and the failure thus avoided. They occasionally break, however, without any warning, due to defects in the metal, or at times to roughness in the track which may cause unusual strain and breakage. When such a break occurs, the engines usually block themselves in such manner that they stay quite level on their bearings, and if so, and broken parts clear the moving machinery, the engines can proceed. But if the engine drops much when such a break occurs, it then throws the engine from her natural bearings and it is likely to run very hot, and in such case the engine must be blocked up to the proper level.

Abusing engines by improper handling, that is, by either unnecessary slipping or allowing sand on rail while slipping usually causes fractures to parts of machine, and may cause a breakdown immediately or later on. The slipping feature also has a tendency to loosen tyres which may result in failure. Carrying water level too high may result in failure by fracturing piston heads, cylinder heads, or cross-head keys, due to water getting into cylinders. By careful observation of the water level such breakdowns should not occur.

We have had, perhaps, one or two engine failures per year on the Lake district on which an average of 75 engines are kept in service, due to injector failures. These failures have been caused by loose joints in the siphon pipes in the tanks, thus making it impossible for the injector to prime when the water gets below that point in the tank. A failure of this sort, when both injectors or both siphon pipes give out is really up to the engineer, as he evidently has not been trying both his injectors and reporting their defects on arrival at terminals as he is required to do.

Air pump failures are becoming fewer as improvements have been made in the valve motion of the pumps. The former slide valve has been replaced by piston pipe valves, with good results. The cause of air pump failures can sometimes be blamed on abuse in running them too fast, and also starting them too fast, and by not draining them of water before starting them. Failures sometimes occur because of engine crews not being careful in their inspection of engines, thus allowing parts of the machinery to become loose and possibly break; also by not making any effort to keep the machinery in such condition as they are expected to, such as keeping the wedges set up and rods properly keyed. When found neglecting this duty they should be severely dealt with.

The failure of the fireman to have proper firing tools and failing to watch the ash pan and the grates sometimes causes failures to engines, through the burning out of the grates, and by the fire getting dirty with no tools on hand to clean it, although the engineer is held responsible for this as well as fireman. It should be the fireman's duty to see that the engine is provided with the necessary firing tools. By making this impression strong with them they will not overlook it.

Failures sometimes happen that cannot be avoided even with the closest watching; parts of the machinery or boiler may be let go out uninspected, or which could not have been detected by the closest inspection. There is no question, however, but that a large number of engine failures can be avoided if all concerned give close attention, and a lot of them are thus avoided at the present time. We are at present making 45,000 miles per engine failure. This I believe is due entirely to proper inspection and the keeping up of the machinery and the engine parts and the making of necessary repairs by the roundhouse force.

Instrument for the Detection of Ice.—A novel instrument for locating ice will be exhibited, with data just obtained, at the Royal Institution on May 31st. The apparatus is the result of 20 years' study of ice formation and water temperature by Professor Barnes, M'Gill University, Montreal. It is a self-recording electrical instrument termed a microthermometer, and has for the first time in the history of navigation made a continuous record of sea temperature during the voyage of the mail steamer Royal George, which arrived at Bristol on the 8th inst. from Canada. It located bergs and field ice 10 miles away, also the proximity of the Irish coast before the lights were sighted. The success of the instrument is due to its ability to detect temperature variations of 1,000th part of a degree. By a recorder on the bridge the navigation officer is immediately warned.

Mine Explosions.—At the Birmingham University on the 9th inst., Sir Henry Cunynghame, K.C.B., delivered an address upon "Modern Theories as to the Nature of Gases in Coal Mines." He urged that not enough was known among students, let alone among mine managers and miners, about the startling and almost unbelievable theory of gases known as the kinetic theory. It was, however, necessary to master that theory if the subject of gas explosions in mines was to be understood. Unfortunately it had not been put plainly in any text-books, and it was enveloped in a perfect fog of mathematics and very difficult mathematics at that. He knew the theory would not assist them in getting coal from the mine, but it would, he hoped, result in preventing people from being blown up, and finding some simple remedy for coal mine explosions. The kinetic theory was destined not only to revolutionise their whole ideas with regard to gaseous combinations, but to revolutionise chemistry in the future.

THE INFLUENCE OF HEAT ON HARDENED TOOL STEELS.*

WITH SPECIAL REFERENCE TO THE HEAT GENERATED IN CUTTING OPERATIONS.

BY EDWARD G. HERBERT, B.SC., LOND.

BEFORE describing the experiments which are to form the subject of this paper, it is necessary briefly to refer to certain previous investigations made by the author, which were fully described in a paper read before the Iron and Steel Institute in May, 1910.† The subject of these investigations was "The Cutting Properties of Tool Steel," and they were carried out with the aid of the tool steel testing machine. This machine has been described both in the paper referred to and in the technical press. Suffice it here to say that the machine measures the durability of specimens of tool steel, which are made into cutting tools of standard shape, and tested by being caused to cut away, by a turning action, a revolving steel tube of standard composition, hardness, and dimensions. The standard traverse of the tool is 0·012in. per revolution of the tube, and the width of the chip is $\frac{1}{16}$in., this being the thickness of the tube wall. The durability of the tool is measured by the length of tube it will turn away before attaining a measured degree of bluntness. Tests are made at a succession of cutting speeds from 20ft. per minute upwards, and the results are plotted out in the form of a "speed curve," in which ordinates represent durability of the tool and abscissæ the corresponding cutting speeds.

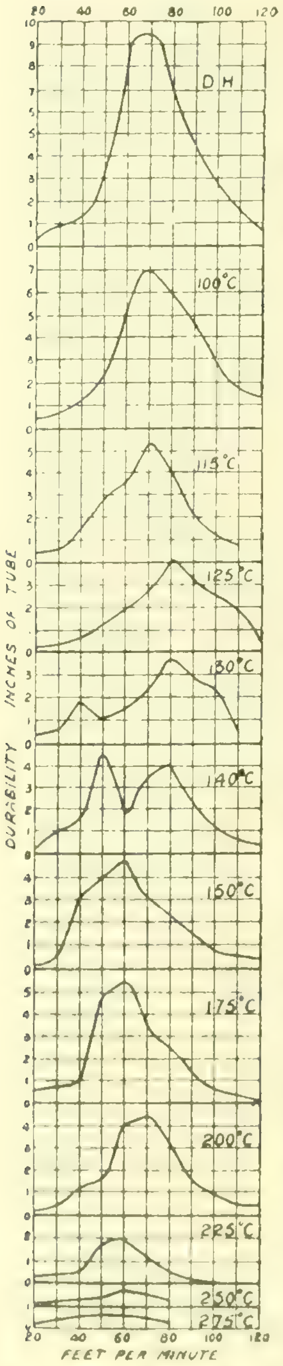


FIG. 1. TEMPER AND DURABILITY CARBON STEEL.

A set of speed curves is shown in Fig. 1. These curves exhibit the changes in the durability of a carbon steel, made dead hard and tempered for 15 minutes at various temperatures indicated on the diagrams. The general characteristics of these curves are: A very low durability at the lower cutting speeds; an increase of durability as the cutting speed increased; a maximum durability at cutting speeds of 50ft. to 80ft. per minute; and a decline of durability to a very low value as the speed was further increased. Two of the curves, taken from tools tempered at 130° C. and 140° C. respectively, show two maxima with a depression between them.

These general characteristics are common to the speed curves of all the tool steels that have been tested, whether of the carbon, tungsten, or tungsten-vanadium varieties. All are capable of giving either single or double-peaked curves, according to the heat treatment they have received, and all show a low durability at low cutting speeds, this characteristic being especially marked in the case of some high-speed steels, which latter often retain their durability at very high speeds.

In the paper referred to the theory was put forward that the observed changes in the durability of cutting tools are mainly caused by changes in the temperature of the cutting edge, due to varying quantities of heat generated at different cutting speeds. The heat theory was confirmed by experiments showing that changes of durability corresponding to those which occur under varying cutting speeds can be produced by varying the temperature of the tool in other ways while the cutting speed remains constant, viz., by varying the temperature of the water with which the tool is flooded; by varying the depth of cut (a heavy cut generating more heat than a light one), or by dispensing with the cooling water. It was shown also that the results of Mr. F. W. Taylor's classical experiments with cutting tools are in strict conformity with the "cube law of cutting speeds" deduced by the present writer from a theoretical consideration of the heat generated in cutting. The cube law is thus expressed: "For constant durability of the cutting tool the speed varies inversely as the cube root of the product of area of cut by thickness of shaving."

So much by way of introduction. In the present paper the heat theory of durability will be taken as experimentally

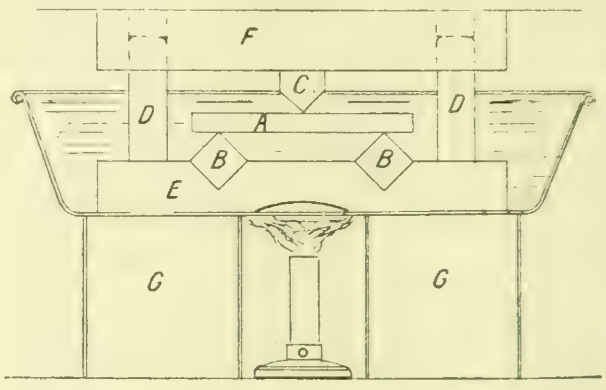


FIG. 2. APPARATUS USED IN BREAKING TESTS.

established, and an attempt will be made to connect the observed changes in the cutting durability of tool steels with changes in the physical properties of the steels as shown by breaking tests made at various temperatures. The various problems that are to be dealt with may be clearly stated as follows:—

(*a*) It has been found by experiments on the tool steel testing machine that all tool steels, without exception, have a very low durability, and are very quickly blunted when cutting under water at low speeds and fine cuts, under conditions, that is to say, which preclude any considerable heating of the cutting edge; and it has been found that any alteration in the cutting conditions which tends to increase the temperature of the cutting edge, results in an increased durability of the tool. What, if any, are the correlative changes in the physical properties (strength, hardness, toughness, &c.) of hardened steel which occur when it is raised from a low to a higher temperature?

(*b*) All varieties of tool steel have been found to be capable, when suitably hardened, of producing double peaked speed-durability curves, the characteristics of such steels being that at a certain speed they are less durable than at higher and lower speeds. Is it possible to correlate this low durability at a certain speed with a particular physical condition at a certain temperature?

(*c*) All tool steels are found to lose their durability when the cutting speed is raised above a certain limit. Is there any corresponding change in their physical properties when they are heated above a certain temperature?

(*d*) Assuming that each cutting speed corresponds to a definite temperature of the cutting edge (the weight of cut and all other conditions remaining constant), what are the actual temperatures of the cutting edge corresponding to the various cutting speeds, and corresponding to the various changes in the durability and physical properties of the steel?

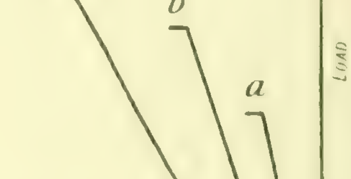


FIG. 3. AUTOGRAPHIC DIAGRAM OF BREAKING TESTS.

Before dealing with these problems it is necessary briefly to consider the nature of the actions tending to wear or blunt a cutting tool, and the correlative physical properties constituting durability which the tool must possess in order to withstand these actions.

The principal action to which a tool is subjected in cutting is one of friction under heavy pressure. This tends to rub the surface of the steel away, by causing the particles of steel to slide over one another. To resist blunting by this action a tool must possess hardness. But the stress on the tool point is not constant; as the chip is detached it breaks

* Paper read before the Iron and Steel Institute, May 1912.

† See "The Mechanical Engineer," May 13th, 20th and 27th, 1910, pp. [illegible], and [illegible], Vol. XXV.

up into a series of short segments (more or less completely separated), and this process subjects the tool to a succession of changes of pressure, amounting almost to blows, and tending to chip off portions of the cutting edge. To withstand this action the tool must possess toughness.

If we make a tool of glass and another of copper, and use them to turn a cylinder of soft material such as lead in the lathe, we shall find that both are very soon blunted, but

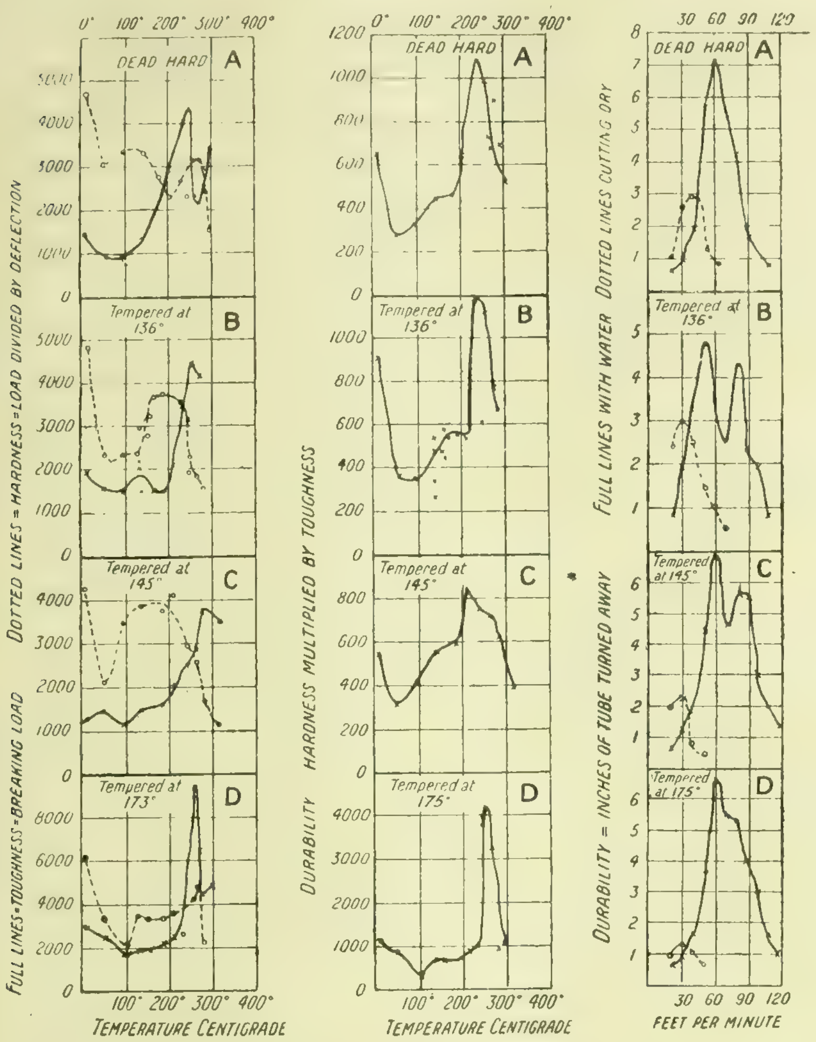


Fig. 4. Fig. 5. Fig. 6.

Fig. 4.—Curves representing toughness (full lines), and hardness (dotted lines) of carbon steel variously tempered. Fig. 5.—Temperature-durability curves from breaking tests, carbon steel. Fig. 6.—Speed-durability curves from cutting tests, carbon steel.

from totally different causes. The glass tool, though extremely hard, is brittle, and is blunted by the chipping away of minute particles of the cutting edge. The copper tool, though very tough, is soft, and is blunted by the rubbing away of the cutting edge.

If now we imagine that by some subtle alchemy we can gradually change the tool of glass into one of copper, it will probably pass through some intermediate stages where it will retain some of the hardness of glass without all its brittleness, and will have attained to some of the toughness of copper without all its softness. The tool in this intermediate state will probably keep its sharp cutting edge much better than either the glass or the copper tool. A diagram showing the durability of such a tool in its successive stages would be likely to take the form of some of the curves in Fig. 1, the durability rising to a maximum as the tool lost its brittleness, and then falling to a low value as it lost its hardness.

In order then to measure, throughout a range of temperatures, those physical properties of a steel which constitutes its durability, it is necessary to test it at each temperature for hardness and for toughness. The usual method of testing toughness is that of the impact pendulum. Some preliminary experiments were made by this method, but it was found that whereas one specimen might be shattered with an absorption of the energy of the pendulum so slight as to be difficult of measurement, another specimen only slightly different in temper would absorb the whole of the energy of a heavy pendulum without being bent or broken. It became evident that a shattering blow bears so little resemblance to the stress to which a cutting tool is subjected as to afford very little useful information relative to durability.

The method finally adopted was that of breaking the specimen, supported at the ends on knife edges, by a load applied transversely at the centre. The apparatus employed is illustrated in Fig. 2. The specimen A was in all cases 3in. long, ¼in. deep, and ½in. wide. It was supported on knife edges BB, 2½in. apart. A third knife edge C was affixed to a plate F, and guided by pins DD sliding freely in holes in F. The whole was placed in a bath containing water, oil, or salt, according to the temperature under investigation, the specimen being completely immersed in the liquid. The bath was rested on iron blocks GG, with gas burners or blow pipes between them, and the whole was placed under the crosshead of the Olsen 100,000lbs. autographic testing machine.

In operation the bath was first heated, and the temperature (measured by a mercury thermometer) allowed to become stationary. The specimen was placed on the knife edges, and five minutes were allowed for it to arrive at the temperature of the bath. The load was then applied, and the specimen broken or bent. The load and the deflection were autographically recorded by the testing machine. Some of the resulting diagrams are reproduced in Fig. 3. The height of each curve represents the maximum load applied to the specimen to break or bend it, and this maximum load is taken as a measure of toughness. Curve *a* is from a specimen broken cold: being brittle, a small load sufficed to break it. Curve *b* is from a similar specimen broken at 238° C. It was tougher, and broke at a higher load. Curve *c* is from a specimen tested at 278° C. In this case the specimen was very tough. It supported a heavy load, and bent without breaking.

For the purpose of the investigation it was necessary to ascertain the hardness of the specimens at each temperature as well as their toughness. The somewhat elusive quality of hardness may be defined as the power of resisting deformation under stress. It is commonly measured by pressing a hard steel ball into the surface of the specimen with a definite force. The material which takes the smallest impression or, in other words, which shows the greatest resistance to deformation, is taken to be the hardest. The ball test cannot be applied to very hard materials, but the diagrams in Fig. 3 give us a means of measuring resistance to deformation or hardness. The relation between the load and the resulting deflection is shown graphically by the slope of the curve. Specimen *a* was very hard: it gave only a small deflection for each increment of load, and the resulting diagram is nearly vertical. Specimen *b* was softer, and *c* very soft, and the slope of the diagram was greater as the hardness diminished. Numerically the hardness may be expressed as the load required to produce $\frac{1}{10}$in. deflection, and the hardness number is obtained by dividing the maximum load in pounds by the deflection in tenths of an inch.

$$H = \frac{L}{10D}.$$

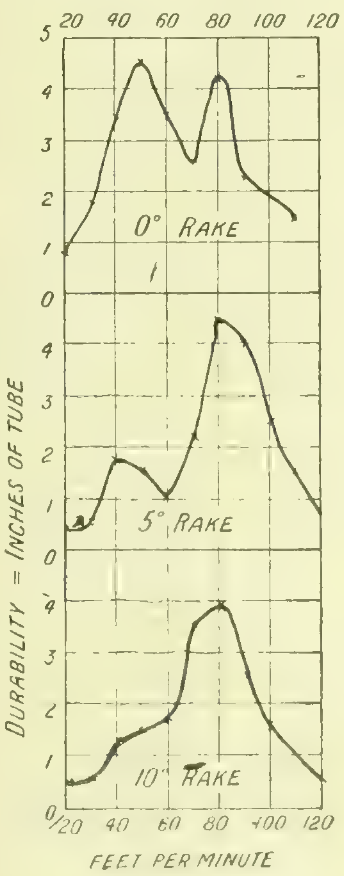


Fig. 7.—Speed-durability curves from the same tool differently ground.

Experiments were first made on crucible steel containing about 1·3 per cent. carbon. A bar ½in. by ¼in. section was cut into pieces 3in. long, which were heated to 800° C. and quenched in water. Some of the specimens were left in the dead-hard state, others were tempered by being placed for 15 minutes in an oil bath at 136° C. Others were tempered in like manner at 145 and 175° respectively. The problem was to ascertain how the physical properties of steels thus treated would be affected by the heat generated in cutting at various speeds. It was certain that a very high cutting speed would heat the cutting edge of the tool sufficiently to soften it and cause it to be blunted immediately, but it was not

known what would be the effect of the lower temperatures generated at lower cutting speeds. In order to reproduce these temperatures artificially, the specimens were heated in the apparatus illustrated in Fig. 2, and broken at various temperatures as described.

The results of the breaking tests are plotted out in diagrams A, B, C, D, Fig. 4. The full lines in these diagrams represent maximum loads at which the specimens were broken or bent (toughness), and the dotted lines represent the hardness, or maximum load divided by deflection. Referring first to the toughness curves (full lines), it will be seen that the diagrams have certain features in common. There is a decrease of toughness as the temperature rises from that of the atmosphere to 100°, and a more or less regular increase of toughness between 100° and 250° or 275°.

Referring now to the dotted curves representing hardness, we again see certain characteristics common to all the specimens. The hardness was relatively high at atmospheric temperature, it was very much less at 50° or 100°, it again attained a high value at temperatures varying from 150° to 250°, and it fell very low at 275° to 300°, at which temperatures the specimens were so soft as to bend without breaking. It will be noticed that the hardness and toughness curves have widely different shapes, an increase of the one quality being very generally accompanied by a decrease of the other, though both decrease together between 20° and 100°.

We have here, according to our theory, two of the elements for determining the variations of durability with temperature; but it is very difficult to say, from inspection

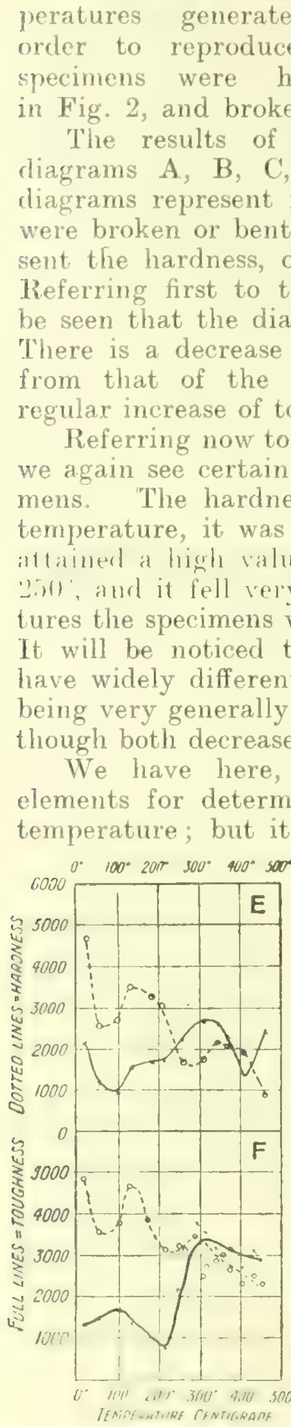


FIG. 8.

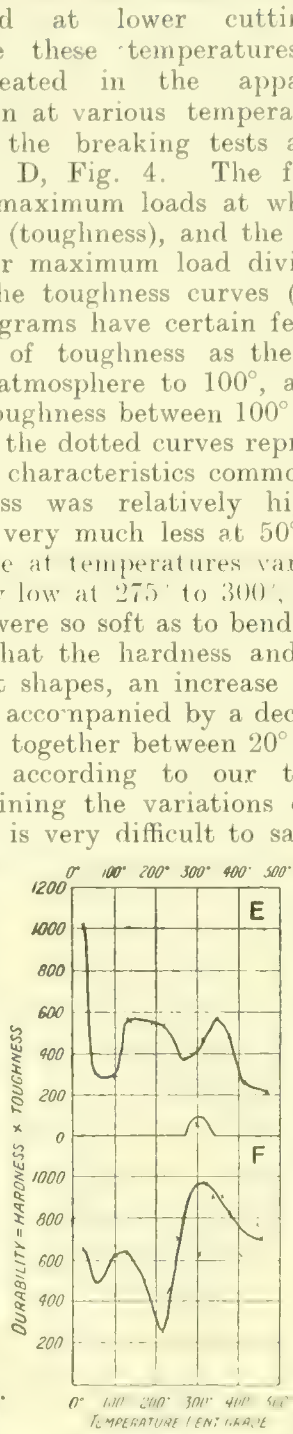


FIG. 9.

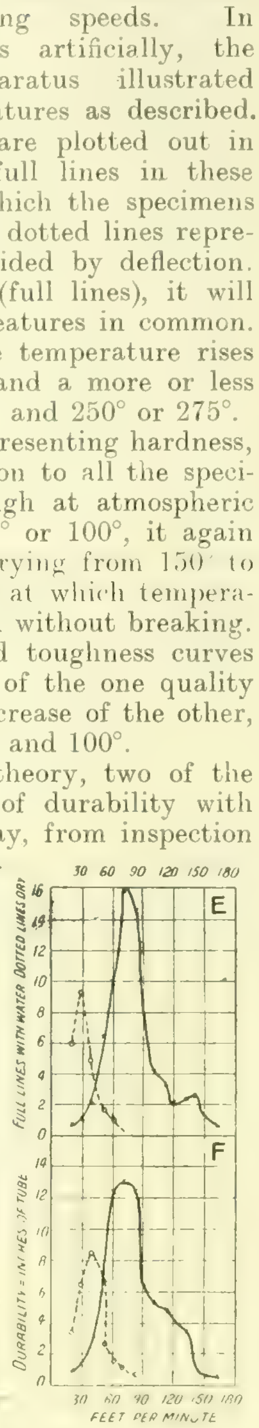


FIG. 10.

Fig. 8. Curves representing toughness (full lines), and hardness (dotted lines) of two high-speed steels, broken at various temperatures. Fig. 9. Temperature-durability curves from breaking tests, high-speed steel. Fig. 10. Speed durability curves from cutting tests, high-speed steel.

of the curves, which temperature might be expected to give the highest durability to the steel. The durability will be high when both the hardness and toughness are high; the durability will be low when either the toughness or hardness, or both, are low. Now it is evident that if we multiply the hardness number by the corresponding toughness number for each temperature, we shall obtain a new series of numbers fulfilling the conditions just stated—they will be high when the hardness and toughness are both high; they will be low when either hardness or toughness, or both, are low. These numbers should therefore be in some degree proportional to the durability of the steel. We cannot say that they will be strictly proportional to durability unless we assume that hardness and toughness are the only qualities constituting durability, and that they are equally important factors in durability, but these are assumptions we have no right to make. Either hardness or toughness may be the more important factor, according to the nature of the material the tool is required to cut. It is an established fact that the steel which is best for cutting hard materials such as tyre steel is not necessarily the best for cutting soft materials such as mild steel or brass, and this may be because a harder tool is required for one class of material and a tougher for the other. Nor can we safely assume that hardness and toughness are the only factors in durability. Some steels (notably the tungsten steels) possess a property of resisting abrasion which does not appear to depend directly on hardness or toughness, and can only be measured by an abrasive test—preferably an actual cutting test. A breaking test may give no evidence of the presence or absence of this quality. The evidence to be obtained from the breaking tests must therefore be regarded as mainly negative evidence. It is certain that a tool which is very soft or very brittle will not be durable. It is almost certain that a given tool will gain in durability as it becomes harder and tougher; but it by no means follows that the specimen of steel which carries the heaviest load with the least deflection will make the most durable cutting tool.

Recognising, then, that the product of hardness and toughness may bear only an approximately proportional relation to durability, let us examine the curves produced by plotting these products on a temperature basis. The curves are shown in Fig. 5, and the durability-speed curves obtained from specimens of the same steel by actual cutting tests made on the tool steel testing machine are shown in Fig. 6. Two sets of curves are shown in this figure. The full lines represent the durability of tools cutting under water, and the dotted curves are taken from the same tools cutting dry.

It is at once apparent that there is a very striking similarity between the curves obtained by breaking (Fig. 5), and those obtained by cutting (Fig. 6). In each case there is a very low durability at low speeds or temperatures, a rise to a high maximum as the speed or temperature increases, and a fall to a low value when the speed or temperature exceeds a certain value. It is especially noticeable that the range of speeds and temperatures which gives the steel a high durability is a very narrow one. One important difference will be noticed. The breaking tests all show a high durability at atmospheric temperature and a rapid fall to 50° or 100°, but this feature is entirely absent from the curves obtained by cutting. From this it might be surmised that at the lowest cutting speed, viz., 20ft. per minute, the edge of the tool was at 50° to 100°, and that the tools would have a higher durability when cutting at still lower speeds. Some experiments have been made with a view to confirming this inference, but hitherto without success. Tests were made at speeds as low at 2ft. per minute, and the tool was flooded with a freezing mixture, but the wear was extremely rapid, and no increase of durability was found. There is no doubt a considerable amount of heat generated in cutting a tough steel, no matter how slow the speed, and it may be that the cutting edge was considerably above atmospheric temperature even under the extreme conditions mentioned. This point, however, requires further investigation.

Two of the tools used in the cutting tests, namely, those tempered at 136° and 145°, gave double-peaked curves. It had previously been found (see Fig. 1) that carbon steels tempered between 130° and 150° give curves of this character, and one purpose of the investigation was to find an explanation of this phenomenon. It cannot be said that the explanation is complete, though each of the breaking tests, and especially B, shows a rudimentary first peak. The relation between the hardness and toughness curves is complicated, their maxima and minima generally failing to coincide, and it is not surprising that the resultant curve of durability should assume a complicated form. It has already been pointed out that the actual shape of the durability curve will depend on the relative importance of the hardness and toughness factors, and that this will depend on the cutting conditions. It has been found by experiment that the shape of the curve is by no means constant when the cutting conditions are altered. Thus Fig. 7 shows durability-speed curves obtained from the same tool ground with 0°, 5°, and 10° rake. The height of the first peak diminishes as the rake of the tool is increased. Again, it is seen in Fig. 6 that tools which give a double peak when cutting under water usually give only a single peak when cutting dry. In this connection it may be pointed out that the cutting temperature is much more definite when the tool is cutting under a copious stream of water than when cutting dry. In the former case the extreme edge of the tool, embedded in the metal, is heated to a temperature depending on the speed and remaining constant throughout the test. When no cooling medium is employed, the tool, the tube, and the adjacent parts of the

machine become gradually hotter as the test proceeds, the temperature becoming constant only (if at all) when the generation of heat is balanced by radiation. This may account for the fact that dry cutting tests seldom, if ever, give double-peaked speed curves.

Breaking tests were made with high-speed steels of two well-known brands. These specimens, 3in. by $\frac{1}{4}$in. by $\frac{1}{4}$in., were hardened by being preheated for $2\frac{1}{2}$ minutes at 850°,

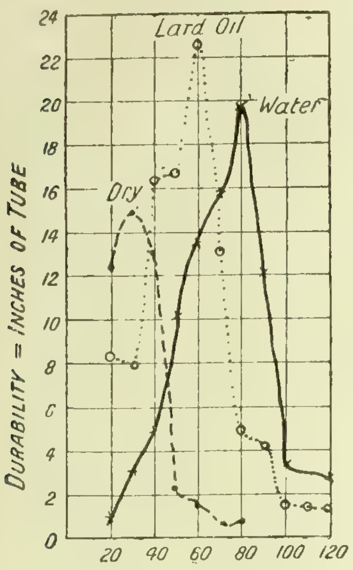


FIG. 11.

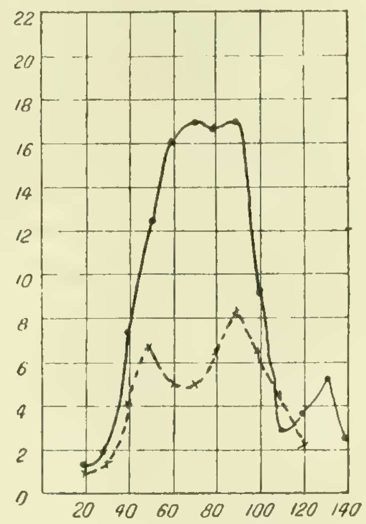


FIG. 12.

Fig. 11.—Speed durability curves of a high-speed steel cutting with and without lubricants. Fig. 12. Speed durability curves of the same high-speed steel differently hardened.

then heated for 50 sec. at 1,275°, and quenched in salt bath at 672° for 30 sec. The hardening of all the carbon and high-speed steel specimens used in these experiments was kindly undertaken by Mr. S. N. Brayshaw. The breaking tests were carried out in the manner described above, and the resulting hardness and toughness curves are shown in Fig. 8. The hardness curves (dotted) are somewhat complicated, but the curves of the two steels closely correspond with each other, and bear some resemblance to the hardness curve A (Fig. 4), taken from the dead-hard carbon steel. There is a marked fall in hardness from atmospheric temperature to 50° and 100°, followed by a rise to 130°, a fall to 280°, with a smaller rise and fall at higher temperatures. The two toughness curves (full lines) also correspond in general form, though there is a great difference in the temperatures at which the first minima occur (100° and 220° respectively).

Multiplying together the hardness and toughness numbers as before, we obtain the durability-temperature curves in Fig. 9. The durability-speed curves obtained from two of the specimens by cutting tests on the tool steel testing machines are given in Fig. 10, the dotted curves being obtained by cutting dry, and the full curves with water.

The durability-temperature curves (Fig. 9) resemble those of the carbon steels (Fig. 5) in showing a marked fall in durability from atmospheric temperature to 50°, this feature being entirely absent in the curves obtained by cutting (Fig. 10). Both the temperature-durability curves, E and F (Fig. 9), show marked double peaks, and it will be noticed that in the case of steel E the first peak occurs between temperatures 100° and 260°, thus corresponding roughly with the main peaks of the carbon steels (Fig. 5). The second peak in steel E occurs between 260° and 400°, at which temperature the carbon steel would be soft.

Turning now to the cutting tests, we see in curve E (Fig. 10) two peaks, the first occurring between 20ft. and 120ft. per minute, thus corresponding with the carbon steel curves in Fig. 6, while the second peak in E (Fig. 10) occurs at 140ft. per minute, at which speed the carbon steels were incapable of cutting. There is thus a close correspondence between the durability curves obtained by breaking and by cutting tests. It is true there is a great disparity as regards the relative heights of the two peaks, but this was to be expected. Even though the steel were equally hard and tough when cutting at 70ft. and at 140ft. per minute (as would appear from Fig. 9), the higher speed would naturally blunt the tool more rapidly.

The curves of steel F are somewhat anomalous. The breaking tests show two distinct peaks with a low minimum at 220°, the second peak being a very large one, whereas the cutting tests (Fig. 10) show only a single peak extending from 20ft. to 150ft. per minute.

The dotted curves obtained by cutting dry (Figs. 6 and 10) are in all cases to the left of the corresponding "wet" curves, and it is especially to be noted that all the tools when cutting at very low speeds were more durable when water was not used—*i.e.*, when they were allowed to become heated.

This effect of temperature on durability is clearly shown in Fig. 11, which represents the speed-durability curves of a high-speed steel tool cutting (1) dry, (2) with lard oil, (3) with water. At the low speeds, 20 and 30ft. per minute, the tool was most durable when cutting dry, and least durable with water. At the highest speeds the position is reversed, while at intermediate speeds the lard oil gave the highest durability. The oil appears to exercise a double function. It acts as a cooling medium, and enables the tool to work at much higher speeds than are practicable when cutting dry; but, as a cooling medium, it is inferior to water, and therefore less conducive to durability at very high speeds. It has, however, a lubricating effect which is not possessed by water, and is highly conducive to durability at speeds which do not generate an excessive amount of heat. The oil gives the highest durability, but not at the highest speed.

The curves in Fig. 12 illustrate the extreme importance of the time factor in the hardening of high-speed steel. The dotted curve represents the durability of a high-speed tool which was preheated for 4 minutes at 850°, heated for one minute at 1,275°, and quenched in salt at 675° C. The full curve shows the durability of the same steel preheated for $2\frac{1}{2}$ minutes and heated for 50 seconds at the same temperatures. Evidently the first tool had been injured by too prolonged heating.

Let us now see how far the results of the experiments enable us to answer the questions with which we set out.

A. The low durability of all tool steels, cutting under water at low speeds and light cuts, seems to be completely explained by the low values of hardness and toughness which always occur at cutting temperatures of 50° to 100°. The breaking tests have shown in every case that the product, hardness × toughness, increases in value as the temperature is raised above 100°. The cutting tests have shown in every case that the durability increases when the cutting speed is raised above 20ft. per minute. These cutting tests have also shown that the durability always increases when a tool working at 20ft. per minute is allowed to cut dry instead of with water, or with hot water instead of cold. It is impossible to doubt that these are different manifestations of the same physical change in the steel.

A clear recognition of this phenomenon is of great practical importance. A great deal of the metal cutting in every engineer's shop consists in taking fine finishing cuts, often with water on the tool. If such cuts are taken at a slow speed, the temperature of the cutting edge may not rise above 100°, in which case the tool will be quickly blunted. Its durability can be increased by increasing the speed or by cutting dry. Many cases are known to have occurred in ordinary workshop practice, where an increase in cutting

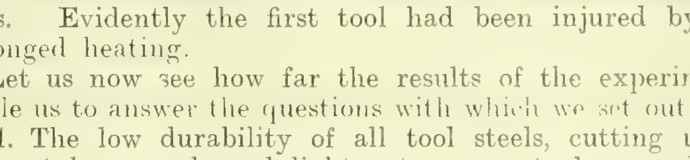


FIG 13.—APPROXIMATE SCALE OF CUTTING TEMPERATURES AND SPEEDS FOR TOOLS CUTTING WITH WATER ON THE TOOL STEEL TESTING MACHINE.

speed has actually resulted in increased durability of the tool.

Low durability at low cutting temperatures (on, for example, finishing cuts)* is a familiar characteristic of high speed steels, and is most marked in tools which have been suitably hardened for very high temperature work. High speed steel can be so hardened as to retain its durability at fairly low temperatures, and there are now on the market tungsten steels specially adapted for low temperature work.

* There is reason to believe that the condition of low durability in [illegible] steel may occur at temperatures much higher than 100° (see E, Fig. 9).

such as finishing very heavy forgings; but every description of steel known to the writer loses its durability if the cutting temperature is low enough. It should be noted that a low cutting temperature can only occur when there is a combination of low speed with light cut. A heavy or moderate cut raises the temperature of the cutting edge above 100°, even at very slow speeds.

B. The phenomenon of the double-peaked curve is not completely elucidated, though the evidence goes some way to explain it. The variations of hardness and toughness with temperature are of a complicated character, and the cleft between the two peaks of a durability curve appears to be caused by the conjunction of depressions in the hardness and toughness curves at a particular temperature. The relative heights of the two peaks are found to vary with the conditions of cutting, and this variation may be due to a change in the relative importance of the hardness and toughness factors, according to the quality of the material cut, or the shape of the tool.

C. The decline in durability which takes place when a certain limiting speed is exceeded is evidently caused by an actual softening of the cutting edge by the heat generated in cutting. This softening, which is extremely local, takes place even when the tool and the work are practically immersed in running water. The speeds and temperatures at which the softening occurs depend largely on the particular hardening process which has been applied to the tool, and are generally highest in high-speed steel.

D. It is not yet possible to establish an exact scale of cutting temperatures corresponding to the scale of cutting speeds, but a comparison of the temperature-durability curves obtained by breaking tests (Figs. 5 and 9), with the speed-durability curves obtained by cutting tests (Figs. 6 and 10), enables us to make an approximation, as in Fig. 13.

To establish a correspondence between the speeds of cutting with and without water, a comparison may be made between the full and dotted curves in Figs. 6 and 10, from which it appears that the effect of using water is approximately to double the cutting speed; in other words, the edge of a tool flooded with water attains about the same temperature as the edge of a tool cutting dry at half the speed. This must not be taken as a general statement applicable to all cutting operations. The dry cutting temperature depends largely on the volume of metal operated upon. The tube used in the tool steel testing machine is small in diameter and light in-section; it becomes considerably heated under a dry cut. In machining a large forging the body of metal absorbs a great deal of heat, with only a slight rise in temperature, and the use of water has less effect on the cutting speed.

Considerable interest attaches to a comparison of the durabilities of carbon and high-speed steels. It appears from Figs. 6 and 10 that the high-speed steel has two distinct features of superiority. The speeds at which it attains its maximum durability are not very different from those at which carbon steel is most durable, but the high-speed steel is several times as durable at these speeds. Quite distinct from its superior durability at moderate cutting temperatures is the property possessed by high-speed steel of retaining some durability at temperatures high enough to soften carbon steel, but its actual durability under such conditions is much less than under conditions which do not unduly heat it. In other words, its abrasive quality appears to be more important than its heat resisting quality.

A comparison of the curves in Figs. 5, 6, 9, and 10 lends force to the warning already given, that no absolute measure of durability can be obtained by a breaking test. The highest durability calculated from breaking tests was that of tool D, but the actual durability of this carbon steel, measured by cutting, was not particularly high, and was much less than that of high-speed steel E, which broke under lower loads.

Welsh Coal Developments.—The Bedwas Navigation Colliery Company is fitting up its north pit with permanent guides, carriages, &c., for coal raising. The south pit is being used for working both shafts. Pumping engines are being erected and large lodge rooms for water are being prepared.

FATAL RAG BOILER EXPLOSION AT BURY.

ON Saturday morning, the 11th inst., the inquest was held at Bury on the body of Joseph Plews, beaterman, who was killed as the result of the explosion of a revolving rag boiler at the East Lancashire Paper Mill on the previous Tuesday.

George Fowler, fire beater, employed by the East Lancashire Paper Mill Company, said that about 9-30 p.m. on April 30th, while following his employment, he heard a loud report. He went to the top of the fire-hole and was told there had been an explosion. He went to the "brown mill," where rags were boiled for making brown wrappers. He looked behind the pan and saw Plews. He asked deceased if he was fast, and he replied "No." Witness asked if he could get out, and Plews said he could not get past some "boxes." Witness then helped Plews to a place of safety. He asked Plews if the pan had burst, and he said he thought it was the shafting that had broken.

John Prestwich, foreman of the preparation department, said he saw the scene of the accident about 10-30 p.m., on April 30th. At that time two men had been removed to the Infirmary. The pans were the revolving rag-boilers, and one had the end opposite to that at which the steam entered blown out and through the wall. He explained the system by which the steam was directed into the pans and the arrangement of safety valves. He could not explain how the accident happened. The boilers were tested in March, and he had looked at them from time to time and had found no sign of weakness. The end was blown clean, straight out, as though a large amount of pressure had been applied.

Frank Allen, engineer, said he was in his house, which is near the mill, when he heard the explosion and ran out. In the first instance he went on the road side and saw the wall had been blown out. It was too dangerous to go through, and he ran round to another door and got through the size house. The men had been got out when he got there. Witness found the boilers were down and the steam shut off. The steam piping was down for a distance from the pans. He assisted in getting the injured men away. He had since examined the boilers. The end of one of them was blown out; it was fractured part way through the angle and the rest of the way round it had broken through the rivet holes. The other boiler was not damaged so far as he could see, except the gearing. Both boilers were fed from a 1in. pipe which branched off at a point into each boiler. The steam passed through a reducing valve set to 25lbs. There was a steam gauge and a "dead weight" valve which blew off at 30lbs. pressure. The boilers were of iron plates single riveted, and three years ago they were tested hydraulically. They were tested by the Insurance Company about four years ago, and were passed up to 50lbs. The last outside examination was in March, and there were no complaints.

The report of the company's inspector of June, 1911, was produced, and it stated that the boiler was in working order for the pressure required, but there was certain wasting which would want watching. Asked if he had had any talk with the inspector about the wasting, the engineer said he just remarked about it, but nothing special. The boilers were insured up to 25lbs., and they did not usually work either above 15lbs. Witness added that he looked at the boilers occasionally, and thought they were quite safe to work. It was only a low pressure. He could not understand what had caused it to go. The plates were half an inch thick. The Board of Trade inspector had inspected it since the explosion. Witness said he had had no misgivings about the boiler, which was the last he should have expected to go.

Continuing, the witness said the rivets were 1in. and 2in. pitch. The boilers were old ones, and were on the ground when he went to the mill, being used for tanks. They had previously been used at 40lbs. pressure. Plews was an experienced man, and practically had charge of the boilers. He could not say what was the cause of the explosion. The valves seemed to be all right after the accident. He did

not put the boilers into use for boiling rags until they were tested up to a pressure of 50lbs.

The Deputy-Coroner reviewed the evidence, and said the question was whether anyone responsible had acted recklessly and carelessly, which in plain English would lead the jury to the conclusion they were guilty of manslaughter, or whether there had been an error of judgment. If they found that every care had been exercised and that the boiler had been examined periodically, and the conclusion arrived at that it was safe to work, it was simply a case of accidental death. The jury returned a verdict of "Accidental death."

KÖRTING'S INJECTOR.

We illustrate herewith a design of injector, the invention of Körting Bros., of Linden, near Hanover, of the kind that are adapted to deliver to a boiler or other apparatus water under pressure higher than atmospheric pressure, and wherein, for the purpose of putting or keeping the water reservoir under pressure by the working steam of the injector, the reservoir and injector are in piped connection. It comprises a chamber independent of the overflow chamber of the injector, and connected with either the atmosphere or a condensing vessel, for the purpose of reducing the pressure or condensing the working steam in the reservoir and pipes preparatory to the admission of a fresh supply of water to the reservoir. The valves for connecting the reservoir and condensing vessel with the injector are so constructed and arranged that the opening and closing of them is effected by a common regulating member. When it is desired that there should be a continuous flow of water to the reservoir and a continuous flow through the injector to the boiler, means are provided whereby warning is given when the reservoir is either full or empty or in both states.

In the accompanying illustrations Fig. 1 shows diagrammatically an injector working in conjunction with other apparatus, whilst Fig. 2 shows the injector in vertical section. In Fig. 1 the injector is connected through pipes M and U with a water-pressure reservoir O, into which, through several connections Z, hot water at a temperature of from 90° to 100° C is led under pressure or not from steam traps or other sources. The hot water to be fed through the injector flows through the pipe U, whilst, if necessary, through the pipe M the working steam of the injector is supplied to the water reservoir O, in order to effect or supplement, by the excess of pressure of the working steam over that in the reservoir O, the flow of water to the injector. In order now to bring the reservoir, filled after supplying the hot water with working steam, back to the low pressure necessary for taking up the fresh hot water, the reservoir having been emptied through the injector, the pipe Q is connected with a pressure equalising vessel N_1, formed as a condenser, but is again cut off when the injector is restarted. In the example shown in Fig. 2 the injector steam admitted to the water reservoir O issues from the chamber C, into which the steam passes by way of the valve B from the chamber A connected with the steam pipe. The steam nozzle D is adapted to be closed by the cut-off valve E, which is arranged on a spindle F common to it and the valve B, and the nozzle D is kept closed, after the opening of the valve B, by means of the collar G, for a portion of the stroke of the spindle F.

The connection of the water reservoir O or the chamber C with the condenser N_1, for the purpose of equalising the pressure, is controlled by the valve H, for the chamber C, after the opening of this valve, is put in communication through the collar J with the chamber K, to which the pipe Q leading to the condenser is connected. The chamber K is arranged completely independent of the overflow chamber L, and can if necessary, for the purpose of equalising the pressure or reducing the pressure in the vessel O, communicate directly with the atmosphere, which, however, would entail the loss of whatever steam was at the time in the empty water reservoir O. The valve H is also arranged on the same spindle as the overflow valve S, which is provided with packing for the purpose of making the connection between the chamber C and the overflow chamber L steam and water-tight. Both spindles F and N are fixed to a traversing member on the screw spindle P, and can, therefore, be simultaneously adjusted by the hand-wheel shown. The overflow valve S has two projecting portions or collars R and T, each of which is adapted, when in proper position, to effect the closing of the overflow chamber L from the pressure chamber X. By means of the coned surfaces on the valves B, H, and S effective closures are assured, while, at the same time, a limitation of the stroke of the spindles N and F is obtained.

The working of the injector is as follows: In the positions shown the chambers C and K, the water reservoir O, and the condenser N intercommunicate, and therefore there is atmospheric or a higher pressure in both chambers, according to the temperature of the hot water to be fed in. The valves B, E, and S are, when in the position shown, closed, that is the injector is cut off. To start the same by means of the hand wheel, first of all the valves B and S are simultaneously opened—the latter by the upper collar R issuing from the valve opening, while the valve H is closed by the collar J, whereupon steam from A passes to the reservoir O and forces the hot water in the latter through the pipe U

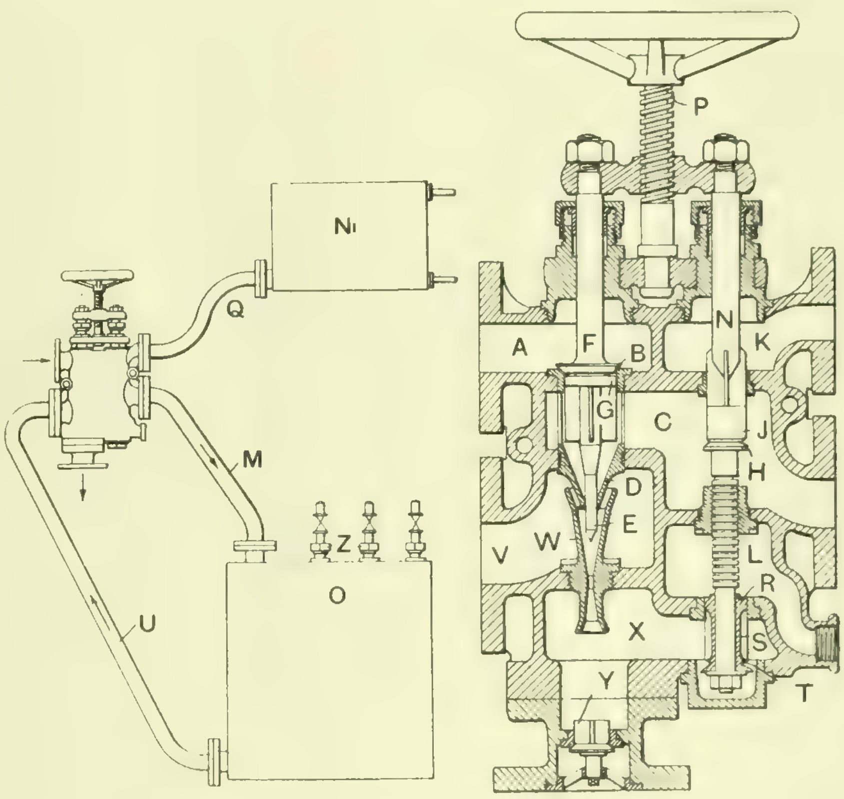


Fig. 1. Fig. 2.
Körting's Injector

into the mixing chamber V, whence it passes through the mixing nozzle W and valve S into the overflow chamber L. On the subsequent further lifting of the spindle F and N the steam nozzle D is opened, and simultaneously or directly afterwards the overflow valve S is closed again by the lower collar T, so that the steam passing through the mixing nozzle, owing to its kinetic energy, carries along with it the pressure water entering the nozzle and forces it into the boiler through the non-return valve Y. When the water reservoir O is empty the injector is again cut off, that is, it is brought again into the position shown in Fig. 2 for the purpose of equalising the pressure in the reservoir O.

In cases in which there is required a continuous flow of hot water to the reservoir O, and also a continuous flow through the injector to a boiler or other apparatus, it is advisable to put the reservoir in communication with an alarm adapted to sound when the reservoir is either full or empty, or both. This alarm may be operated by means of a float in the reservoir, directly or indirectly connected with it, in a manner that it will sound an alarm as soon as the injector should be re-started or cut off. In this manner interruptions in the flow to the reservoir are prevented with certainty, which otherwise would occur both when the reservoir is full, and therefore unable to receive more hot water, and also when the vessel is empty and kept so owing to the pressure of the steam coming from the injector.

THE CORROSION OF NICKEL, CHROMIUM, AND NICKEL-CHROMIUM STEELS.*

By J. Newton Friend, J. Lloyd Bentley, and Walter West.

The effect upon the rate of corrosion of iron and steel produced by the introduction of alloying elements is a study which has been much neglected, although the influence of the same elements upon the general physical characteristics of the metal has in general been fairly completely dealt with. The corrodibility of steel may be influenced in at least three different ways by the introduction of foreign elements, namely:—

(1) A few elements, such as carbon, nickel, and silicon, yield compounds which offer a stout resistance to oxidation, and thus greatly enhance the stability of the metal towards corroding influences.

(2) Some elements yield readily fusible alloys or compounds of variable melting points, which, during the solidification of the steel, tend to produce unequal distribution of the materials in the solid metal. This segregation is one of the most serious causes of galvanic activity and "pitting" with which the engineer has to contend.

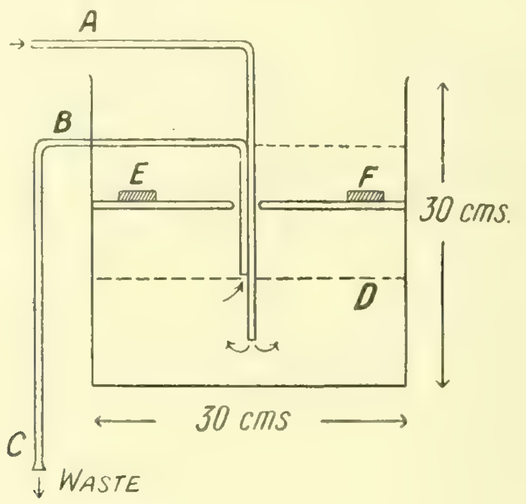


Fig. 1.

(3) Finally, a few elements, like sulphur, when present in steel, exist in the form of relatively oxidisable bodies which yield sulphurous acids, and thus greatly enhance the rate of corrosion of the metal when once it has begun. Now, although a good deal of isolated work has been done from time to time on the corrosion of nickel steels, most investigators have contented themselves with determining the relative rates of corrosion under only one, or at most two sets of conditions, the most usual being exposure to salt water and acid respectively. We felt it was desirable to investigate more thoroughly the influence of nickel, and likewise to study that of chromium and of a mixture of nickel and chromium, upon the corrodibility of steel—the last two branches of the subject having received but little attention hitherto, very few published data being extant. We are supplementing the work detailed in this memoir with several series of "long-period" tests, and hope, at a later date, to communicate the results and discuss them fully.

The steels experimented upon were kindly supplied to us in the form of bars by Messrs. Cammell, Laird, & Co., of Sheffield, and were tool turned and sliced into discs 0·7 centimetre thick and 2·8 centimetres in diameter, by the Darlington Forge Company. To both of these firms we wish to express our hearty thanks. The analyses of the steels, kindly supplied to us by Mr. B. Deby, of Sheffield, were as follows:—

Analyses of Steels.

Steel No.	Carbon Per Cent.	Silicon Per Cent.	Phosphorus. Per Cent.	Manganese Per Cent.	Sulphur. Per Cent.	Nickel Per Cent.	Chromium
1	0·29	0·14	0·023	0·39	0·024	...	...
2	0·39	0·208	0·023	0·685	0·036	...	...
3	0·19	...	...	0·29	...	3·72	...
4	0·24	...	...	0·46	...	6·14	...
5	0·08	...	...	0·38	...	26·24	...
6	0·32	...	...	0·36	...	...	1·12
7	0·14	...	...	0·110	...	...	3·58
8	0·09	...	...	trace	...	...	5·30
9	0·52	0·127	...	0·41	...	3·40	1·00
10	0·54	...	...	0·58	...	3·5	1·12

* Paper read before the Iron and Steel Institute, May 9th, 1912.

It will be observed that while the steels have not a perfectly uniform composition with respect to the alloying elements, other than nickel and chromium, the discrepancies are relatively small and of minor importance compared with the range of nickel and chromium covered. Any results obtained with these, therefore, may probably be regarded as reliable. The discs of steel were carefully polished with emery-paper, weighed, and subjected to corroding influences as follows:—

(1) *Tap-water Tests.*—The discs were laid flatwise on a circular sheet of paraffin wax in a glass crystallising dish, covered with tap water to a depth of 6 centimetres, and kept in a dark cupboard to prevent any irregularity of corrosion consequent upon unequal illumination. The paraffin served to reduce to a minimum the possibility of galvanic action, and also prevented the corrosive action of the silica—always observed if iron lies for any length of time in direct contact with glass. After 64 days the discs were removed, cleaned, and weighed, the loss in weight being taken as a measure of the corrosion. The results were as follows:—

Corrosion of Steels in Tap Water.

Steel No.	Nickel Per Cent.	Chromium Per Cent.	Original Weight. Grammes.	Loss in Weight. Grammes.	Corrosion Factor.
1	...	...	35·6201	0·0961	100
2	...	...	37·4186	0·1038	108
3	3·72	...	33·5506	0·0798	83
4	6·14	...	30·1416	0·0666	69
5	26·24	...	33·4796	0·0488	51
6	...	1·12	28·7101	0·0817	85
7	...	3·58	28·6826	0·0558	58
8	...	5·30	31·1996	0·0400	43
9	3·4	1·00	30·8926	0·0736	77
10	3·5	1·12	31·5880	0·0844	87

(2) *Sea-water Tests.*—This series was conducted in a precisely similar manner to the previous one, save that the tap water was replaced by sea water taken from Bridlington Bay. We desire to acknowledge the kindness of Miss Agnes Harrison in obtaining and forwarding this to us. After 64 days, the loss in weight of the steels was found to be as follows:—

Corrosion of Steels in Sea Water.

Steel No.	Nickel Per Cent.	Chromium Per Cent.	Original Weight. Grammes.	Loss in Weight. Grammes.	Corrosion Factor.
1	...	...	34·4619	0·1136	100
2	...	...	37·5729	0·1196	105
3	3·72	...	30·9664	0·0886	77
4	6·14	...	32·9744	0·0906	79
5	26·24	...	30·2324	0·0516	45
6	...	1·12	28·7259	0·0686	60
7	...	3·58	25·9639	0·0291	26
8	...	5·30	30·9149	0·0261	23
9	3·4	1·00	30·6344	0·0936	82
10	3·5	1·12	29·1314	0·1026	90

(3) *Sulphuric Acid Tests* (0·05 per cent.).—These results were obtained in an exactly similar manner to the preceding, the corroding liquid being 0·05 per cent. sulphuric acid (that is 0·5 gramme of acid in 1,000 grammes of solution with water). The results obtained after 60 days' exposure are given in the accompanying table:—

Corrosion of Steels in 0·05 Per Cent. Sulphuric Acid.

Steel No.	Nickel Per Cent.	Chromium Per Cent.	Original Weight. Grammes.	Loss in Weight. Grammes.	Corrosion Factor.
1	...	...	37·9886	0·1594	100
2	...	...	37·2552	0·1560	98
3	3·72	...	32·2582	0·1350	85
4	6·14	...	31·8352	0·1320	82
5	26·24	...	31·4352	0·0860	54
6	...	1·12	29·2676	0·1134	71
7	...	3·58	29·9346	0·1088	68
8	...	5·30	30·8742	0·1086	68
9	3·4	1·00	30·8136	0·1394	87
10	3·5	1·12	32·4194	0·1492	93

(4) *Sulphuric Acid Tests* (0·5 per cent.).—These experiments were similar to the preceding ones, the acid being of the

strength 0·5 per cent. by weight. The results obtained after 53 days' exposure were as follows:—

Corrosion of Steels in 0·5 Per Cent. Sulphuric Acid.

Steel No.	Nickel Per Cent.	Chromium Per Cent.	Original Weight Grammes.	Loss in Weight. Grammes.	Corrosion Factor.
1	...	...	34·4266	0·9608	100
2	...	...	36·6388	2·4878	259
3	3·72	...	32·1346	0·5308	55
4	6·14	...	31·9370	0·6042	63
5	26·24	...	31·9886	0·0770	8
6	...	1·12	28·8042	2·1420	223
7	...	3·58	28·9772	0·5830	61
8	...	5·30	30·6176	0·7514	78
9	3·4	1·00	30·9126	1·2722	132
10	3·5	1·12	33·6036	3·9672	413

(5) *Alternate wet and dry Tests.*—These experiments were carried out in a large iron thermostat, of the dimensions and shape shown in Fig. 1, the metal discs (E, F, &c.) being laid, as before, in a circle flatwise on a sheet of paraffin wax. Water entered slowly by tube A, and being admitted to the centre of the apparatus, affected all the discs equally. The paraffin disc was perforated by numerous small holes, and rested on a similarly perforated iron disc, to enable it to bear the weight of the steels. When the water reached the level B, it was quickly siphoned off automatically by BC, and the level fell to D. It then began to fill again. In this way the metal discs were exposed to alternate wet and dry, the process of filling the thermostat requiring two hours each time. A loosely fitting cover was placed on the top to keep out dust, and to maintain darkness within, in order to prevent, as before, any irregularity of corrosion consequent upon unequal illumination. The results obtained after an exposure extending over 52 days were as follows:—

Corrosion of Steels exposed to Alternate Wet and Dry.

Steel No.	Nickel Per Cent.	Chromium Per Cent.	Original Weight. Grammes.	Loss in Weight. Grammes.	Corrosion Factor.
1	...	...	38·5536	0·2706	100
2	...	...	28·7170	0·2720	100
3	3·72	...	28·3870	0·1165	43
4	6·14	...	31·8660	0·0985	36
5	26·24	...	30·8160	0·0220	8
6	...	1·12	28·5846	0·2512	93
7	...	3·58	28·3886	0·0806	30
8	...	5·30	30·8406	0·0556	21
9	3·4	1·0	29·8748	0·1274	47
10	3·5	1·12	32·7956	0·1404	52

Discussion of the Results.—In order to facilitate the discussion of these results, the following table has been drawn up in which the corrosion factors of the steels as obtained by each method is given:—

Corrosion Factors of Nickel, Chromium, and Nickel-Chromium Steels.

Steel No.	Nickel Per Cent	Chromium Per Cent.	Corrosion Factor for— Tap Water.	Sea Water.	Wet and Dry.	0·05 Per Cent. Acid.	0·5 Per Cent. Acid.
1	...	...	100	100	100	100	100
2	...	...	108	105	100	98	259
3	3·72	...	83	77	43	85	55
4	6·14	...	69	79	36	82	63
5	26·24	...	51	45	8	54	8
6	...	1·12	85	60	93	71	223
7	...	3·58	58	26	30	68	61
8	...	5·30	43	23	21	68	78
9	3·4	1·0	77	82	47	87	132
10	3·5	1·12	87	90	52	93	413

A careful study of the above table reveals a number of highly interesting facts. These may be summarised as follows:—

(1) The corroding media may be divided into two groups, namely, acid and neutral, and the results obtained are usually very different in the two cases. Very dilute acid resembles the neutral corroding media in its action. This we might expect, since the so-called neutral media (tap water, sea water, &c.), always contain a minute quantity of acids, such as carbonic.

(2) Acceleration tests as usually carried out with sulphuric acid, yield very misleading results as to the general corrodibility of the metals tested. Thus, for example, the two standard steels corroded at almost identical rates when exposed to tap water, sea water, wet and dry, and to 0·05 per cent. sulphuric acid. But in the 0·5 per cent. acid the second steel corroded some two and a half times as rapidly as the first. Very similar discrepancies occur with steels Nos. 6, 9, and 10, the last named corroding more than three times as much as steel No. 9, although in the other tests the two steels behaved similarly, as we should expect from their analogous compositions.

These observations are in perfect harmony with those of Frazer,* who found that whilst samples of basic and acid steel of analogous composition corroded at practically identical rates under ordinary conditions, yet when exposed to the action of dilute sulphuric acid the results were most irregular, in one case the acid steel corroding five times as rapidly as the basic steel. The results of the Corrosion Committee of the British Association emphasize the same fact, and C. M. Chapman, working in America, has been led to similar conclusions.

The explanation is not far to seek. Two opposing forces are called into play when steel is immersed in a corroding medium, namely:—

(1) Galvanic activity between the relatively incorrodible portions and the easily oxidisable ferrite, the latter functioning as the anode and the former as cathode. The corrosion of the ferrite is thus accelerated. Amongst the incorrodible materials we must class cementite, in ordinary steel, and in the steels studied in this memoir we have the various complexes of iron, carbon, nickel, and chromium, all of which function cathodically.

(2) On the other hand these incorrodible materials offer a very effective mechanical protection against corrosion by preventing the corroding medium from coming into direct contact with the ferrite, and thus tend to protect the metal from corrosion.

A moment's consideration will show, however, that by intensifying the corrosive media, as, for example, by the employment of sulphuric acid, the two forces mentioned above will not be affected to the same degree, and that the results obtained will not be the same as they would be had the metal been exposed to a less intense action for a longer time. Consequently the two methods are not strictly analogous.

The honeycombed appearance of the surface of steels Nos. 2, 6, and 10, was so pronounced as to render doubt impossible as to the intensity of the galvanic action which had taken place. The fact that no nickel and chromium could be detected in the corroding acid shows that these metals were constituents of the cathode, and the excessive corrosion of these steels makes it clear that the galvanic activity was stimulated out of all proportion to the mechanical protection afforded by these metals.

(3) From the results with steels Nos. 6, 7, and 8, in 0·5 per cent. acid, it would appear that there is an optimum concentration of chromium which yields the maximum resistance to acid attack, and that if this amount be exceeded (as in steel No. 8) the steel becomes less permanent. This is thoroughly in accordance with the results obtained by Hadfield, and more recently by Monnartz.

(4) In neutral corroding media the resistance offered to corrosion apparently rises with the percentage of chromium. This is particularly the case for salt water, and the employment of chromium steels in the construction of ships would appear to be fully justified on this ground alone.

(5) Nickel steels appear to be resistant to acid and neutral corroding media alike, the resistivity increasing with the percentage of nickel. The permanence of the 26 per cent. nickel steel towards 0·5 per cent. acid is particularly noteworthy.

(6) The corrosion factor does not appear to be a purely additive quantity. Thus, for example, in exposure tests with tap water, the corrosion factors of steels Nos. 3 and 6 respectively are 83 and 85. We might expect, therefore, that since the 3·72 per cent. of nickel and the 1·12 per cent. of chromium each separately yield the same protection, by having both together in the steel the same result should accrue as by either doubling the nickel or the chromium content alone. This, however, is not the case, as is evident from a consideration of the results obtained with steels Nos. 4, 7, 9, and 10. Similar

* "Journal of the West of Scotland Iron and Steel Institute," 1907, Vol. XIV, p. 82.

conclusions are arrived at from the sea water, and other tests with the same steels.

Whilst these results are extremely important they are not final. They have only been obtained from experiments carried out at room temperature (12° C. to 15° C.), and the period of testing has not exceeded 64 days. We are continuing the work at different temperatures and with long-period tests, so that the conditions may resemble as closely as possible those actually experienced under working conditions. In conclusion, we wish to urge the necessity of determining the corrosion of iron and steel under conditions closely similar to those to which the metal will be subjected in practice, otherwise the results will be unreliable and lead to much confusion.

CAUSES OF BOILER EXPLOSIONS.*

BY S. F. JETER.

THE causes of steam boiler explosions are so varied that it will only be possible to mention the more prominent ones in this paper. Broadly speaking, there is one explanation for all boiler explosions, namely, the boiler or some part of it is too weak to withstand the stress brought upon it. However, there are many causes contributing to such weakness. The public and many engineers assume that most explosions are caused by some mysterious influence which cannot be foreseen or guarded against; but as an actual fact, a definite cause can be given for most explosions. That a large percentage of boiler explosions are from causes that might have been foreseen and prevented, is a well-established fact.

One cause of boiler explosions which I will deal with first, because it is of particular interest to the manufacturer, is faulty design. Boilers are sometimes constructed too weak for the pressure to be carried. This does not mean that the boiler will necessarily explode as soon as pressure is raised. Explosions from this cause usually occur after years of use, the overload on the parts having had time to gradually weaken them until they are no longer capable of resisting the excessive stress. Of course, a manufacturer has practically no control over the steam pressure to be used on a boiler after he has delivered it to the purchaser. Proper inspection and fixing pressures by experts is the logical remedy for explosions due to this cause.

Lack of properly flaring the tubes and nipples in water-tube boilers has frequently resulted in explosions. The Hartford Steam Boiler Inspection and Insurance Company has always advocated proper flaring, and sometimes manufacturers have taken issue with the company on this point. Experience has fully demonstrated the correctness of its position in this matter. The safety of the joint between a tube and plate when expanded and flared or merely expanded is not a question of the relative strength of such connections newly made. When a connection of this kind becomes loose due to a movement of the parts from expansion or vibration, together with the excessive weight sometimes sustained, the tube or nipple with a flared end is decidedly more safe than one which is merely expanded. The flared nipple usually gives warning of its looseness by leakage before it pulls out.

A cause of explosions which is particularly reprehensible because of its being preventable is due to an owner's willingness to pit his judgment against more competent advice. Often boilers are known to be in need of repairs, but the work is put off to a more convenient season. A feed pump refuses to start, and instead of fires being drawn as soon as the water reaches the lowest safe level, a chance is taken that it can be run a little longer. Pressures are sometimes carried higher than reasonable safety would permit, to avoid the expense of larger engines, or better boilers. Boilers are forced beyond a reasonable duty for the heating surface they contain.

This last is a feature that must be reckoned with more in the future than it has been in the past. Many engineers are apparently trying to discover by experiment the limit to the rate of transfer of heat from fire to water through the medium of boiler tubes and plate. In order to show minimum investments necessary and other economies resulting from high rates of driving, some engineers are prone to advise overloads on both engines and boilers, and all seem to overlook the all important question, "Is it safe?"

* Abstract of paper read before the American Boiler Manufacturers' Association, March, 1912.

Boiler explosions also result from neglect or carelessness in operation. Scale and deposit are often allowed to collect in quantities that are dangerous. Connections to water columns are permitted to become stopped. Oil is permitted to enter the boiler with the feed water. Repairs to settings which may affect the safety of the boiler are neglected. Safety valves are not regularly tested to ascertain if they are in operating condition.

Occasionally a boiler owner who discovers his safety valve leaking, with an eye blind to every consideration except the prevention of loss of steam, places a stop valve on the connection to the safety valve or plugs the outlet. A steam gauge registers incorrectly and the engineer overloads the safety valve in an endeavour to make the gauge show the correct pressure. Again, the pressure of steam is not sufficient to produce results desired with the machinery using it, and the safety valve is deliberately made inoperative to overcome the difficulty. All of these conditions have been the cause of boiler explosions in the past and they probably will continue to contribute their share in the future until the steam user is more thoroughly educated in the matter of the risk he runs by such carelessness.

Tube failures, which are chiefly confined to the water-tube type of boiler, are a source of grave concern to the boiler insurance interests on account of the difficulty of guarding against the usual failure of this kind by inspection. A defective weld usually does not show on the surface of the tube, and even where the surface indications would lead to suspicion, a large percentage of the tubes in water-tube boilers are beyond the reach or vision of the inspector. The thorough inspection of tubes before they are placed in the boiler, while very unsatisfactory even taken in connection with the mill test, is about the only protection possible against accidents due to defective tubes.

The seamless tube, of course, will prevent accidents due to defective welding, but tubes made by this process are not always of uniform thickness, and with the cold-drawn product there are apparently internal strains produced by the process of manufacture which sometimes cause the tubes to break when merely heated. If cold-drawn tubes are used for boiler purposes, the annealed stock should be obtained. Hot-drawn seamless tubes are meeting with considerable favour among engineers for boiler purposes.

A considerable percentage of tube failures occur without the slightest evidence as to their cause. A welded tube frequently breaks through the solid metal away from the weld, without being corroded or weakened in any way that may be detected by the eye, and without evidences of overheating.

It is a fact that while pressures and rates of driving have been remarkably increased during the past 15 or 20 years, no increase in the thickness or strength of tubes has occurred. That the thicker tube is safer seems to have been demonstrated by a number of cases where heavy tubes have been put in place of those of standard gauge at the recommendation of the Hartford Company, and tube troubles have ceased.

Of course it can be contended that the theoretical factor of safety is higher on tubes even of standard thickness than on almost any other portion of the boiler. However, under operating conditions accompanying high rates of driving, is it not possible that there are decided fluctuations in the temperature of the material in the tubes? The rapid formation of steam bubbles removes for a certain interval of time the water protection from the inner surface of a tube, and the thinner the material, the higher will its temperature rise during a given time in which it is not protected. It is conceivable that the structure of the metal in a thin tube may be affected in time by this constant change in temperature until it gives out, while the thicker tube might not be affected to the same degree.

The importance of the question of tube failures to the operator of boilers as well as to the insurance interests can be appreciated when I say, as I believe I can conservatively, that the toll of loss of life and limb exacted by such failures probably exceeds other classes of boiler accidents when the relative number of fire-tube and water-tube boilers in use is considered.

A Labour Dispute Settled.—Work was resumed in the new seam at the International Colliery, South Wales, a few days ago, the men accepting the cutting prices offered by the management at the outset.

GRINDING MACHINES.

At a recent meeting of the Institution of Automobile Engineers' a paper on "Grinding" was read by Mr. J. J. Guest. The process of machine-controlled grinding, he said, was now firmly established as a manufacturing operation. Initially the principal abrasive available was emery, an impure form of corundum. Deposits of nearly pure corundum had since been found, and this was the natural material now mostly in use. Artificial abrasives were now produced by the use of the electric furnace, and although their manufacture dated back only a few years, they were used very extensively. The first of the artificial abrasives discovered was carborundum (carbide of silicon), and when crushed into particles for the purpose of wheel making, it fractured into very keen-edged fragments of distinctly crystalline appearance. It would seem to be an ideal abrasive for the formation of wheels. More recent artificial abrasives were alundum and crystolon; the former was used largely, and was probably the best for certain classes of hard steel. The crushed particles resembled those of corundum in the nature of fracture, and were generally of less acute formation than the crushed particles of carborundum. Generally speaking, abrasives differed in hardness, in angle of natural crystallisation, in fracture, in specific gravity, and in resistance to high temperatures. The general cutting power depended upon the hardness and the shape of the edges; the specific gravity affected the speed at which the wheels could be run safely; while it was necessary that a high temperature should not affect them, primarily that they might withstand the heat produced in cutting metal rapidly, and, secondly, that they might not be injured by the temperature (about 3,000° Fah.) employed in making wheels by the "vitrifying" process, which produced the best wheels for most purposes.

The latest development in grinding machines was the automatic steady, which bore on the work with a slight constant force, and moved towards the work as it decreased in size, while a continuous ratchet consisting of a ball moving in a tapering race positively prevented the work from moving back. This arrangement required very little attention from the operator beyond the initial setting, and left him free to attend to the other requirements of the machine. In the author's opinion the modern grinding machine afforded the most economical mode of producing much external work. The efficient wheels and high power of the present-day machine enabled parts in many cases to be manufactured from stampings more cheaply than by any other method.

For internal operations the workhead spindle was now live and had a most important effect on the accuracy and quality of the work, and the grinding spindle presented several points of difficulty, particularly when it was to be used on small work. Unless the grinding spindle end carrying the wheel overhung from its bearings by at least the depth of the hole to be ground, the space for the wheel-end bearing of the spindle was very much circumscribed. This rendered difficult the adjustment arrangement, dust protection and lubrication of the bearings, as also the water supply if the machine ground wet. In the case of small holes, these difficulties led to the employment of overhung spindles, and in turn this introduced the difficulty that, as the spindle must be small in diameter so that the bearings did not give trouble owing to the high speed of the spindle necessary to give a reasonable speed to the circumference of the wheel, the overhung part of the spindle was apt to be springy. It also multiplied, by its overhang, the effect of any defects in the bearing. The length of the hole which it was possible to grind commercially was therefore very limited.

The high speed of grinding machines necessitated very considerable accuracy in the workmanship of the parts, and of the spindle especially, if the apparatus was to run well. To minimise the effect of errors the spindle was frequently made in two parts connected by a double tongue, or the part of the spindle connecting the two journals was made sufficiently thin to be flexible. For the smaller machines, ball-bearing spindles had been experimented with; the spindle could then be overhung from the bearing without incurring the danger of spring in the spindle itself.

As the art of grinding now stood, it afforded the best means of manufacturing some machine details when regard was had to cheapness of production only, of very many when quality and cheapness were considered, and for some details it was a necessary process. The advance which had been made from the stage where grinding was a costly operation, only used where unavoidable or extremely desirable, to the stage where it was in competition with other means of production on the matter of cost only of the product, and where it gave the added qualities of finish and truth of product, had resulted in changes of design of the product, and enabled parts to be made of harder quality or of hardened steel where previously they had been soft, and had enabled bearings to be reduced in size owing to the surfaces produced being closer to the geometrical surface desired. With increasing precision of its parts, the speed of a machine might frequently be increased without troubles from noise and vibration, and with the increase of speed, when the question was one of power and not of force transmitted, the parts might be reduced in size a little further.

These differences of design were not only due to the maker, but also to the user of the machine, who by his demands turned the newer design into the necessary one. In considering the advisability of grinding instead of machining parts in other ways, these points were to be considered—for although the cost of a detail part was always a consideration, yet the product had to be sold, and the user was to be considered at each step. The process had proved to be one of increasing economy, and therefore it was certain that the demand for improved machines, and for the machines now beginning to be used for flat and form grinding, would repay the efforts of the pioneers in these lines, and thus lead to growth of the process.

MANUFACTURE OF ACCURATE SOFT METAL CASTINGS IN METAL MOULDS.

The extensive use of die-castings at the present time, many of them for purposes where a good ordinary casting would answer, perhaps, were it cast in an accurate mould, has brought to mind the fact that there are many instances in which metal castings can be employed with excellent results where now either brass castings with expensive machine work on them or die castings are used.

The soft metals used for casting in metal moulds are of three kinds: (1) Alloys with tin base. (2) Alloys with lead base. (3) Alloys with zinc base.

The alloys with the tin base are known by the name of babbitt-metal, britannia-metal, and often pewter. They are the best for many classes of work. While they are costly, they are strong and give good castings. For ordinary work, where good casting qualities are desired the following mixtures can be used:—

Tin	95 per cent.
Antimony	4 per cent.
Copper	1 per cent.

The alloys with the lead base are the cheapest and can be used for a large variety of work. They cast very well and do not shrink but very little. These alloys are usually known under the name of "antimonial-lead" and where the strength is sufficient, they will be found very satisfactory. The most common alloy used for casting in metal moulds is the following:—

Lead	87 per cent.
Antimony	13 per cent.

If it is found, however, that this mixture does not run sufficiently free, then tin can be added as follows:—

Lead	80 per cent.
Tin	10 per cent.
Antimony	10 per cent.

The tin in the mixture will cause the metal to run very sharp and free and it can be used for the finest kind of detail.

As for the zinc alloys, let it be said that they are not particularly suited for casting in metal moulds unless pressure is used. The sluggish nature of zinc will prevent it from running into thin sections and taking a sharp impression, unless pressure is used. It may be used for large castings, such as bearings, but even with such castings, the results, without the use of pressure, are not good. It is advisable, therefore, to confine the manufacture of metal castings to alloys with the tin or the lead base. These will be found suitable for many classes of work.

The use of steel cores in making soft metal castings is a matter that should be investigated by those who desire to use this kind of work. When employed, it is possible to make a very strong and accurate casting, and with little difficulty the

steel cores are made on automatic machines at a small expense. Brass, copper, or bronze cores may also be used if desired. The advantage of using them will be fully appreciated when it is realised that frequently both the advantages of screw machine work and die castings can be obtained. In ordinary die castings, the weakness of the metal is the main objection, but by casting the core in the mould, a strong casting is obtained.

In casting the metal, the whole mould, cores and all, should be warm, but not hot. If cold, the metal will not run well, and if too hot, the castings will shrink unevenly. The arriving at the right temperature is a matter that requires more or less skill, but the operator soon acquires it with a little practice. As the mould is constantly increasing in temperature when used, it is cooled by frequent immersion in water. The cooling, however, is not allowed to go on too much or the mould will become stone cold and the water will not evaporate from the surface. The idea is to cool the mould a little so that the metal will run well, but still not so much as to prevent the water from evaporating. When properly done, the water remaining on the surface after the mould has been removed, will almost immediately evaporate from the metal, leaving the mould in condition to cast metal in at once.

The making of the mould itself is a matter that requires more or less skill. In the first place, bronze is almost exclusively used for the purpose. Cast iron is too hard to cut and a smooth mould is very difficult to make out of it. The metal, too, is apt to be porous and full of flaws. Cast iron, except for large and rough moulds, is never used. Steel is coming into use for some classes of work on account of the fact that the surface can be made very smooth and there is less danger, when the mould becomes hot, of the metal adhering to it. The cost of a steel mould, however, is excessive, as it necessitates cutting the mould from a solid block.

The bronze moulds have been found the most satisfactory and, as previously mentioned, are almost exclusively used. They can be cast soundly and almost in the finished condition. The natural softness of the metal allows chasing without difficulty so that the castings will come out in a practically finished condition. It must be taken into consideration that unless the surface of the mould is smooth, the castings will not come out in any better condition. This fact explains why steel moulds have been used. The surface, when polished, allows castings to be made with a practically polished surface so that no finishing at all is required.—"The Brass World."

Flux for Soldering Aluminium.— The difficulty of soldering aluminium is due to the fact that aluminium is very readily oxidised at high temperatures, and the formation of oxide is the chief obstacle in soldering. Mr. Otto Nicolai, of Boppard-on-Rhine, has invented a flux which combines with alumina to produce a compound which remains fluid in soldering and completely counteracts the effect of the oxide. The Nicolai process can be employed with aluminium bronze, and is in current use at the arsenal of Friedrichsort. It is not only suitable for aluminium, but also for all the aluminium alloys, such as magnalium, or for zinc, copper, nickel, iron, and steel.

Characteristics of Aluminium Conductors.— Some interesting information relating to aluminium conductors is contained in a bulletin recently issued by the National Electric Light Association, New York. Some of the physical constants of aluminium as now manufactured commercially for electrcial purposes are as follows: Melting point, 1,157° Fah.; elastic limit, 14,000lbs. per square inch; ultimate strength, 26,000lbs. per square inch; modulus of elasticity, 9,000,000; electrical conductivity, 62 per cent.; specific gravity, 2·68; coefficient of linear expansion, 0·0000128. At present aluminium is used only to a limited extent for large conductors owing to the difficulty of employing the ordinary methods of soldering. The weight of a length of aluminium wire is only 47 per cent. of that of a copper wire of the same length and resistance. Expansion and contraction with changes in temperature are greater for aluminium than for copper. A solid wire of small size gives a great deal of trouble through breakage due to crystallisation of the wire from swaying in the winter. The greater expansion and contraction make it necessary to be especially careful to avoid stringing lines too tightly in warm weather. The increased sag necessary for aluminium makes the liability to crosses unduly high. Joints between copper and aluminium wire give a great deal of trouble due to electrolytic action.

INDUSTRIAL AND TRADE NOTES.

Shipyard Wages.—The joint trades in the national shipyard agreement have made application for an advance of 5 per cent. in wages, and the claim will be considered at a grand conference to be held at Edinburgh on Wednesday, May 22nd.

International Exhibition of Non-ferrous Metals. — In consequence of the dislocation of business occasioned by the coal strike, it has been decided to postpone the exhibition for a few weeks, and it will now be held from Saturday, June 15th, to Friday, June 28th, inclusive.

Proposed Extensions at Palmer's Shipbuilding Company. — It is reported that the Palmer Shipbuilding Company propose to carry out important extensions to their rolling mills and steel works department. This will include the laying down of the latest plant and machinery, and the output will be greatly increased, and, in all probability, find work for a large number of additional employés.

Apprentices in Shipyards. — The Central Conference, which was held in Edinburgh on the 8th inst. between representatives of the Shipbuilding Employers' Federation and the Boilermakers' Society failed to effect a settlement of the dispute over the organisation of apprentice boilermakers, and further discussion of the subject was adjourned to a Grand Conference, at which all the shipyard unions which are signatories to the National Agreement will be represented. The date of this conference has not yet been fixed.

Dates of Operation of the New Mines Act.—The Home Secretary has informed the Mining Association of Great Britain that he cannot see his way to postpone the date on which the Coal Mines Act of last year is to come into force. He recognises, however, that the interruption in the work in the mines due to the strike may make it difficult to complete the structural alterations required under the Act by July 1st, and the inspectors will, under the circumstances, allow a reasonable time for these to be carried out.

Industrial Development of Canada.—Arrangements have, we learn, just been completed for the visit to Canada, at the end of the present month, of from 80 to 100 of the leading manufacturers of Great Britain, with the view to ascertaining the opportunities that exist in the Dominion for the establishment of branch factories, the openings for capital in industrial undertakings, and the possibilities of extending the market for British made goods. The party will visit every important industrial centre of the Dominion.

Demarcation in Shipbuilding.—The trade unions in the shipbuilding and engineering industries are now taking a ballot of their members on the question of accepting the national demarcation agreement which was drawn up early this year between representatives of the societies and Shipbuilding and Engineering Employers' Federations. The vote will not be completed until about the end of June, as several of the societies are balloting at their June branch meetings. If the agreement is accepted it will come into operation at July 1st.

Demarcation Dispute.—A demarcation dispute has arisen between the platers and the sheet iron workers in the shipbuilding yard of Messrs. John Brown & Co., Clydebank. It seems that the platers object to the sheet iron workers handling plates beyond a certain thickness, and on that account they left their employment on Thursday afternoon, the 9th inst. They afterwards held a meeting to consider the matter, as a result of which they appointed a deputation to lay their grievances before the management. The platers returned to work on Friday last pending a settlement.

Light Railways Bill.—A meeting of the Standing Committee of the House of Commons on this Bill was held on the 9th inst., when Mr. H. Lawson moved a new clause having the effect of excluding London from the trackless trolley system proposals of the Bill. He said that if there was any demand for the system in London a private Bill for it could be promoted in the ordinary way. Mr. J. M. Robertson, Parliamentary Secretary to the Board of Trade, accepted the amendment, and it was agreed to. It was also decided that the licensing of car drivers and conductors on trackless trolley routes should be in the hands of the local authorities.

Renewal of the German Steel Works Syndicate.—With reference to the proposed renewal of the German "Stahlwerksverband" (Steel Works Syndicate), H.M. Consul-General at Dusseldorf reports that the syndicate has been renewed for five years from May 1st as regards the "A" products, *i.e.*, half finished iron goods, railway materials, and shaped iron. With regard to the "B" products no agreement could be arrived at, and therefore the following goods have been excluded from the syndicate, viz., rod iron, roll wire, pig iron, railway axles, &c. The disagreement

with regard to the "B" products was caused by the large number of new works erected during the last five years, which specialise in certain goods and therefore want to keep a free hand. H.M. Consul-General adds that he is informed that the change will not make very much difference, as the "A" products are the more important.

Malleable Iron Makers Combine.—The proposal put forward some time ago of amalgamating the whole of the malleable iron concerns in the West of Scotland, has now practically been carried out. Many of the firms in the Coatbridge district had some sort of an agreement to regulate minimum selling prices, but this understanding broke down last year, and a ruinous kind of competition ensued. At last 13 concerns, operating 15 works, have agreed to come together in one new company, to be styled the Scottish Iron and Steel Company, Ltd. The present combined output of these firms is about 250,000 tons per annum of hoops, strips, and shapes.

Electrical Undertakings.—According to Garcke's Manual of Electrical Undertakings," there are in the United Kingdom at the present time 1,417 electrical undertakings, with a capital of £423,726,470, as against 1,369 undertakings and £404,700,552 in 1911. The totals for the current year are made up by telegraphs, 32 undertakings, with £36,201,846; telephones, 17 companies, with £15,428,775, and four municipalities, &c., with £11,286,666; supply, 261 companies with £52,532,060, and 320 municipalities with £45,704,059; traction, 190 companies with £165,546,429, and 173 municipalities with £45,903,038; manufacturing, 257 firms with £44,766,619; and miscellaneous, 163 concerns with £6,356,978.

Working of the Patents Act.—In the House of Commons a few days ago the Chancellor of the Exchequer was asked if he would give the latest figures for each year, showing the result of the operation of the Patents Act, 1907. The President of the Board of Trade, replying, said that Section 27 of the Act, which relates to the revocation of patents in certain cases, became operative on August 28th, 1908, since which date there have been 82 applications for revocation, one of which has not yet been decided. As a result of these applications 19 patents have been revoked. There is no official information available with regard to the extent to which the fear of revocation under this section has led to the establishment of new works in this country, or the employment of additional capital or workpeople in manufacture.

United States Output of Steel Ingots and Castings in 1911.—The bulletin of the American Iron and Steel Association of May 1st publishes the following particulars of the production of steel ingots and castings in the United States in 1911, as compared with the two previous years:—

—	Bessemer.	Open Hearth.	Crucible, and all other.	Total Ingots and Castings.	Total Castings alone.
	Tons of 2,240lbs.	Tons of 2,240lbs.	Tons of 2,240lbs.	Tons of 2,240lbs.	Tons of 2,240lbs.
1909	9,330,783	14,493,936	130,302	23,955,021	656,242
1910	9,412,772	16,504,509	177,638	26,094,919	946,832
1911	7,947,849	15,598,650	129,002	23,675,501	646,022

British Iron and Steel Production in 1911.—The British Iron Trade Association has published the following statistics relating to the production of iron and steel in Great Britain during the year 1911: The pig iron production (9,718,638 tons), while being greater than in any year prior to 1910, was 498,107 tons less than in that year. The production of Bessemer steel ingots last year fell to below the amount recorded for 1910, being 1,461,140 tons. Open-hearth steel ingots, on the other hand, showed the highest production on record for the country, or 5,000,472 tons, the previous highest figure being recorded in 1907, when the production of this class of steel totalled 4,663,489 tons. The advance last year on the 1910 production was 405,106 tons. Puddled iron showed the highest figure since 1899, being 1,191,499 tons, as against 1,118,893 tons in 1910, 1,129,412 tons in 1909, and 1,201,609 tons in 1899.

Steam Navigation: Centenary Exhibition in Glasgow.—In connection with the celebration of the inauguration of steam navigation, the Corporation of Glasgow has authorised an exhibition to be held in Kelvin Grove Museum from July 1st to December 31st, illustrating the history of the application of steam to marine propulsion. It is hoped that a comprehensive and authentic collection, illustrative of the early and experimental stages of the steamboat, will be laid before the public, and with this object in view a prospectus has been drawn up showing the extensive character of the proposed exhibition. The Organising Committee invite the co-operation of persons or firms who possess models, relics, portraits, &c., appropriate for their purpose, and request particulars of such specimens as could be had on loan to be sent to Mr. James Paton, superintendent, Art Galleries and Museum Kelvin Grove, Glasgow.

Mining Examinations.—In pursuance of the provisions of Section 8 (1) of the Coal Mines Act, 1911, the Home Secretary has appointed the following persons to be members of the Board for mining examinations: Mr. Frank Brain, Mr. John Gemmell, Mr. Samuel Hare, Mr. A. H. Leech, Mr. G. Alfred Lewis, Mr. Evan Williams, as representatives of owners, or agents of mines, or managers of mines, or mining engineers; the Right Hon. Chas. Fenwick, M.P., Mr. Enoch Edwards, M.P., Mr. J. G. Hancock, M.P., Mr. Thomas Richards, M.P., Mr. Stephen Walsh, M.P., Mr. Robert Smillie, as representatives of workmen employed in mines; Mr. R. A. S. Redmayne, H.M. Chief Inspector of Mines; Dr. W. N. Atkinson, I.S.O., H.M. Divisional Inspector of Mines for the South Wales District; Mr. W. Walker, H.M. Divisional Inspector of Mines for Scotland; Dr. J. S. Haldane, F.R.S., and Prof. S. Herbert Cox, as persons eminent in mining and scientific knowledge.

Coal Exports in 1911.—A Board of Trade White Paper just issued shows that the total exports of coal from the United Kingdom during 1911 amounted to 64,599,266 tons, as compared with 62,085,476 tons in 1910, 63,076,799 tons in 1909, 62,547,175 tons in 1908, and 63,600,947 tons in 1907. Nearly half the coal was exported at from 8s. to 11s. per ton. As a result of the strike coal shipments for the first four months of this year show an immense fall. In all, there have been sent abroad from the ports of the United Kingdom 13,967,000 tons of coal, and with coke and patent fuel 14,651,000 tons. This is 6,257,000 tons less than in the same months of last year. There were also shipped in foreign going steamers 4,893,000 tons of bunker coals, making the total sent out of coal, &c., 19,546,000 tons, or a reduction of more than 7,500,000 tons in coal and other fuel in the four months. The value of the coal is slightly higher per ton.

Boilermakers' Society.—In the May report of the Boilermakers' Society, the General Secretary, Mr. John Hill, states that the membership of the union is now 57,000. In addition, there are now organised over 5,000 apprentices. The balance at the end of the year was £172,564. The output of shipbuilding is increasing month by month, and there is work sufficient to employ all the members for another year. In reference to the proposed amalgamation of the Boilermakers' Society with the Shipwrights and Ship Constructive Association and federation with the Liverpool Shipwrights, the voting of the branches had been as follows: For amalgamation with the Shipwrights' Society 4,379 votes, against 1,247, majority in favour 3,132; for federation with the Liverpool Shipwrights, 4,766 votes, against 806, majority in favour 3,960. The Executive Council are also moving towards amalgamation with the Amalgamated Society of Engineers. A number of joint meetings with them have been most successful.

Electric Cranes.—We have received from Messrs. Babcock and Wilcox an illustrated booklet showing the various types of electrically operated cranes constructed by them for transporters, furnace charging machines, capstans, winches, and other lifting and hauling appliances. The cranes are manufactured at Renfrew, Scotland, where the firm has a special department equipped with the most modern and up to date machinery for the economical production of high-class cranes and similar work, and ample facilities for fully testing all such plant before it leaves the works. In all the cranes the practice is to cut the teeth of the gear wheels from solid blanks, and to grind by automatic machinery the journals of the shafting to ensure a perfectly true bearing surface. A very elaborate and efficient system of gauging has been adopted for the manufacture of the mechanical parts, and standard crane parts are kept in stock, so that, in case of need, replacements can be quickly dispatched.

Smoke Nuisance: Prosecution of a Bradford Firm.—At the Bradford City Police Court on the 9th inst. the Stipendiary Magistrate delivered judgment in a prosecution by the Bradford Corporation of Messrs. Daniel Illingworth & Sons, worsted spinners, for smoke nuisance. The Stipendiary Magistrate observed that the substantial cause of the emission was that the defendants were driving their machinery with insufficient power, and they knew that until they increased their engine power unconsumed smoke would continue to issue from their furnaces. That circumstance excluded the defendants from the protection of the exemption portion of the statute. It was not alleged by the prosecution, however, that the new plant which was being installed would be otherwise than efficient in remedying the emission of smoke, nor that there had been any unavoidable delay on the part of the defendants. Having regard to the extenuating circumstances under which the offence was committed, it was inexpedient to inflict any punishment. He accordingly made an order dismissing the summons. The Stipendiary Magistrate declined to make an order as to costs, in view of the fact that the Act had been broken.

Municipal Exhaust Steam Installation.—To cope with the increasing demands from power and lighting consumers, the West Hartlepool Corporation some time ago decided to extend their electricity undertaking, and obtained sanction from the Local Government Board for the borrowing of £38,000. An agreement was entered into with the Seaton Carew Iron Company, Ltd., whose works are within the Borough of West Hartlepool, for the utilisation by the municipal authority of the exhaust steam from the blowing engines and the waste gases from the blastfurnaces. The first portion of the scheme will be to utilise only the exhaust steam, and for this purpose two mixed-pressure turbines, each of 1,250 kw. capacity and generating at 6,000 volts, are to be installed at the blastfurnaces. The contract for these has been placed with Messrs. Richardsons, Westgarth, & Co., of Hartlepool, who will also supply the Siemens alternators and all necessary condensing plant, cooling towers, &c. The existing municipal power station in Burn Road, West Hartlepool, will become the main town sub-station and will be provided with rotary converting plant, whilst the present steam plant will be held in reserve as a stand by for the town direct-current supply. The rotary converter for this and for other sub-stations will be supplied by the British Westinghouse Company.

Rescue Work in Mines.—With respect to the Order made by the Home Secretary and published recently concerning the formation and training of rescue brigades and the supply and maintenance of appliances for use in rescue work in coal mines, the Home Office has just issued a circular giving details of the course of training approved by the Secretary of State. The Order is to come into force at once, and therefore it will be necessary for each mineowner to take steps without delay to comply with its requirements. Reasonable time, says the document, will be allowed in which to complete the formation of the brigades and to obtain the requisite supply of breathing appliances, certain of which may in certain circumstances be discharged by the affiliation of the mine to a central rescue station. The circular goes on to state that where oxygen breathing apparatus is used care must be taken to ensure a high standard of purity in the oxygen, and supplies, unless guaranteed by the manufacturers, should be tested by analysis. The course of training approved by the Secretary of State will consist of practices with breathing apparatus in a gallery so constructed as to represent the conditions existing in a roadway of a coal mine, and shall extend over three consecutive months. There shall be at least one practice a week, the first to be carried out in a respirable atmosphere, and subsequent practices in an irrespirable atmosphere. Each practice shall last at least two hours. A record will be kept of each person undergoing training, and the date and character of each practice attended.

Government Enquiry into Industrial Unrest.—The recent industrial disturbances and the methods of preventing them were discussed in the House of Commons a few days ago. The Chancellor of the Exchequer, discussing the suggested remedies, said he was not quite sure that nationalisation would put an end to strikes. He did not object to the nationalisation of railways. There was a good deal to be said for it from the point of view of traders and the country generally. Lord Robert Cecil had raised the matter of co-partnership. He personally would not rule it out as a subject for enquiry, and he hoped Lord Robert would place his views before the Cabinet Committee which was to enquire into the subject of unrest. Nationalisation of the railways was a question which ought to be considered on its merits. It ought to be considered as a business proposition, and he thought it was well worth considering as such. He thought it was worth while the railway companies examining it, because they could not go on with the present wasteful system of expenditure, which did them no good and imposed a heavy burden on the community. The Cabinet had come to the conclusion that the subject should be examined into, and they were conducting an enquiry. Whether it would be necessary to have another and more searching enquiry was a matter they would have to come to a conclusion upon. In the meantime they were looking into the matter. What conclusion they might come to it would not be fair to indicate now. They could not, upon the facts in their possession at the moment, come to reliable conclusions without further enquiry. Co-partnership was in an experimental stage, and it was a matter on which they ought not to come to a hasty conclusion.

The British Engineers' Association.—This association was formally incorporated on April 26th last under a license from the Board of Trade. The organisation was undertaken by 22 of the best known engineering firms in Great Britain. Altogether, previous to incorporation, over 60 members were elected, and there are a number of other applicants for election. During the period of organisation the association was controlled by a powerful committee of the promoting firms, but as soon as the first general meeting has taken place a president, vice presidents, and other members of Council will be elected from all the members. The aim of the association is not to serve the interests of any individual firm or clique of firms, or to carry on trade in any way, but to establish itself as a great national organisation for the promotion on the broadest lines of the overseas interests of the British engineering industry. Its intention is to employ the great collective influence vested in the engineering industry to encourage the British Government, financial organisations, shipping companies, merchants, and others to promote the interests of British engineering throughout the world in the same manner as the interests of our foreign competitors are promoted by their Governments and other bodies. The efforts of the association will in the first place be directed to China. In that country, especially in view of the new régime, the organisation and strengthening of British engineering interests is urgently needed. The technical education of Chinese engineers on British lines and in the English language will be encouraged. Mr. Stafford Ransome is the secretary pro tem., and the temporary office is at Queen Anne's Chambers, Westminster.

Co-partnership in Industry. — The 26th annual meeting of the Labour Co-partnership Association was held on Thursday last week in London. The president, in his inaugural address, said that the events of the past year had forced the nation to realise that it was necessary to set its industrial house in order, with a view to preventing a recurrence of the experiences which, if they were repeated on any sufficiently frequent scale, would gradually reduce this country to an intolerable condition of insecurity, poverty, and despair. He did not claim that co-partnership principles could be at present universally applied, for their successful application depended on the moral and mental standard of employers and employed. But he did contend that wherever co-partnership principles were applied under right conditions the cost of production would be lessened and the possibilities of profit increased, to the great benefit of the capitalist, the worker, and the consumer. The great fact was that labour and capital were organised in opposing camps, with the object, not of promoting the common well-being of all connected with industry, but of securing advantage for themselves. The capitalist was inclined to give the minimum that was necessary to secure the labour which he required, and the worker in return considered that all that should be required from him was the minimum of labour which would save him from dismissal. If they wished to maintain the old friendly relations between the employer and employed then they must establish business on lines which would automatically create a feeling of loyalty on the part of all connected with the industry. How was that to be done? By co-partnership—which was a system under which worker and consumer shared with capitalists in the profits of industry.

Turbo-Alternators for the Argentine.—Two 3,000 kw. turbo-alternators have been ordered from Messrs. C. A. Parsons & Co., Newcastle-on-Tyne, by the River Plate Electricity Company, Ltd., for their power station at Ensenada, where the present plant, consisting of two 1,500 kw. Westinghouse turbo-alternators, has become inadequate to meet the demand for current. The new turbines, each driving its own alternator, are to be placed side by side and arranged so that the steam passes from one to the other in series. Under normal full-load conditions the first turbine will expand the steam from 155lbs. per square inch absolute down to about 15lbs. absolute, while the remainder of the expansion will be carried out in the low pressure turbine. The two when run together will thus form one complete 6,000 kw. unit, but the pipes and connections will be so arranged that the high pressure turbine can exhaust either direct to the condenser or to atmosphere when the low pressure one is being overhauled, or the latter can be run alone with the help of a reducing valve. This arrangement is flexible and economical, practically all the advantages of the larger plant being obtained, while the cost of spare parts is considerably less, and the chance of both units being out of commission simultaneously is exceedingly remote. The surface condenser, complete with Parsons vacuum augmenter and motor-driven air pumps, is to be capable of dealing with all the steam at 20 per cent. overload, with cooling water at 70° to 80° Fah. The alternators are three phase, and are to be each capable of giving a normal full load of 3,000 kw., 0.8 power factor, 5,500 to 6,000 volts, 50 cycles, 1,500 revs. per minute, as well as an overload of 20 per cent. for two hours. The temperature rise is guaranteed not to exceed 60° Fah. after six hours' run at full load, unity power factor. Each alternator has its own exciter which, however, is large enough to provide current for both units.

British Westinghouse Company.—The annual meeting of the British Westinghouse Electric and Manufacturing Company, Ltd., was held on the 9th inst. in London. In moving the adoption of the report and accounts, the Chairman referred to the loss

of £36,719 on the sale of the plant and apparatus in the steel foundry, and explained that, in view of the general reserve for depreciation of over £50,000, the directors did not think it necessary to depreciate specifically against this loss. As he had said before, the works were originally designed on too large a scale in many respects. When the capital was reduced in 1907 a large provision was made to meet this, but, in view of what had since happened, it had for some time been the opinion of the Board that before the company could enter upon a dividend paying stage there must be a further reduction of capital. Proposals to that effect would probably soon be presented. The gross trading profits for the year amounted to £126,144, as against £112,539 in 1910, an increase of £13,605. The net profit was £20,708, as compared with a profit of £12,437 last year, and a loss in 1909 of £798. Orders were coming in well, and, barring unforeseen circumstances connected with labour unrest, the directors hoped the next accounts would show a still further improved position. A shareholder having asked for further information respecting the projected reduction of capital, the Chairman directed attention to the action at law pending between the company and the Underground Electric Railways Company. If the decision of the House of Lords confirmed that of the arbitrator and the Courts below, the company might, he said, have to pay £120,000. Should that prove to be the case it would be a long time before they could pay dividends, because this loss would first have to be met. They would reach a dividend-paying stage more quickly if the capital was reduced.

Trade Circulars and Catalogues.—We have received from Messrs. Schäffer & Budenberg, Ltd., Whitworth Street, Manchester, several supplementary sections to their voluminous catalogue of gauges of all kinds, in addition to a new list of gauge-testing apparatus, in which we observe several novelties.—Messrs. Wailes, Dove, & Co., Ltd., Newcastle-on-Tyne, send us a little booklet illustrating numerous installations to which their patent bitumastic solution, in one or other of its various preparations, depending upon the nature of the work, has been applied.—Messrs. D. Bridge & Co., Ltd., Castleton, Manchester, forward us a new sectional catalogue they have just issued, dealing with friction clutches, hauling plants, and mill gearing installations generally.—From Hans Renold, Ltd., Brook Street, Manchester, we have received a copy of a new catalogue, dealing fully with their steel block chains more particularly used for elevating, conveying, and feeding purposes. The catalogue illustrates the various applications of the chain, and, in addition to particulars and dimensions, gives some useful hints on the choosing and the laying out of this kind of transmission gear.—Messrs. Mansfield & Sons, Ltd., Hamilton Square, Birkenhead, forward us an illustrated booklet dealing with the application of their gas producing plants for villages and small towns, for lighting, cooking, and heating purposes. The producers are adapted for making gas from any kind of oil, mineral, animal, or vegetable, and, it is claimed, it is permanent and will not condense, while it is at the same time of a high illuminating power.—Messrs. The Harris Patent Feed Water Filter, Ltd., Newcastle-on-Tyne, send us circulars describing their water softening and purifying plants and condenser-tube corrosion protector.—Mr. John Jardine, Deering Street, Nottingham, sends us particulars of a new type of detachable coupling for shafts which he is introducing, and which possesses some very convenient features. It is made in both split-muff and solid muff designs, and well deserves the attention of all mill managers or engineers who have to deal with power-transmission plant.—The Parsons Motor Company, Ltd., Southampton, send us a very full catalogue of their petrol and paraffin engines, which are designed for both stationary and marine work.

British Iron Trade Association.—The annual meeting of the British Iron Trade Association was held in London on Friday last. Mr. Parkes, who presided, devoted his remarks to the matter of labour unrest. There could be no doubt commerce had entered upon a new phase, and they, as large employers of labour, had to enquire what would be the outcome. He had seen it suggested that elimination of competition might meet the case, but he believed competition was bound to increase in severity, and to try to disregard or evade it would be to go back 100 years in the history of the country's commerce. It was the life and soul of progress. What he feared was that people who discussed these questions disregarded the inexorable laws of economics, because neither employers nor men could long hope to hold out a position in defiance of economic laws. His view was that there need not necessarily be disagreement between employers and employed, whatever grievances either might have. Strikes paralysed trade, were barbaric and absurd, and inevitably inflicted more harm upon workers than upon any other class of the community. There was no real need for capital and labour to be at daggers drawn, a fair and square discussion of their difficulties face to face would generally remove or mitigate them. Some sort of sliding scale or system of profit sharing commended itself to him in order that workers should participate in any rise or fall in the prosperity of their employers. Failing some such solution the trade of the country was in great jeopardy. Capital was being frightened away, and shoals of the best workers were emigrating. He hoped the Government would take the matter up and endeavour to secure some reasonable means of settling disputes. Sir John Randles said sliding scales were largely in force in the North of England, and fluctuations in wages and in prices generally were practically regulated by the price of pig iron. The difficulty in dealing with the workers was that they occasionally got out of hand. Mr. Skelton reported that, on behalf of the association, he attended the International Committee to consider the question of adopting an international standard for exported steel. He was convinced that any change would be in the direction of lowering the high British standard of quality and workmanship, and to that he would never be a party. The annual report, which was unanimously adopted, recorded an appreciable increase in the output of open hearth steel, but a decrease of 500,000 tons in pig iron. The report also referred specially to industrial unrest, and said that, although the general outlook in the steel and iron trade seemed promising the future was fraught with menace unless the methods of arbitration and arrangement happily prevalent in the iron trade could be more generally extended to other industries.

Turbine Pumps.—Messrs. Mather & Platt, Ltd., Salford Ironworks, Manchester, have issued a new catalogue of their turbine pumps, a type of pump in which they have for some years been specialising. The adaptability of turbine prime movers to the direct driving of electric generators and other forms of rotary machines is now widely recognised, and its rapid application in the last few years to pumping operations is causing it to take the lead over reciprocating types in many directions. At the present time the use of the turbine pump has been so extended that it is difficult to find services to which it will not advantageously apply. Although the wide development of the turbine pump in recent years is undoubtedly due to the advent of the high speed motor, it was first introduced before the possibility of direct driving in this manner was foreseen. The first patent for a turbine pump was taken out by Prof. Osborne Reynolds in the year 1875. Immediately following this, Mather & Platt built the first Mather-Reynolds turbine pump for the Owens College, Manchester, which pump is still in work. Another of these pumps, but with vertical spindle, is at work in Russia in an artesian well 100ft. deep. This is belt driven through bevel gearing and a vertical shaft, and from the time of its installation, some 13 years ago, has only once been brought to the surface for examination. The modern turbine pump is a more efficient form of the ordinary and well known centrifugal pump, and consists of a revolving vane or impeller, similar to that of a centrifugal pump, but discharging into one or more correctly designed passages arranged around the circumference, the object of which is to receive the water or liquid delivered at a high speed from the impeller, and gradually to reduce its speed until it is converted into an equivalent pressure head. These stationary guide passages conduct the water without loss to the delivery outlet, or in the case of a multiple impeller pump, to the eye of the succeeding impeller. These pumps are made in single and multiple chamber types. In the former the required pressure is obtained by means of a single impeller and guide ring, whilst in the latter, the total pressure is the sum of the pressures obtained by several such units working in series. All multiple chamber pumps develop an hydraulic axial end thrust which requires to be taken up, and the manner in which this is done determines the reliability of the pump under working conditions. In the Mather & Platt pump this thrust is balanced by an improved hydraulic balancing arrangement, automatic in its action, requiring no thrust bearings of any kind. The experience gained during a period extending over 30 years of the application of turbine pumps to all classes of work has enabled the firm to effect radical improvements in design to obtain the highest efficiency, and to ensure thorough reliability of action. These pumps have actually been built for quantities up to 15,000 gallons per minute, for heads up to 1,600ft., and for speeds up to 3,000 revs. per minute.

Wireless Installation at Liverpool University. — Sir William Hartley has presented a complete installation of plant for wireless telegraphy to the Liverpool University. Time and weather messages are received morning and night from the Eiffel Tower in Paris. Professor Marchant proposes to give a course of lectures for the benefit of ships' captains and others.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Rotary internal combustion engines. Haubner. 1627.
Apparatus for analysing gases. Sanders & Sanders, Rehders, and Co. 1683.
Cross slides of lathes of the turret type. Austin. 9379.
Power driven hammers. Bradley. 9380.
Carburetting apparatus. Kelly. 9421.
Valve springs for internal combustion engines. Salmson, Canton, & Unné. 9451.
Internal combustion engines. Griffin. 9498.
Gear trains particularly applicable for hoisting apparatus. Shepard. 9517.
Motor for transmitting to a distance continuous or intermittent angular movements. Spalazzi. 9555.
Rotary elevators. Smith. 9583.
Treating peat for the production of fuel. Anderson & Hippius. 9657.
Variable speed and balance gearing. Materikin & Serguieff. 9752.
Centrifugal pumps and fans. Watson & Billetop. 9789.
Method and means of storing heat and the liberation and utilisation of heat so stored. Bastian. 9794.
Method of manufacturing ribbed tubes. Calvert & Cardell. 9810.
Miners' safety lamps. Best, Ponsonby, and Best's Contract Company. 9847 and 9848.
Two stroke cycle internal combustion engines. Lanchester. 9873.
Raising and forcing of liquids. Akt.-Ges. Brown, Boveri, et Cie. 9937.
Sand mould jarring machines. Chipchase. 9955.
Hydraulic transmission apparatus. Hele-Shaw & Martineau. 10039.
Lubricating systems. Boult. 10168.
Safety suspending apparatus applicable to mine cages. Fairweather. 10202.
Machinery for marine propulsion. Alquist. 10374.
Steam power plants in which a turbine is driven by the exhaust from a steam engine. Golder, Kubler, Woollatt, and Fraser and Chalmers, Ltd. 10941.
Driving mechanism of automobiles. Austin Motor Company and Austin. 11575.
Rotary engine. Burns & Burns. 12238.
Steam superheaters and feed water heaters for locomotive boilers. Marks. 12468.
Liquid fuel supply arrangement of internal combustion engines. Higginson & Arundel. 12835.
Muffle furnaces. August. 13016.
Ships' propellers. Sayers. 13453.
Automatic railway coupling. Davis. 13639.
Nut locks. Johnson. 13649.
Balance weights employed in internal combustion engines. David Brown & Sons (Huddersfield), Ltd., and Burgess. 14539.
Elevators or conveyers. Donald & Matthews. 14713.
Railway signalling apparatus. Bosson. 15199.
Elevators or conveyers. Matthews, and Rowinson, Drew, & Clydesdale, Ltd. 15822.
Governing mechanism for elastic fluid turbines. Warwick Machinery Company (1908). 16638.
Manufacture of cores and moulds for casting purposes. Kurze. 16734.
Surface condensers. Oddie. 16896.
Blades for fans, ventilators, and propellers. Ewart. 17133.
Apparatus for raising and forcing liquids. Koerver. 17283.
Method of and apparatus for operating the injection valve of a Diesel engine by hydraulic pressure. Gunther. 17446.
Steam superheaters for locomotive boilers. Robinson. 17508.
Machine for testing the brittleness of metals. Guillery. 17705.
Friction clutches of the plate type. Albion Motor-car Company, and Murray. 18837.
Tool holders. Grillenberger. 18894.
Steam generators. Gartner. 20372.
Valve packings. Bugatti. 21159.
Apparatus for starting multi-cylinder internal combustion engines. Robert Bosch. 21169.
Valves of internal combustion engines. Harrison. 22631.
Shaft couplings. Ruthardt & Co. 23211.
Apparatus for performing work of short duration at predetermined times for automatically operating gas valves, electric switches, &c. "Novitas" Fabrik Elektrischer Apparate Akt.-Ges. 24031.
Rotary engines. Leffman. 25612.
Cup leathers or collars for hydraulic machines. Heucken. 25769.
Internal combustion engines. Brandis. 26013.
Carburetting apparatus. Boeckem. 26048.
Portable hand driven drilling machine. Ott. 27600.
Hydraulic couplings. Hansen Ellehammer. 28144.
Apparatus for locking ground levers employed for operating railway switch points. Hodgson, and Saxby & Farmer, Ltd. 28709.
Method of cleaning blastfurnace gases. Werndl. 28926.
Pistons. Allen. 29128.
Composition for use in casting for constructing moulds and cores. Bainbridge. 29180.
Construction of ships' hulls. Von Keissler. 29398.

1912.

Hoists. Gehricke. 2466.
Springs for railway vehicles. Spencer. 4059.
Grabs for ore and coal. Palm. 5399.

ELECTRICAL, 1911.

Electric motor controllers. Barnard & Edwards. 4190.
Carbon electrode for galvanic batteries. Benko. 9649.
Telegraph transmitters. Mackenzie. 10044.
Relay device. Orling, and Orling's Telegraph Instruments Syndicate. 10105.
Controlling means for electric circuits. British Thomson-Houston Company. 11350.
Machines for pasting storage battery electrodes. Lake. 11516.
Electrical coupling devices. Day. 14179.
Secondary storage batteries. Oldham. 15453.
Production of long stable electric arcs for the treatment of gases. Johnson. 16636.
Spark plugs for use in internal combustion engines. Davis. 17463.
Electrical conductors. Pilkington. 18908.
Spark plugs. Wright. 19685.
Electro magnetic apparatus for actuating electric switches, valves, &c. Coleman. 24154.

1912.

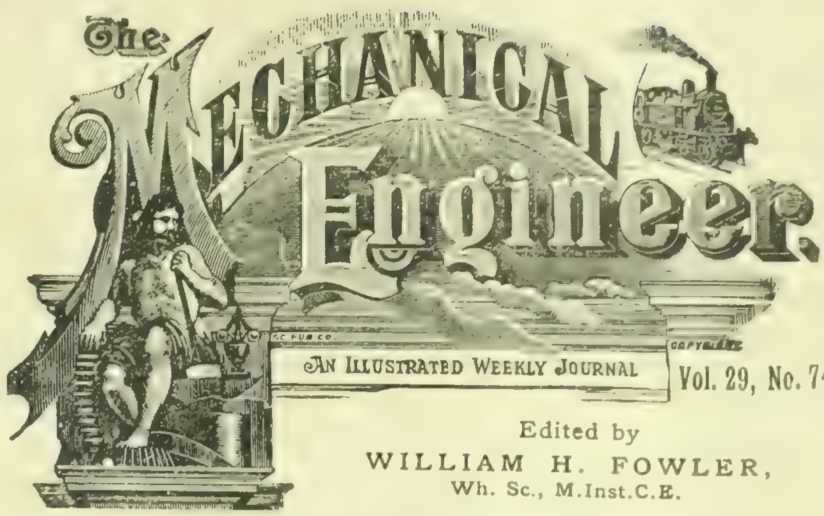
Vapour alternating current rectifiers. Hartmann & Braun Akt. Ges. 2471.

METAL QUOTATIONS.

TUESDAY, MAY 14TH.

Aluminium ingot	67/	per cwt.
„ wire, according to sizes, &c. ......from	102/-	„
„ sheets „ „ ...... „	120/-	„
Antimony .... £27/-/- to	£28/-/-	per ton
Brass, rolled	$8\frac{1}{4}$d.	per lb.
„ tubes (brazed)	$10\frac{7}{8}$d.	„
„ „ (solid drawn)	9d.	„
„ „ wire	$8\frac{5}{8}$d.	„
Copper, Standard	£72 2/6	per ton.
Iron, Cleveland	$54/1\frac{1}{2}$	„
„ Scotch	$60/1\frac{1}{2}$	„
Lead, English	£16/17/6	„
„ Foreign (soft)	£16/11/3	„
Mica (in original cases), small	6d. to 2/	per lb.
„ „ „ medium	2/6 to 4/-	„
„ „ „ large	4/6 to 8/6	„
Quicksilver	£8/5/-	per bottle.
Silver	$27\frac{1}{16}$d.	per oz.
Spelter	£25/15/-	per ton.
Tin, block	£211/10/-	„
Tin plates	$14/7\frac{1}{2}$	„
Zinc sheets (Silesian)	£29/-/-	„
„ (Stettin; Vieille Montagne)	£29/7/6	„

A Hardening Solution.—A solution for hardening small tools, such as taps, dies, &c., is given in a recent issue of "Machinery," as follows:—To 15 gallons of water add 1lb. of cyanide of potassium 6lbs. of saltpetre, 2lbs. of common lime, and ¼oz. of permanganate of potash. Distilled water, if it can be obtained, should be used, but rain water, if pure and clean, will also answer the purpose, although distilled water is better. Before dipping the tools they should be heated to a cherry red, and when dipped in the bath they should be kept moving, so that they will harden uniformly. It is not necessary to draw the temper after hardening. Pieces hardened in this solution, it is claimed, are extremely tough, and will withstand considerable pressure.



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Electric Furnaces.

ENGINEERING practice is largely the outcome of a process of evolution, even when it appears at first sight to be the result of some individual's brilliant invention. The invention may, indeed, have produced a radical change in practice, but in its turn the new machine or process generally has to lean very heavily on the modifications and improvements arising out of practical service before it can claim commercial success. This is true of the electric furnace. There is some ground for thinking that Davy in 1810 and Pepys in 1815 used simple laboratory forms of the electric furnace, but it does not appear that any commercial furnace was tried until the brothers Cowles attempted the reduction of zinc and aluminium ores in the eighties. Since that time a great many patents have been taken out and a few commercial furnaces built, but with the exception of those at Niagara Falls very little progress was made until about five years ago. With the extension of the field of the electric furnace to the commercial production of iron and steel the rate of progress has been rapid owing to the valuable moulding influence of practical metallurgists and engineers in Europe and America. This process is far from being at an end, but so much progress has been made that the electric steel furnace at least is now a useful, practical, and commercial thing for certain conditions, and the keen interest which steel makers feel in this class of furnace was evidenced at the reading of a paper by Dr. Hans Nathusius at the recent meeting of the Iron and Steel Institute.

In his paper Dr. Nathusius was at considerable pains to insist upon the defects of the induction furnace, and to describe the advantages of his own form of the arc, or arc and resistance, furnace. The advantages are, however, not wholly on one side, and it may be useful to review the salient features of the two types of practical furnaces and some of their more prominent practical representatives. In the first place, it is important to keep in mind the fact that electricity is simply a heating agent in such furnaces as are employed in steel production, and, so far as is known, produces no chemical or

physical change except such as are directly due to the heating and the reactions of suitable ores, metals, slags, and furnace linings. In some processes, notably in the reduction of aluminium, the action is partly one of electrolytic decomposition assisted by the more or less high temperature of the fluid mass undergoing reduction, but in the majority of electric furnaces the process is purely one of reduction or refinement by heat. Thus from the metallurgical point of view the character of the electric current used is immaterial, but from a works point of view it is important, as it is closely related to the type of furnace which is employed.

Electric furnaces fall into two distinct classes, the arc and induction. In arc furnaces there are usually two carbon electrodes intruding through the roof to within a very short distance of the surface of the slag and metal on the furnace hearth. Electric arcs pass between the electrodes and the bath of metal, and the heat from these arcs, together with some little heat generated by the passage of the current through the slag and metal from one electrode to the other, gives the required temperature for the melting or refining reactions. Usually the furnace is charged with molten metal mixed with more or less cold scrap, ore, and pig, but melting from the solid can also be carried out. The induction furnace differs radically from the arc furnace. There are no carbon or metal electrodes within the furnace itself, and the necessary heat is generated by the passage of a heavy current through the mass of the metal itself. This current is induced in the metal on exactly the same principle that a current is induced in the secondary coil of a transformer, or induction coil. Indeed, electrically considered, the induction furnace is an alternating current transformer, in which the metal of the furnace forms the secondary coil. As in all transformers this coil, and also the primary coil, are wound round a common iron core, or where 3-phase currents are employed, three cores. The presence of this internal core passing through the body of the furnace is a structural defect from the metallurgist's point of view. Whether electrical or other methods of heating are adopted certain reactions take place in the furnace, and a good deal of slagging and rabbling of necessity takes place. This is most readily carried out when the metal occupies a well or bath approximating to the round or rectangular in shape, and the comparatively narrow channels of the induction furnace are a disadvantage in this respect. In order to overcome this disadvantage the channel is sometimes opened out into a bath of moderate proportions in which the rabbling and charging can be more conveniently carried out. This is conveniently arranged, for instance, in the 3-phase Rochling-Rodenhauser induction furnace. There are three iron cores, protected, of course, by firebrick and other furnace materials. Around each a narrow channel of metal constitutes a secondary coil, and the three channels unite in a central bath or hearth. One important feature of the induction furnace is the rotation of the molten metal, which is literally dragged round by the magnetic lines at a high speed. This action ensures a thorough mixing of the metal, but is somewhat detrimental to the lining, and, it is said, does not ensure the proper interactions between the slag and the metal which are at the basis of all metallurgical furnace work. Electrically the induction furnace is not altogether satisfactory. It can only use alternating current, preferably of low frequency, and owing to its low power factor requires an extra large generating plant for the actual consumption of power involved.

On the other hand, the arc furnace is not without its defects. It lends itself well to a good metallurgical hearth, but the roof through which the carbon electrodes intrude is not too strong. The carbon electrodes themselves are very costly, and in some cases tend to increase the percentage of carbon in the molten steel above what is desirable. Again, the arc gives rise to intensely high local temperatures. There is some doubt as to whether these high temperatures burn or otherwise detrimentally affect the steel, but it is noteworthy that Dr. Nathusius, in his design of furnace, has specially aimed at a more uniform distribution of heat by the use of three equally spaced electrodes above the bath. In this furnace also he embodies the principle of resistance heating upon which the induction furnace wholly depends. Three metal electrodes are buried in the hearth, and the current in passing between these and the upper carbon electrodes and between one another generates internal heat, so that his furnace is a combined arc and resistance furnace. Of the simple arc furnaces perhaps the Héroult is the best known. It is usually arranged to tilt so that molten metal can be run in or out by the spout. The electrodes, two in number, are supplied with either continuous or alternating current, and intrude vertically through an arched roof.

Three or four electric furnaces are in use in Sweden and the United States for the direct smelting of iron ores, but the majority are used for the refining of molten steel produced and partially refined in an ordinary fuel-fired furnace. The electrical furnace possesses two distinct advantages. By suitably varying the electrical input the temperature of the furnace can be adjusted at will, and maintained uniform for any length of time. A greater range of temperature is available than with ordinary furnaces, and this greatly facilitates the exact control of the reactions upon which quality of the ultimate steel largely depends. Also with fuel-firing the flames frequently carry impurities, particularly sulphur, to the metal. These impurities are absent in an electrical furnace. In America and on the Continent there are one or two instances of electric furnaces installed for refining steel for rails and structural shapes, and one such furnace is also installed in this country, but in the majority of cases the furnaces are refining high-class steels of crucible quality or for special castings.

The main objection to the electric furnace is the important, indeed vital, one of cost. Considered purely as a thermal appliance it is probably more efficient than a fuel-fired furnace of the best type, but when the cost of the heat is taken into account it is very rarely that it can compete. Thus in average coal at ten shillings a ton there are about 235,000 thermal units for a penny. Electricity at a farthing a unit only gives 13,700 thermal units for a penny. Even after making a very liberal allowance for the superior thermal efficiency of electrical methods of heating it is clear that under these conditions electricity cannot compete. Where waste gases are available current can be supplied to a furnace under the most suitable conditions at about one-eighth of a penny per unit, but at present this is the lower limit. Electricity must therefore in this country fall back on its special advantages, to which reference has been made. To refine a ton of steel will usually take from 200 to 300 units, according to the conditions. Charging current at 0·2 penny per unit at the furnace it appears that the cost of power for refining will be between 3s. 4d. and 5s. per ton. There are, of course, other factors to be considered, but it is clear that the cost of electrically refining high-class steels and special steel alloys is not prohibitive, and we may legitimately anticipate a more extended use of electric furnaces, not only on the Continent, but in this country also. As experience increases and evolutionary improvement takes place the scope of these furnaces will also no doubt widen, but at present there is no reason to anticipate that they will displace existing fuel fired furnaces for the bulk of steel making processes.

THE INNER STRUCTURE OF SIMPLE METALS.

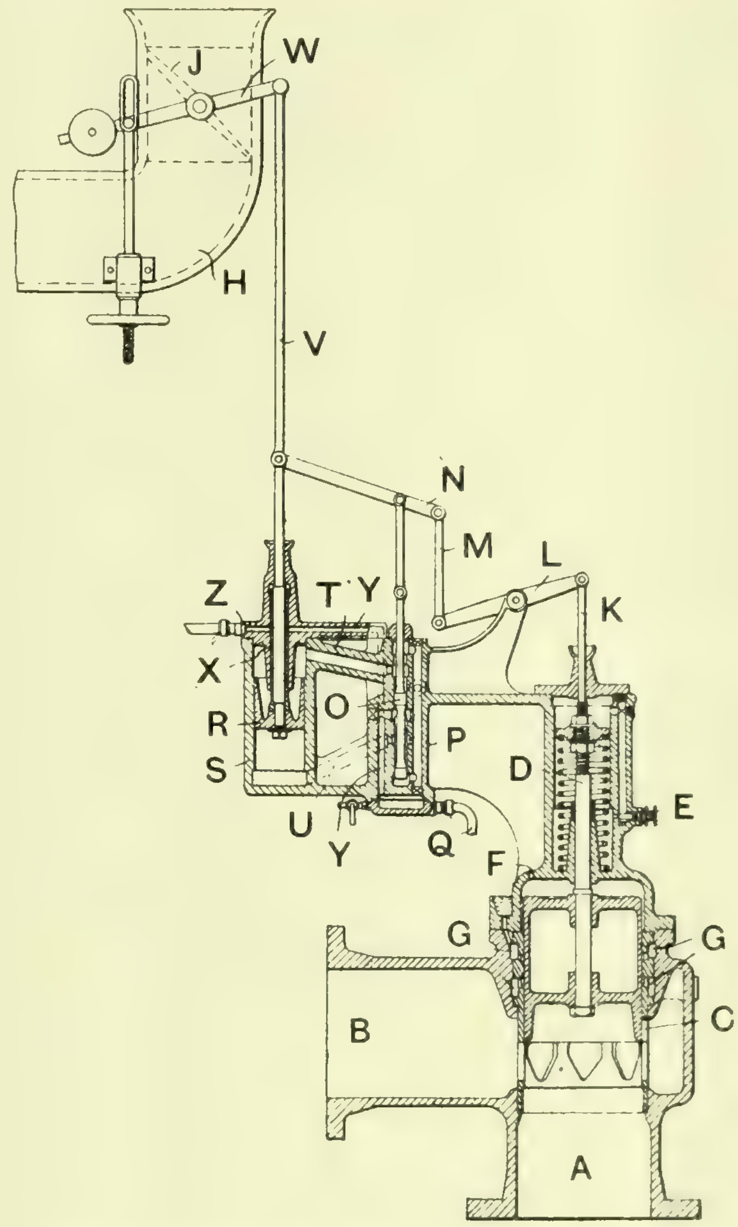
SIR J. A. EWING delivered the third May lecture of the Institute of Metals at a meeting held in London on the 10th inst. The lecturer, who took as his subject "The Inner Structure of Simple Metals," said that the use of the microscope in the hands of experienced observers had led to a good deal of knowledge being obtained regarding the constitution and structure both of simple metals and of alloys. There, however, existed a point beyond which the microscope could not penetrate, and it was his intention to attempt to pierce the barrier at which it received its check. In endeavouring to determine what was the character of the inner structure of metals it was necessary to know what were the elementary particles of which the metal was composed, how they were arranged, and the reasons for that arrangement.

With regard to the shape assumed by the crystalline grains of metals, he showed, both by a number of photomicrographs by Dr. Rosenhain, Dr. Stead, and other workers, as well as by actual experiment, that the shape of any particular grain was determined by the behaviour of neighbouring grains. This was true of metals, not only in the cast, but also in the wrought state, and indeed of those which had been annealed. Experimental work, some of which had been carried out by Dr. Rosenhain and himself, had proved that the structure of metals was capable of surviving the effects of severe strain. When a metal was subject to severe strain its crystals showed the effects of slip, and the establishment of the existence of what were termed slip lines was a step in advance in the study of the inner structure of metals. It gave the key to many things which had been previously a mystery, and it was possible on that theory to account for distortion without any interruption of the continuity of crystalline structure. Probably there was some loss of true crystalline structure, and Dr. Beilby had given grounds for that belief, which was sustained by the observed facts connected with the fracture of metals following fatigue.

A point of fundamental importance was the occurrence of the phenomenon known as "twinning," which, while sometimes resulting as the direct effect of strain, was more frequently in evidence after the metal had been strained and then annealed. The condition of twinning was conspicuously absent in iron. Twinning might, however, be regarded as of fundamental importance in relation to any conjectures as to the ultimate structure of the particles composing a metal. It was an interesting speculation whether the structural units of a metal were molecules or aggregations of molecules, and even if they were molecules there could be little doubt that they possessed a somewhat complex structure. The molecules of a metal might be assumed to be composed of small spheres in contact with one another, giving a symmetrical form. In the simplest possible arrangement each ball in the molecule would be in contact with six others; in a more complex arrangement each ball would be in contact with eight others; and in another arrangement each ball would be in contact with 12 others. In this connection the question of polarity was of great interest, and it might be assumed either that there was a positive and negative polarity in each of the units, or that there were numbers of units either positive or negative. There were many grounds for believing that it was the closest mode of packing which the crystals of a metal actually assumed, and if that were so with that arrangement there was bound up a particular kind of polarity. He merely put these views forward as indicating the direction in which the solution of the problem involved should be sought. It was necessary in the region beyond which the microscope could penetrate that recourse should be had to the imagination.

EXHAUST STEAM PLANTS FOR OPERATING TWO-STAGE COMPRESSORS.

WHEN power plants in which a steam turbine is driven by the exhaust steam from a reciprocating engine are employed in driving a two stage fluid compression set the reciprocating engine drives a piston compressor which acts as a second stage compressor, a rotary compressor driven by the turbine acting as a first stage compressor, and delivering a supply of compressed fluid to the piston compressor. Now in plants of this kind it has been found difficult to prevent air from passing into the condenser during periods of small demand, since the quantity of steam delivered to the turbine is small at these periods and consequently the pressure in the steam pipes and in the steam receiver usually employed between the turbine and the reciprocating engine falls below that of the atmosphere thus allowing air to leak into the receiver through the various joints. On an increased demand upon the plant this air is carried over into the condenser thereby impairing the vacuum. In cases where the condenser air pumps are of a sensitive character, sudden increased demands upon the plant will cause total loss of vacuum in the condenser and consequent stoppage of the turbine. It follows that these defects are chronic in plants working with considerable fluctuations of demand, such as in fluid compressing plants of the kind referred to.



VALVE ARRANGEMENTS FOR OPERATING TWO-STAGE COMPRESSORS.

To obviate the above defects Messrs. Fraser & Chalmers, Ltd., 3, London Wall Buildings, London, have designed and patented the arrangement illustrated herewith. In this arrangement a valve is employed controlling the inlet to the turbine directly actuated by the steam pressure and so arranged as to have a lift proportional to the steam passed and adapted to maintain automatically a practically constant back pressure slightly above that of the atmosphere, in the steam receiver into which the exhaust steam from the reciprocating engine passes before reaching the turbine and so obviate the formation of a partial vacuum during any part of the stroke of the pistons of the reciprocating engine. In the case of two-stage fluid compressing plants this valve being arranged so as to have a lift proportional to the steam passed will, when a small quantity of steam is passing from the piston engine and the turbine is running slowly, have a lift corresponding to this speed and therefore the valve may be utilised for operating a blow-off valve on the air or gas delivery main of the turbo-compressor at a pre-determined

point. In such fluid compressing plants when the output from the turbo-compressor is small special difficulty is encountered in consequence of the current of air or gas delivered becoming pulsatory. This difficulty has hitherto been overcome by opening by hand a blow off valve on the air delivery main of the turbo compressor.

This blow off valve is opened automatically at a predetermined point corresponding to a small output and consequent slow speed of the turbo-compressor at which pulsation is about to commence, by means of the automatic pressure regulating valve used for controlling the steam admission to the turbine. To this end the blow off valve may be connected either directly or through a servo-motor or relay, with the pressure regulating valve. Again, when the output of the plant is small it is sometimes wasteful to continue the running of both parts of the plant, the piston compressor alone being of sufficient capacity to supply the demand. The turbo-compressor can then with advantage be shut down. The shutting down of the turbine may be effected automatically at a suitable predetermined point by causing the pressure regulating valve controlling the steam admission to the turbine, to actuate suitably a valve or valves for cutting off the steam from the turbine and allowing it to pass directly into the condenser,

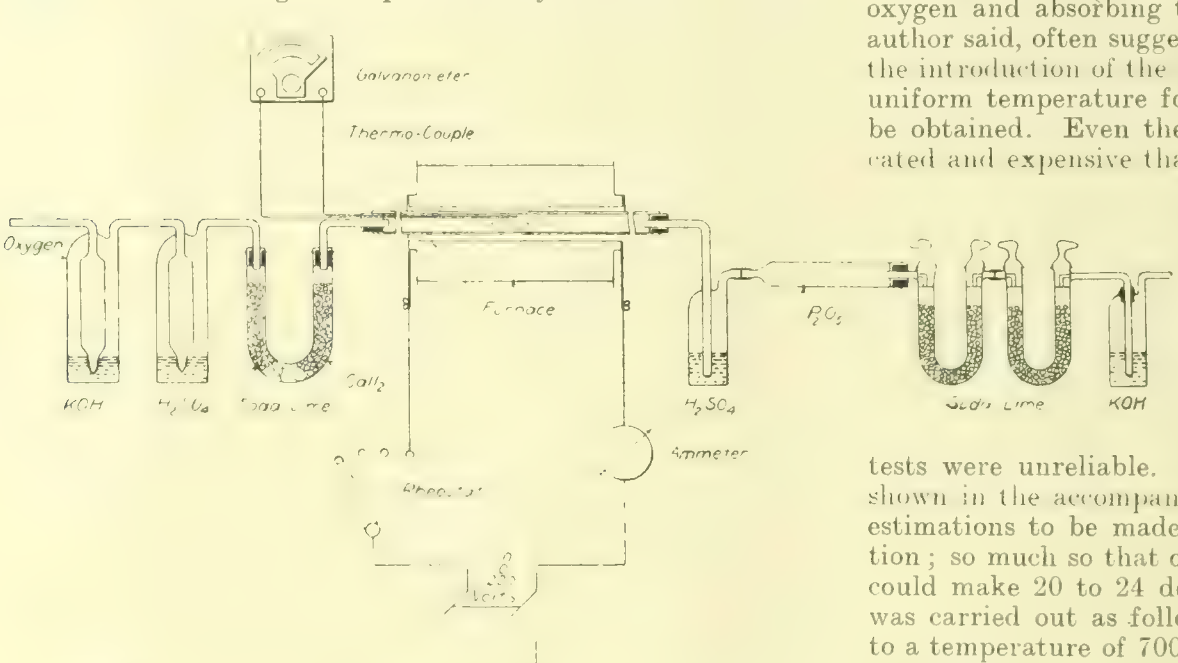


Diagram of Apparatus to Determine Carbon in Iron and Steel.

the arrangement being such that the turbine is automatically restarted when the output rises beyond a predetermined point.

Referring to the illustration, the steam pipe A is connected to a steam receiver into which the exhaust steam from the piston engine passes, the steam being led into the turbine through pipe B. A pressure regulating valve C is provided on the inlet pipe to the turbine, this valve having ports designed to admit a proportionate weight of steam for each part of its stroke. The weight of the valve is supported by a spring arranged within an oil dash-pot D for damping the oscillations of the valve. A regulating screw E controlling an oil passage is provided for regulating the flow of oil in the dashpot. The top of the valve is open to the atmosphere through the aperture F. To prevent air leaks into the valve water seals G are provided. The valve being practically balanced between the pressure of the atmosphere and the steam pressure will maintain a substantially constant back pressure in the pipe A and the receiver connected thereto, this back pressure being slightly greater than atmospheric pressure. The air delivery main of the turbo-compressor, as shown at H and J, is the blow off valve thereon. To enable the pressure regulating valve C to operate this valve J the valve stem K of the valve C is connected by a pivoted lever L and link M to a floating lever N which is connected to a pressure operated servo motor or relay of the following construction.

A piston distributing valve O working in a casing P admits fluid pressure supplied by a pipe Q on to the top or bottom of a control piston R working in a cylinder S, through passages T, U as the case may be. The distributing valve O is connected to the rod N as shown, and the control piston R to the blow off valve J by a rod V and a weighted lever W. With this construction if the valve C drops, owing to the reduced steam supply in pipe A bringing the turbo-compressor near its pulsation point the rod M is raised causing the valve O to admit pressure fluid to the top of the piston R lowering the rod V and opening the blow off valve J. When the piston R is at the bottom of its stroke or at some other predetermined point the piston compressor will be delivering a small quantity of air only and it is therefore wasteful to continue running the turbo-compressor. The turbine is then shut down in the following manner: The piston rod V is provided with a sleeve X, which when the piston is in the predetermined position comes below the passages Y, Z, and so puts them in communication, allowing pressure fluid to pass through pipe Z to a piston operating a valve on the turbine which is thus opened, and allows the steam to pass to the condenser instead of to the turbine.

DETERMINING CARBON IN IRON AND STEEL.

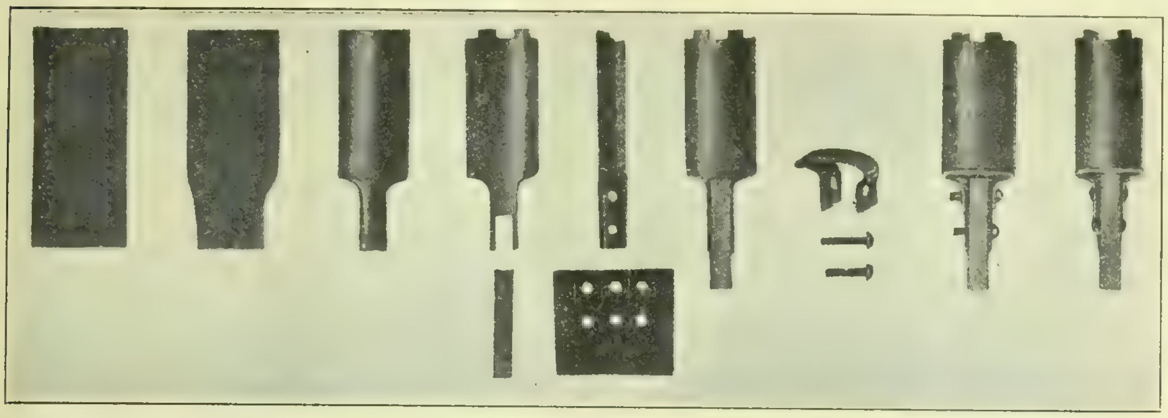
A quick method of determining carbon in iron and steel was described by Mr. F. W. Robinson in a paper read before the American Electro-Chemical Society on April 19th. The theoretical simplicity and directness of determining the carbon content of iron and steel by burning in a stream of oxygen and absorbing the carbon dioxide produced had, the author said, often suggested this method to chemists, but until the introduction of the electric resistance furnace a sufficiently uniform temperature for a satisfactory combustion could not be obtained. Even then the estimation remained so complicated and expensive that it failed to find any marked favour. It had recently been shown, however, by G. Mars, of the Boehler Steel Works, in Germany, that with a suitable furnace this method was not only simple and accurate, but on account of its rapidity was eminently suitable for use with the Martin process, particularly when, with varying charges, the Eggertz tests were unreliable. The arrangement of the apparatus, shown in the accompanying diagram, enabled any number of estimations to be made successfully almost without interruption; so much so that one man working two sets of apparatus could make 20 to 24 determinations a day. The combustion was carried out as follows: The furnace was first heated up to a temperature of 700° to 1,000° C. (for cast iron 700° C. or 1,300° Fah.; for ordinary steel, 900° C. or 1,650° Fah.; and for some special steels 1,000° C. or 1,825° Fah.) during which a slow stream of oxygen was passed through the apparatus. The soda-lime tubes were then weighed (all weighings were made with the soda-lime tubes full of oxygen) and connected to the apparatus again. One to two grammes of the metal in the form of turnings were then weighed into a porcelain boat and the boat slid into position in the furnace. This was done from the front end so that the thermo-couple and oxygen inlet tube need never be disturbed. The boat should be slid in so far that the back end was flush with the junction of the thermo-couple and during this operation the stream of oxygen should not be interrupted. The rubber stopper was immediately replaced in the combustion tube and the taps of the soda lime tubes opened. The temperature of the furnace was then gradually raised, with steel for 15 min., with cast iron for 20 min., to a maximum of 1,150° to 1,200° C. The commencement of the reaction could be noticed by a visible reduction in the rate of the gas through the sulphuric acid wash-bottle. Provided the turnings used were not too coarse, the heating current might be cut off as soon as the maximum temperature was reached, otherwise this temperature should be maintained for 5 min. to 10 min. before cooling down. After completion of the combustion the stream of oxygen was continued for 5 min. to drive all the carbon dioxide into the absorption tubes; these were then disconnected and weighed. As regards accuracy this method had been found to give results in perfect agreement with those obtained by the best and most tedious of the wet methods. To obtain accurate results with the slowly combustible materials such as ferro-chromium and ferro-manganese the turnings must be mixed with an oxygen yielding substance such as bismuth oxide and the combustion conducted as before. Although only introduced two years ago this method had already found very wide application in German iron and steel works.

THE PRESENT STATE OF DEVELOPMENT OF LARGE STEAM TURBINES.*

BY A. G. CHRISTIE.

(*Continued from page 607.*)

Turbine Details.—In the early days of steam turbine building it was difficult to secure suitable materials to withstand the stresses set up at high speeds of rotation. But as the demand for such materials increased, much study was given to the requirements for this service so that it has been possible through the use of more suitable material to increase very considerably the speeds of all sizes of steam turbines. Higher steam velocities are possible with increased peripheral speed, and thus fewer rows of blades or stages are required. This results in a shorter and more rigid shaft construction, which is therefore less liable to vibration. Many builders, especially those of Parsons turbines, have found this construction to give an increase in steam economy over the slow-speed types, so that the more compact modern high-speed machine is more desirable than the older type.



1 2 3 4 5 6 7 8 9

FIG. 6.—METHOD OF MANUFACTURE OF BLADING FOR RATEAU SECTIONS OF BERGMANN TURBINE.

Blading.—The requirements of a satisfactory blading material are that it shall withstand without deformation stresses due to centrifugal force, and temperature or pressure changes, it shall not cut out with high velocities of steam, and that it shall withstand the corrosive effects of moisture. Parsons turbines have used special bronzes and copper-nickel alloys. Steel blades have also been used in some cases. In these turbines the steam velocities are low and there is usually no cutting on this account. The principal problem with this blading is to manufacture it cheaply and secure it in such a manner that it will withstand all stresses to which it is subjected. This blading design is therefore a question of detail, and, as shown in Table I., many ingenious schemes have been devised.

In Parsons turbines the blades are usually cut, punched or pressed into proper form from strips of drawn material. The original Parsons blading consisted of alternate blades and distance pieces placed in a slightly dovetailed slot and caulked tight. Many European builders thread blades and distance pieces on holding wires before caulking in. In this case the blading is made up in sections. Other builders of turbines of the Parsons type use Sankey's solid foundation ring held in place by a soft metal caulking strip. Allis-Chalmers employ this well-known construction. As this form is usually all machine made, it is considered by many engineers to be safer than where dependence is placed on hand work, such as must ordinarily be done where each distance piece is caulked separately.

There are many methods in vogue for spacing and reinforcing the ends of Parsons blading. The Westinghouse Machine Company use a comma-shaped wire threaded through the blades near their outer end and bent over between them. Similar schemes are used by manufacturers in Europe. As a rule, however, European builders follow the old Parsons method of silver soldering or brazing the blades to a holding wire near their outer ends. They generally thin down the tips of the blades to reduce weight and to avoid injurious effects to spindle or casing from accidental rubs. Some builders, such as Sulzers, do not thin off their blades or use shrouds, but make their spindles so rigid and well balanced that the blades can be made with a very heavy cross-section and hence need no support. Several manufacturers rivet the outer ends of their blades into channel-shaped shroud rings. This gives an especially stiff construction.

Advocates of the shrouded blading claim that it provides a labyrinth passage for the steam and thus reduces the leakage losses from row to row. It also holds the blades at the required angles. It has been noted, however, that with wet steam there is a tendency for the moisture to pit the casing opposite the edges of the shrouds and thus increase the clearances. This action has also been noticed with unshrouded Parsons blading. The shrouded blading is usually so stiff that serious damage is done if rubbing starts between the blading and the spindle or casing.

The blading of impulse turbines is of nickel steel, frequently with 25 per cent. nickel in the high-pressure section and special bronze in the other stages. Experience with this 25 per cent. nickel-steel blading material has not been entirely satisfactory, and several manufacturers are now using a low carbon steel alloy with just sufficient nickel to prevent corrosion, usually about 5 per cent. These blades are said to be stronger and less liable to fatigue of material. Special bronze and monel metal have also been successfully used. These impulse blades are stamped from sheets, drop forged or milled from solid bars with or without a wide base to act as a distance piece, or are made from extruded metal strips of the desired cross-section. Usually these blades are of crescent section, but some are formed of flat strip material and made of constant thickness over the width of the blade. The separate distance pieces are usually of the same material as the blades themselves. In general, all impulse blades are provided with shrouds to prevent vibration and also to provide an enclosed passageway for the steam at high velocities. As there is no drop in pressure between the two sides of a row of moving blades, the clearance can be made large, both on the end and sides, so that there is little possibility of rubbing when in operation. Impulse blading is usually held in place in dovetailed grooves or in tee-shaped slots, although some manufacturers form their blades with two legs which straddle the discs and are held firmly in place by rivets.

The first impulse turbines had blading in which the inlet and discharge angles were equal. Now almost all builders use blading on which the discharge side of the blade makes a sharper angle with the axis than the inlet side. This does not necessarily mean that the discharge area of the blades is smaller than the inlet area,

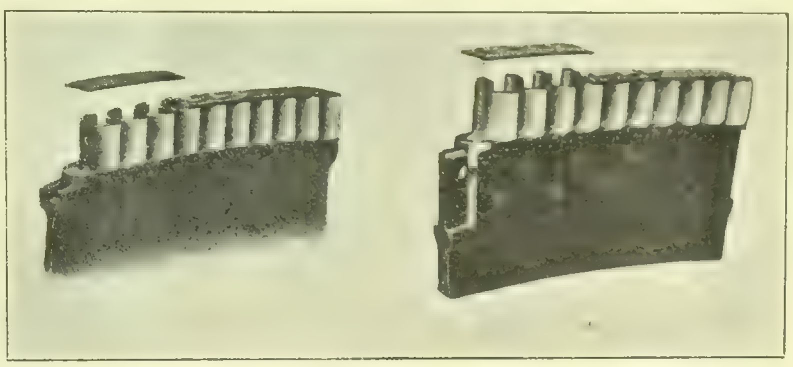


FIG. 7. TYPES OF BLADING USED BY BRITISH WESTINGHOUSE CO.

for the blade is usually lengthened radially on the discharge side. Thus both inlet and discharge areas are made equal. The sharper angle of discharge reduces slightly the relative velocity of exhaust from the moving blade. On turbines of the Curtis type there is usually only a small difference between the inlet and outlet angles of the first row of moving blades, but on the second row of moving blades in the stage, the entrance and exit angles often differ by as much as 15°. Some impulse turbine designs are such that there must evidently be some such reaction effect in the moving blades as is obtained in Parsons turbines, though not of sufficient amount to cause any noticeable end thrust.

* Paper read before the American Society of Mechanical Engineers.

TABLE I. *Data on Steam Turbine Construction.*

Manufacturer.	Type of Turbine.	R.P.M. of Various Sizes.	No. of Stages.	Blade Speed in Ft. per Sec.	Steam Velocities, Ft. per Sec.	Blade Material.	Blade Form.	Method of Blade Manufacture and Insertion.	Nozzles and Diaphragms.
C. A. Parsons & Co.	Parsons & Curtis-Parsons.	....	Usually about 70	270 on low-pressure blades.	540.	Special bronze and delta metal.	Parsons form with very thick rounded inlet, blades thinned off at tips.	Alternate distance pieces held by caulking, ends of blades stiffened by silver soldering to a brass strip; Curtis blades shrouded.	
Westinghouse Mach. Co.	Parsons & Curtis-Parsons.	Up to 3,000 kw., 3,600; 3,000-5,000 kw., 1,800; over 5,000 kw., 750 or 720.	....	Curtis blades 600; Parsons blades 350.	Curtis 2,000; Parsons 600.	Special bronze and soft steel; Curtis blades bronze.	Blades crescent with heavy central portion and sharp inlet edge, dovetail base on impulse.	Alternate distance pieces held by caulking, ends stiffened by comma wire threaded through blades and bent over.	
Willans & Robinson.	Curtis-Parsons.	....	1 Curtis; 12-20 rows Parsons on 1 diam. of drum.	....	....	Bronze and copper-nickel blades.	Parsons rounded inlet, stamped to fit Sankey foundation ring and channel shroud; usual Curtis blades on impulse.	Parsons sections made up by machine and held in place by caulking in soft metal strip, final riveting of shroud completed last.	
[illegible], [illegible] & Co., Richardson, Westgarth, & Co.	Parsons & Curtis-Parsons.	Up to 3,000 kw., 3,000, 3,000-7,500 kw., 1,500.	....	Curtis blades 460; Parsons blades 380.	....	Curtis blades of special alloy; Parsons blades of bronze.	Parsons blades not thinned off, usual form, base of blade notched to fit corresponding lateral projection in the grooves, blades not caulked.	Curtis blades in dovetail slot, no sharp corners on base and shrouded; Parsons blades threaded on wire and silver soldered.	Nozzles made in 3 parts of steel or bronze, and all machined.
Brush Electrical Engineering Co.	Curtis-Parsons.	....	....	....	....	Parsons blades bronze alloy.	Usual Parsons form with caulked distance pieces in dovetailed groove; also use grooved base of blades fitting corresponding grooves in shaft like teeth in a bolt.	Tips of blades thinned off, blades silver soldered to wire strip.	
Franco Tosi	Curtis-Parsons.	Up to 2,500 kw., 3,000, 2,500-8,000 kw., 1,500; 8,000-12,000 kw., 1,000.	1 Curtis; remainder Parsons on 1 diameter of drum.	....	Curtis 2,130; Parsons 230-460.	Parsons and Curtis blades of special bronze.	Blades and distance pieces milled at base, with thread-like projections to fit corresponding grooves in spindle.	Curtis blades shrouded; Parsons blades also have channel shroud-riveted over after blades are in place.	Nozzles of steel or bronze, angles of nozzles 20° to 25°.
Gebrüder Sulzer.	Curtis-Parsons.	....	....	Curtis blades 360; Parsons blades 310.	....	Curtis blades all of special steel; Parsons blades of special bronze.	Parsons blades of very heavy cross-section with standard Parsons distance piece and method of caulking.	Parsons blades not thinned at ends or reinforced in any way; Curtis blades milled to fit dovetail slot.	Nozzles of sheet brass cast in valve chest.
Melms & Pfenninger Breitfeld, Danek, and Co.	Rateau-Parsons and Curtis-Parsons.	Up to 4,000 kw., 3,000; 4,000-9,000 kw., 1,500.	....	Up to 575.	Impulse section up to 2,200; Parsons up to 900.	Rateau blades of special bronze; Parsons blades also special bronze.	Impulse blades have slot in side to fit projection in groove and held in place by soft metal caulking strip; Parsons blades have special base to fit foundation ring and with special shroud on end.	Parsons blade rings made up in halves and fitted to machine, sections held in place by soft metal caulking strip, angle of blades, 20° to 45°.	Nickel-steel guide blades in Rateau section with special labyrinth packing; angle of nozzles 18° to 22°.
Allis-Chalmers Co.	Parsons.	Up to 2,000 kw., 3,600, 2,000-5,000 kw., 1,800.	....	Up to 370.	400-800.	Copper-nickel alloy.	Parsons section with more defined inlet edge, blading uses Sankey foundation ring and shroud, blading made in sections outside turbine.	Sections held in dovetailed slots by soft metal caulking strips, shrouds channel shaped.	
Allgemeine Electricitat Gesellschaft.	Curtis-Rateau.	Up to 3,000 kw., 3,000, 3,000-9,000 kw., 1,500; 9,000 kw. and over, 1,000	1 Curtis; 9-12 Rateau.	....	....	Bronze alloy or nickel-steel.	Blade crescent shaped but of lighter section toward exhaust end, shrouded in groups.	Blades cut from solid bar and set in dovetailed grooves with separate distance pieces.	Nozzles of bronze or nickel-steel, guide blades in diaphragms of nickel-steel cast in place.
Maschinen-fabrik Augsburg Nurnberg	Curtis-Zoelly.	Up to 6,000 kw., 3,000, 6,000-10,000 kw., 1,500, 10,000-15,000 kw., 1,000.	1 Curtis, 6-8 Zoelly.	Up to 650.	Curtis 2,500; Zoelly about 1,300.	Nickel-steel highly polished.	First Curtis rows have blades of heavy section, remaining rows are thin in section, blades are held in a ⊥ slot.	Blades mostly drop-forged, all rows shrouded, outlet and inlet angles vary considerably.	Nozzles of nickel-steel milled from solid, guide blades in diaphragms of highly polished sheet nickel-steel.
British Westinghouse Co.	Curtis-Rateau.	Up to 1,500 kw., 3,000, 1,500-5,000 kw., 1,500	1 Curtis; 6-12 Rateau	300-500.	Curtis 1,500; Rateau 800.	5 per cent. nickel-steel.	Curtis blades have ⊥ base to fit corresponding groove; Rateau blades have 2 projections at base straddling disc and rivets rolled in place.	Blade and distance pieces milled from solid steel bars.	Nozzles of special steel, guide blades of special steel cast in place in diaphragms.
Bergmann Electricitats Werke.	Curtis-Rateau	....	1 Curtis; 8-12 Zoelly.	410-460.	Curtis 2,600; Rateau 1,170.	25 per cent. nickel-steel	Blades stamped from sheet metal with projections at base straddling disc and riveted to it blades of uniform thickness across section.	Distance pieces drop-forged of special bronze and riveted with blades to disc, all blades shrouded.	Nickel-steel nozzles in 4 groups, nickel-steel guide blades cast in place in diaphragms.
Belliss & Morcom	Curtis-Drum Impulse.	Up to 1,500 kw., 1,800; use lower speeds than most builders.	1 Curtis; 25-30 rows of impulse blades on drum.	Not exceeding 400.	....	Curtis blades of steel; impulse blades of phosphor bronze.	Curtis blades, usual form; on impulse section blades are of uniform thickness over section and shrouded.	Blades made with strip at base bent in form of L, distance piece formed with opening at base, the 2 projections spread over base of blade and fill dovetailed slot when caulked down.	Nozzles, steel or bronze, impulse guide blades of brass made in segments.
Escher, Wyss & Co.	Zoelly	Up to 1,500 kw., 3,000; 1,500-3,500 kw., 1,500, over 3,500 kw., 1,000.	3,000 r.p.m., 10 stages; 1,500, 16 stages, 1,000, 20 stages.	....	About 1,400.	5 per cent. nickel-steel.	Blades stamped from sheet metal with ⊥ base, blades sometimes thinned off towards tips, distance piece stands well above surface of shaft.	Blades milled with sharp edges and highly polished after stamping, distance pieces milled from solid bar, only thin shroud ring used.	All nozzles and guide blades of nickel-steel cast in place and highly polished.
Maschinen-fabrik Oerlikon.	Rateau.	Up to 4,000 kw., 3,000; 4,000-7,500 kw., 1,500, over 7,500 kw., 750	10-16 stages with 2 or more mean diameters of blades.	320-520.	1,310-1,700.	Nickel-steel;	Blades punched to shape from drawn metal strips, base is ⊥ shaped, simple band shroud ring used.	Distance pieces milled, slot closed by special locking piece.	Nickel-steel guide blades all cast in place.
Fraser & Chalmers.	Rateau.	....	Are reducing number of stages on all turbines.	Have increased blade speeds recently.	....	Nickel-steel.	Blades with forked base riveted to discs.	Blades milled from solid bar, no shround ring, but head milled on blades like De Laval.	Diaphragm guide blades cast in place.
General Electric Co.	Curtis.	Up to 1,400 kw., 3,600, 1,400-7,000 kw., 1,800, 7,000-20,000 kw., 750 or 720.	4-7.	460-500.	About 1,200 average.	Special bronze extruded metal; Monel-metal and steel used on some low-pressure blades.	Blades milled with dovetail base and have shroud ring, distance pieces also milled.	Blades put in place in special blading machine.	Inlet nozzles of special bronze, steel guide blades in diaphragms cast in place and polished.
British Thomson-Houston Co.	Curtis.	Up to 1,000 kw., 3,600, 1,000-5,000 kw., 1,800, up to 2,000 kw., 3,000, 2,000-7,500 kw., 1,500	Same construction as General Electric Co.	600 as maximum.	About 1,800 from nozzles, 1,100 from diaphragms.	Special bronze and steel.	Same construction as General Electric Co.	Same construction as General Electric Co.	Same construction as General Electric Co.

TABLE I.—*Data on Steam Turbine Construction*—(*continued.*)

Manufacturer.	Shaft and Spindle Construction.	Form and Material of Bearings.	Surface Speed of Journals. Ft. per sec.	Bearing Pressure. Lbs. per Sq. In.	Type of Oil Pump	Governor and method of Governing.	Oil Data.	Type of Glands.	Provision for overspeed Regulation.	Type of Coupling	Additional Notes.
C. A. Parsons and Co.	Spindles usually a single hollow forging, shaft ends fastened in.	Parsons concentric bronze sleeve bearings in self-aligning cast-iron casings, large sizes white-metal lined.	35-50.	40-50.	....	Steam relay system, steam admitted in puffs, not continuous throttling.	....	Steam-packed labyrinth at shaft.	....	Flexible claw.	Simple Parsons turbines, usually very long spindles; large sizes in 2 cylinders.
Westinghouse Mach. Co.	Shaft, hollow quill with blade rings forced on, ends held in by special patented fastening.	Parsons concentric sleeve bearing on small units, cast-iron self-aligning bearings, white-metal lined on large units.	40-50.	50-70.	Rotary oil pump with sliding gate.	Direct throttling from governor, sometimes pulsating; also pulsating oil relay.	Oil pressure on bearings 3lbs. to 4lbs., relay pressure 60lbs.	Water-packed glands with centrifugal impeller.	Emergency governor to shut off steam at about 12 per cent. overspeed.	Flexible claw.	Small sizes simple Parsons; large sizes Curtis-Parsons, double flow in low-pressure, heavy thrust block to take any end thrust.
Willans & Robinson.	Disc, solid forging; drum, hollow rolled forging; ends fastened in by locked bolts; Fullager balance piston used.	Cast-iron, white-metal lined self-aligning.	45-60.	50-70.	Both reciprocating and rotary types used.	Direct throttling from governor.	Bearing pressure about 10lbs.	Steam-packed labyrinth.	Emergency governor for overspeed.	Flexible claw.	
Brown Boveri and Co., Richardson, Westgarth and Co.	Disc, solid forging forced and fastened on hollow forged drum spindle; shaft ends locked into drum; Fullager balance piston used.	Parsons concentric bearings on high speeds, cast-iron, white metal lined, self-adjusting bearings on low speeds.	....	....	....	Rotary pump. Hartung type with oil relay, also slight pulsation to valve; valves on nozzles open automatically.	....	Steam-packed labyrinth.	Emergency goveror closes spring-controlled throttle valve.	Flexible claw.	Effect on steam consumption of changes in (*a*) vacuum, 5-6 per cent. per 1in. vacuum; (*b*) steam pressure, 1 per cent. per 15lbs.; (*c*) superheat, 1 per cent. per 11° Fah.
Brush Electrical Engrg. Co.	Disc, solid and fastened on solid or hollow forged drum spindle.	Cast-iron, white metal lined, self-adjusting bearings on all sizes.	....	....	Rotary pump.	Steam relay system, pulsating action.	....	Steam-packed labyrinth. Water-packed glands also used.	Emergency oil relay control on throttle valve.	Flexible claw.	
Franco Tosi.	Forged steel shaft with spindle rings and impulse disc with balance piston forced on & held by bolts.	Cast iron, white-metal lined self-aligning bearings.	....	55-90.	Rotary gear pump	Hartung type governor, oil relay system on main valve; automatic oil relay nozzle governing.	10·4 gals. per minute pumped on 300 kw.; 18·4 gals. per minute on 12,000 kw.	Steam-packed labyrinth; water-packed glands also used.	Emergency oil relay governor to close main throttle valve at 15 per cent. overspeed; unique device	Flexible claw.	Effect on steam consumption of changes in (*a*) vacuum, 7 per cent. per 1in. at 28in.; (*b*) steam pressure, 1 per cent. per 15lbs.; (*c*) superheat, 1 per cent. per 12·5° Fah.
Gebrüder Sulzer.	Spindle, hollow forging with shaft ends and impulse disc bolted on.	Cast iron, white-metal lined, self-aligning bearings.	....	....	Triple gear pump.	Automatic hydraulic regulator, centrifugal pump on oil only; throttling of supply; oil relay on all gear; no mechanical governor.	Bearing oil pressure 20lbs.	Steam-packed labyrinth consists of large number thin sheets placed radial; close clearance on shaft.	Oil relay control on steam inlet valve.	Flexible.	End thrust all taken up by automatic oil controlled balance piston on end of shaft similar to Franco Tosi's.
Melms & Pfenninger, Breitfeld, Danek, & Co.	Spindle, hollow forging of nickel-steel, impulse disc and balance piston fastened on; shaft ends forced in.	Parsons concentric sleeve bearings on small units, large units have cast-iron white metal lined, self-aligning bearings.	40-80.	35-85.	Eccentric rotary pump.	Hartung type oil relay, throttling governor.	Oil temperature at bearing 105° to 120° Fah.	Steam-packed labyrinth; exhaust end packing adjustable.	Emergency valve to operate at from 10-15 per cent. overspeed.	Flexible claw.	Effect on steam consumption of changes in (*a*) vacuum 28-29in., 5 per cent.; 27-28in., 4 per cent.; 26-27in., 3·5 per cent.; (*b*), steam pressure 1 per cent. per 12lbs.; (*c*), superheat 1 per cent. per 10° Fah.
Allis-Chalmers Co.	Hollow forged quill with blade rings of cast steel forced on; shaft ends forced into quill and held by bolts and nuts; Fullager balance piston.	Cast-iron, white metal lined self-adjusting bearings.	50-60.	60-140.	Rotary lobe pump, auxiliary duplex pump for starting.	Hartung type oil relay, throttling governor.	Bearing pressure 5lbs., relay pressure 30lbs., bearing oil temperature 110° Fah. best; large quantities pumped.	Water-packed glands with centrifugal impeller.	Emergency governor to close spring-loaded throttle valve.	Flexible claw.	
Allgemeine Elecricitäts Gesellschaft.	Solid shaft with discs forced on; discs of steel tapering toward the blades.	Cast-iron, white metal lined bearings, usually water-cooled; only 3 bearings; very small governor bearing carried by front housing.	50-70.	100-125.	Rotary gear.	Hartung type oil relay, governor throttling steam; also automatic nozzle control.	Oil temperatures at bearings from 175° Fah. to 190° Fah.	Steam-packed labyrinth and carbon rings.	Emergency governor to close spring-loaded throttle valve.	Solid.	
Maschinen-fabrik Augsburg, Nurnberg.	Short stiff solid shaft running below critical speed discs of soft steel forced on shaft and locked; discs taper toward blade ends.	Cast-iron, white metal lined self-adjusting bearings; only 3 bearings used; governor bearing very small.	....	45-70.	Horizontal rotary gear.	Hartung type oil relay, governor throttling steam; also automatic steam control on nozzle valves.	....	Graphite rings in glands, steam packed.	Emergency governor.	Solid.	
British Westinghouse Co.	Short, solid, stiff shaft stepped from centre to receive discs which are of forged steel tapering from centre to periphery.	Cast-iron, white metal lined, self-adjusting bearings.	....	....	Rotary gear pump	Heavy Hartung type governor direct connected to throttling valve.	....	High-pressure end, labyrinth and water gland; low-pressure end, water gland with centrifugal impeller.	Emergency governor closes spring-actuated safety valve on steam inlet.	Flexible claw.	
Bergmann Electricitats Werke.	Short, solid shafts not too stiff, as shafts at 3,000 r.p.m. and over, run above critical speed; discs forced on shaft and locked.	Cast-iron, white metal lined, self-adjusting water-cooled bearings.	....	....	Rotary gear pump	Hartung type governor throttling steam; nozzle valves opened by hand.	Relay pressure 30lbs.	Steam-packed labyrinth.	Emergency governor to close throttle at 10 per cent. overspeed.	Solid.	
Belliss & Morcom.	Forged-steel drum fastened to through solid shaft; drum carries impulse disc and balance piston.	Cast-iron, white metal lined, self-adjusting bearings.	40-50.	As high as 90.	Double-acting valveless pump, 80-100 r.p.m.	Centrifugal governor, oil relay simply throttling steam supply.	Relay pressure 40lbs.; estimate 10 % of heat losses to go through oil, design oil pump accordingly.	Multi-cellular with carbon rings and steam packed.	Emergency governor controls oil relay to shut off steam.	Flexible.	Flood bearings with great quantity of oil to flush away heat rapidly.
Escher, Wyss, and Co.	Solid shaft with discs supported on ring so as to make shaft less rigid.	Cast-iron, white metal lined, self-adjusting bearings.	....	....	Gear pumps, 1 for relay, 1 for bearing oils.	Hartung type, oil relay simply throttling governor.	....	High-pressure end, carbon ring packing; low-pressure labyrinth.	Emergency governor to operate at 8-10 per cent. overspeed.	Solid.	
Maschinen-fabrik Oerlikon.	Nickel-steel shafts made heavy in the centre; discs of forged soft steel forced on and locked to shaft.	Cast-iron, white metal lined self-aligning bearings, water cooled in the larger sizes.	Not exceeding 66.	Not exceeding 75.	Rotary gear pump	Hartung type, oil relay governor, throttling steam supply; main throttle valve also opened by oil relay.	Oil usually required is 0·02 gals per kilowatt-minute.	High-pressure graphite; low-pressure, steam-packed labyrinth.	Emergency governor closes main throttle valve through oil relay.	Flexible with leather discs.	Blade angles, 20° on stationary blades 30° on moving blades.
Frazer & Chalmers	Solid shaft with discs forced on.	Cast-iron, white metal lined, self-adjusting bearings.	....	....	....	....	....	High-pressure metal rings and labyrinth; low-pressure, labyrinth.	....		
General Electric Co.	Shaft, solid forgings, discs, cast steel forced on shaft.	Cast-iron, white metal lined self-adjusting bearings with copper cooling pipes cast in babbitt metal lining.	....	....	Rotary gear pumps	Vertical centrifugal governor operating oil relay which controls nozzles; nozzle governing.	Relay pressure about 70lbs., bearing pressure 25lbs.	Carbon ring packing on both ends.	Emergency governor to close unbalanced throttle valve.	Solid.	
British-Thomson Houston Co.	Shaft and discs of steel.	....	50-60.	50-70.	Rotary pump.	Same as General Electric Co.	[illegible] gallon per minute per bearing on 1,000 kw. units; 1½ gallons on 5,000 kw. units; same amounts to thrust.	Carbon ring packing.	Emergency governor to close throttle valve at 15 per cent. overspeed.	Solid.	Effect on steam consumption of changes in (*a*) vacuum 7 per cent. increase per in. above 28in., 150lbs. steam gauge, 8 per cent. decrease per in. below 28in., 150lbs. steam gauge; (*b*) steam pressure 1 per cent. per 10lbs. around 150lbs. pressure; (*c*) superheat 1 per cent. per 10° Fah.

Some recent interesting developments in blading are shown in Figs. 6 to 10. Fig. 6 shows the various steps in the manufacture of the thin sheet metal blading used by Bergmann. The blading of the Rateau discs of British Westinghouse turbines is clearly illustrated in Fig. 7. Brown, Boveri's form of Parsons blading is illustrated in Fig. 8. Belliss & Morcom use a unique form of blading on the drum impulse section. This blading is shown in Fig. 9. Franco Tosi cuts projections like threads in his blade grooves and mills corresponding projections on the base of the blades as in Fig. 10. This is a very satisfactory but expensive form of blading.

The number of rows of blades in any given type depends entirely on the size and speed of the unit, the steam conditions

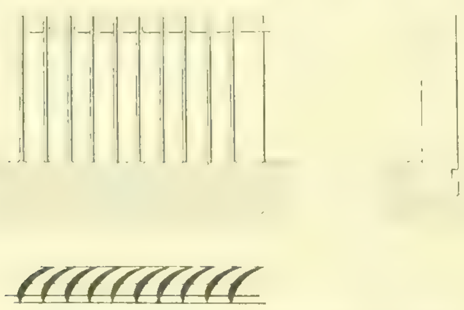


FIG. 8. BROWN BOVERI'S REACTION BLADING.

under which the turbine will operate, and the heat drop per row or stage assumed in the design. Each designer selects such conditions as his experience and judgment lead him to consider the most satisfactory. It is thus hard to draw any general conclusions as to the most desirable number of rows for any class of turbine. In general it may be said that the Parsons turbines require from 40 to 80 sets of moving and stationary blades, the Curtis from 4 to 8 stages, the Rateau from 12 to 25 stages, the Zoelly from 8 to 20 stages, while the Curtis-Parsons and Curtis-Rateau combinations of course require several rows less than the fundamental types.

Nozzles. The high-pressure nozzles in impulse or combination turbines are made of bronze or nickel steel highly polished inside and placed either in the upper end of the casing itself, or, more preferably, in a separate steel casting which bolts upon the casing. In the latter construction the casing itself is never subjected to the high temperature or pressure of the entering steam. The nozzles in the diaphragms between stages are usually made of nickel steel or other special steel, bent to the proper form and cast in place of the diaphragm body. Some manufacturers use brass nozzles in place of steel made up in sections and riveted or bolted in place. All these passages must be smooth and preferably very highly polished to reduce friction losses. After the first stage all nozzles have parallel walls on the discharge side.

Bearings and Lubrication.—Practice varies widely with regard to the design and construction of journals and bearings. Builders of impulse turbines invariably use cast-iron bearing shells provided with spherical self-aligning pads and lined with white metal. These are being used to an increasing extent on Parsons turbines and without exception on all low speed units. Some manufacturers still retain the original Parsons form of bronze-bearing shell with concentric rings on the outside, separated from each other by oil films. It has been claimed for this type of bearing that the oil films dampen any slight vibration of the spindle and thus provide a quieter running machine. Experience has shown that this is not always the case and that such a bearing is often a real source of danger when the added clearance of the spindle due to play between the rings is taken into consideration. This construction is also much more expensive than the white metal bearings.

In Europe many turbines are run with a minimum amount of oil and with oil leaving the bearings at a temperature of 190° Fah. This practice is based on the argument that such a system of lubrication requires the least expenditure of power for oil circulation and in frictional losses. However, practice seems to be tending towards flooded lubrication, in which a great quantity of oil at a temperature of about 100° Fah. is forced through the bearings by a pump of the rotary, centrifugal, or gear type, driven from the main shaft of the turbine. The oil pressure at the bearings varies from 3lbs. to 20lbs. per square inch. The life of the oil is much longer in this system than with very hot oil, and any wear on the bearings themselves is absolutely prevented. Occasionally the bearing shells are water cooled, but this practice should be discouraged. Cooling water can be used much more satisfactorily outside of small oil pipes in properly designed coolers. In case the water is dirty or full of scale-forming impurities, these can be more readily removed from an oil cooler than from the interior of a bearing shell.

Flooded lubrication has enabled manufacturers to cut down

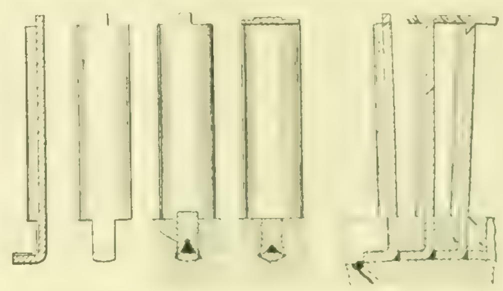


FIG. 9.—BELLISS & MORCOM IMPULSE BLADING.

the length of their bearings and thus reduce the total length of their turbines. The increased pressures per unit area on the bearings have not introduced any difficulties, so that pressures of 80lbs. to 100lbs. per square inch at a surface speed of 60ft. per minute are common practice. The best results are usually obtained with a temperature of about 125° Fah. as the oil leaves the bearings.

Spindle Construction.—Parsons turbines in America are usually built with a hollow quill into which the journal ends are forced and fastened by shrink links or bolts. The high-pressure blading is placed in grooves in one end of the quill itself. The intermediate and low-pressure blades are usually carried on cast or forged steel rings which are afterwards forced and keyed upon the central quill. In Europe excellent hollow steel forgings can be obtained very readily, and hence the spindles of Parsons and other drum-type turbines are usually made up of one forging with the journal shafts fastened into the ends.

The shafts of impulse turbines are usually in one piece and carry the blade discs, which are high-grade steel or nickel-steel forgings or castings. These discs are fitted and keyed on the shaft and held in place by shrink links or lock nuts. It is quite general practice now to design the shafts so that the normal speed of the turbine will be very considerably below the critical speed due to any slight unbalancing of the mass that may be present. This removes the dangerous vibrations often experienced when passing through critical speeds and permits closer clearances to be used on Parsons blading and in the labyrinth passages in the diaphragms between the stages of impulse turbines.

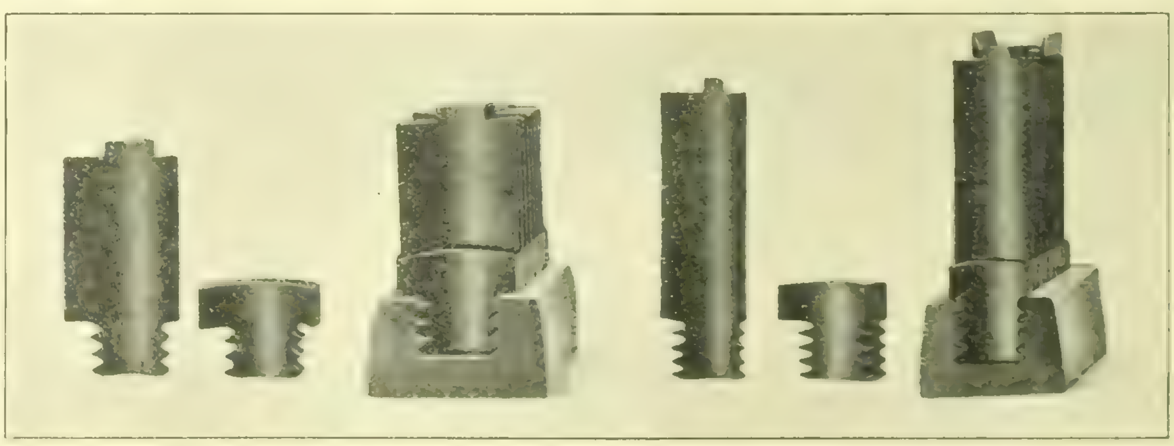


FIG. 10.—FRANCO TOSI'S BLADING.—IMPULSE BLADES ON LEFT; REACTION BLADES ON RIGHT.

Packing Glands. A small impeller supplied with water is provided on all American built Parsons turbines to form an air seal at the shaft glands. European builders prefer to use labyrinth packings with live or throttled steam as an air seal. The objection raised by foreign builders to the water packing is that it takes too much power to drive the impeller and that it provides

a condensing surface for the steam. The amount of water required in a well-designed gland is very small and there is no great circulation. Thus the water can have only a small effect as a condensing medium. Usually the steam directly inside the casing is under vacuum and then condensation would not be objectionable. It requires considerable steam to pack the labyrinth type of gland, and this loss often exceeds that due to the power required to drive the water impellers.

Impulse turbines use carbon rings at the high-pressure gland, especially when superheated steam is used. The leakage past the first rings is carried through a passage and pipe to the low-pressure glands to act as a vacuum seal. The labyrinth packing in the diaphragms is usually of bronze in the high-pressure stages and frequently of white metal in the low-pressure section. The low-pressure shaft glands are made either with carbon or labyrinth packing, sealed by steam.

Thrust Bearings.—Thrust bearings are now provided on all types of turbines. These serve to adjust the position of the spindle and to take up any end thrust present. The end thrust in well designed turbines is usually of small amount and seldom causes trouble. These bearings are usually flooded with oil and are often made with bronze rings which can easily be replaced in case of damage. Several builders of Curtis-Parsons turbines have substituted an oil-thrust piston for the steam balance piston of the usual form. This piston is placed on the governor end of the shaft outside of the casing proper. The thrust is taken up by oil, which is supplied under pressure and which can escape only through sets of labyrinth baffles on the piston and on the surrounding chamber. The piston adjusts itself for the amount of thrust present by a small axial movement of the shaft, thus opening or closing the discharge area for the oil through the labyrinth baffles, and automatically varies the oil pressure on the face of the piston. This arrangement does away with the loss of steam through balance pistons and should improve the turbine efficiency, though a small amount of power is required to pump the oil.

Governing Devices.—The speed of Parsons turbines is usually controlled by a centrifugal governor of the Hartung or similar type, which regulates the position of a balanced poppet valve through the medium of a steam or oil relay. The latter type is coming into more general use on account of its many advantages over the steam relay. The steam is throttled either at constant pressure or by a pulsating action.

Impulse turbines and turbines employing a Curtis high-pressure ring usually govern by means of Hartung type governors and oil relays. The speed is sometimes controlled by simple throttling of the steam, which practice is common in Europe. In this case, additional nozzles can be opened or closed by hand as required. This system would be unsuitable with violently fluctuating loads. Other types employ both throttling and automatic nozzle regulation, while, again, many turbines, particularly of the Curtis type, are built for nozzle governing alone. In Europe there is a difference of opinion as to the most economical method of governing. M. H. Zoelly claims that he gets the best results on his type of turbine by throttle governing. It is generally admitted, however, that impulse turbines give the best results by controlling the number of nozzles that are open at any load. With such control the pressure before the nozzles in service is always the normal pressure for which these are designed. The General Electric Company govern their turbines above 300 kw. by means of an oil relay system which operates through a piston and camshaft to open or close nozzles as required by load conditions.

The Westinghouse Machine Company use a vibrating oil relay system on many of their machines. Recently they have adopted on some sizes a very powerful governor, which is direct-connected to the governing valve and operates it without the use of relays. This system was adopted by some of the early European builders, but was abandoned in favour of the oil relay system.

Sulzers have recently installed turbines in which the conventional centrifugal force governor has been replaced by an hydraulic governor. This governor consists of a simple centrifugal pump, geared to the main shaft and delivering oil under pressure into a chamber beneath a spring-loaded piston. The pressure under this piston is thus dependent on the speed of the main turbine and the piston's position in its cylinder will vary accordingly. The piston is connected to the usual balanced valve of an oil relay, which controls the oil supply from the main oil pump to the throttle valve in the usual manner. There are no mechanical parts to wear in this arrangement. The apparatus is extremely simple and has many distinct advantages.

All turbines are now provided with a small overspeed governor, usually placed at the outside end of the shaft. This operates at a determined percentage over speed and closes the main or secondary steam valve either by means of a steam or oil relay or by a falling weight through a system of levers and springs. The oil relay system has the advantage that the valve shuts immediately should the oil supply fail for any reason.

Parsons turbines are usually provided with a secondary overload valve which automatically admits live steam to the second diameter of blades. Impulse turbines have additional sets of nozzles, with valves which may be opened automatically or by hand in case of overloads.

Casings.—Practice varies widely in regard to the construction of turbine casings. These are generally made of cast iron, though some European builders make the high-pressure front end of cast steel. Parsons turbines are built with the top and bottom halves single castings or made in sections. Some of the older designs of impulse turbines used solid diaphragm plates placed on the shaft between the discs. The clumsiness of handling and the difficulty of making repairs with this construction has forced most builders to make these in halves and to fasten them to the top and bottom portions of the casing. Cylinder casings are now made of symmetrical design and without any deep metal webs or ribs as stiffeners on the outside. Equalising pipes with provision for expansion take the place of passages formerly cast in the casings themselves. Strains due to unequal temperatures must be avoided in all portions.

Bedplates.—Several European builders make a practice of filling the hollow portions of their turbine and generator bedplates with concrete after erection. This adds more mass to the turbine unit and is said to dampen any slight vibration that may be present.

(To be continued.)

AIR COMPRESSOR LUBRICATION.

SOME useful hints on "Air Compressor Lubrication" are given in a little publication recently issued by the Joseph Dixon Crucible Company, Jersey City, N.J. In the lubrication of air compressors and pneumatic tools a common fault is to use too much oil, and oil that has too low a flash point. An air compressor does not require as much oil as a steam cylinder; in fact, it is far better to limit the use of oil to a minimum. Oil tends to cause the valves to stick, and thereby necessitates frequent cleaning. If kerosene is used to remove the deposit the valves must be taken out, although engineers have been known to introduce kerosene through the air inlet valves for this purpose. Kerosene will clean the valves, but it is also equally effective in producing an explosion. In spite of the care exercised in designing and operating compressors, disastrous explosions still occur and are usually traceable to the presence of inflammable gas in the air lines. Such a condition is nearly always due to the improper use of lubricating oils. The company recommends the lubrication of air compressor cylinders with soapy water and flake graphite. Such a mixture, they state, provides economical, efficient, and safe lubrication and keeps the valves clean. A little oil should be introduced when shutting down the compressor to prevent any tendency of the soap suds to cause rusting. By this method all dangers attending the use of oil are overcome. Flake graphite has a strong tendency to attach itself to metal surfaces, and, when thoroughly worked into the inequalities, imparts a superficial glaze or veneering of great smoothness, high polish, and endurance that prevents the actual contact of metal to metal, and makes it possible for relatively small quantities of fluid lubricants to provide a safe and sufficient film or lubricating layer. Flake graphite is an inert mineral; its normal smoothness is quite unaffected by any degree of heat attainable in the air compressor cylinder. Under no condition can it be volatilised, carbonised, or baked into a hard or gummy mass to interfere with the free action of the valves. On the contrary, its presence upon working surfaces is a guarantee of smooth operation.

STEAM ENGINES FOR DRIVING REVERSING ROLLING MILLS.*

BY JOHN W. HALL.

A STEAM engine working a large reversing mill has to perform the most severe duty demanded of any engine. To drive the rolls fast enough to finish long lengths at a single heat, the piston must run at the highest rate possible. To attain this speed promptly, there must be a sufficient reserve of power to impart to the crank shaft immediately after starting a twist about twice as great as that needed to run the engines up to full speed, at which they will develop close upon 10,000 h.p.

The engine must be under such perfect control that it can be kept creeping round until the rolls bite the piece to be treated; it must stop instantly when the piece leaves the rolls, and must reverse at once to take it back again; it must gather full speed so promptly that during the last few passes, when the section has become so thin as to cool rapidly, it can be got through the mill before it becomes so hard from loss of heat as to damage the rolls. To ensure promptitude in starting, stopping, and reversing the revolving weights must be low and the steam pressure high, and yet the reciprocating masses must be light, or their weight will produce dangerous shocks.

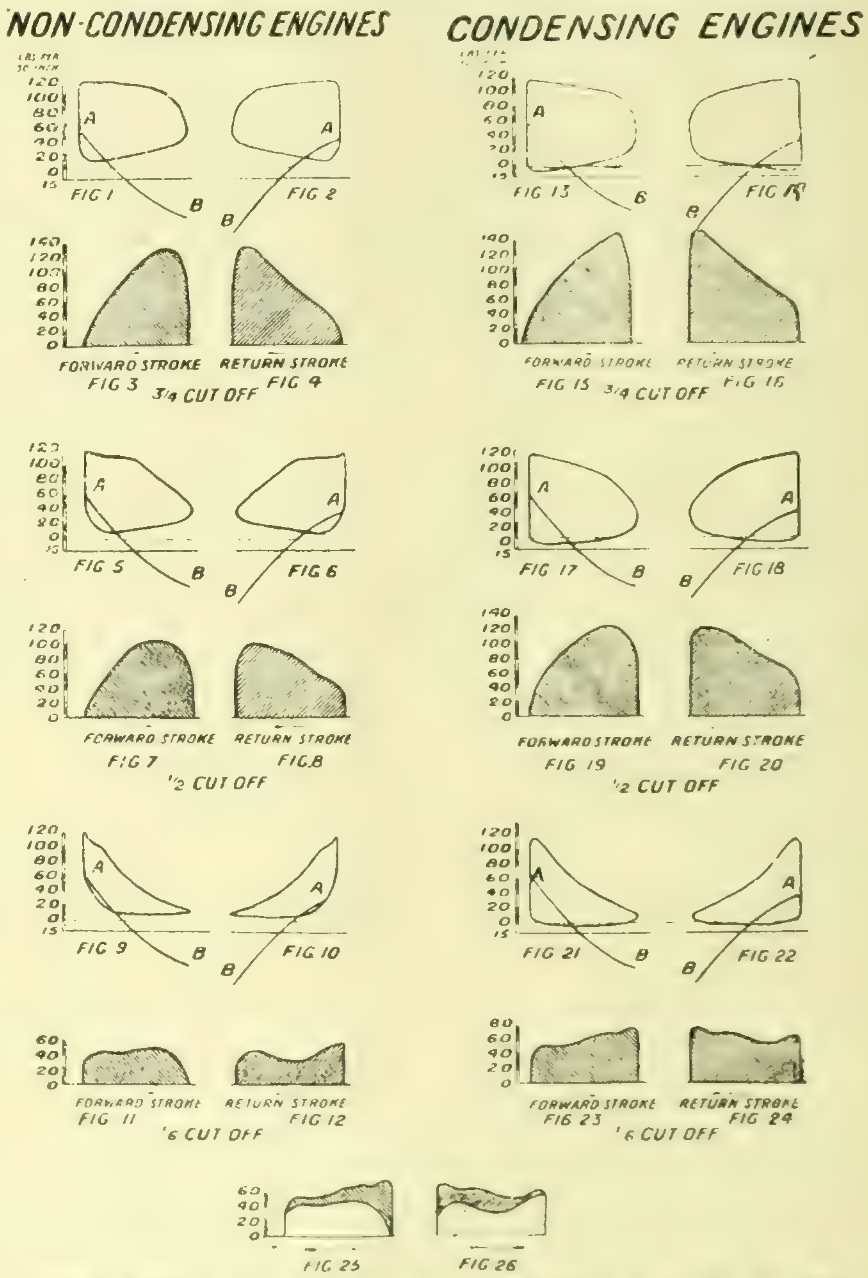
The engines employed for the work usually have pistons of about 48in. diam., with a stroke of about 5ft., and make about 120 revs. per minute. At the beginning of each stroke the reciprocating parts, consisting of the piston with its rod cross-head and connecting rod, by reason of their inertia, offer a great resistance to movement. The pressure must be high enough to overcome this, and to give them, in one-eighth of a second, a velocity of 31·4ft. per second, which gravity would need nearly a whole second to impart, did they fall freely in space from a height of nearly 16ft. The initial pressure necessary to do this is about 120lbs. per square inch. The momentum imparted must then be absorbed and the parts brought to rest in another one-eighth of a second, or a violent blow will be struck on the crankpin and passed on to the crank shaft bearings, wasting much power in mere destructive hammering of the brasses.

The slowing down is best effected by closing the exhaust port at a fairly early period of the stroke, so as to confine, between the rapidly advancing piston and the cylinder cover, as much as possible of the exhaust steam still remaining in the cylinder from the previous stroke. This is compressed into the port and clearance space, where it will replace an equal weight of live steam which otherwise would have to be taken from the boiler. In this way the piston returns energy not utilised in overcoming the resistance of the mill, and stores it for use on its return stroke. The cushion of steam reduces the knock on the pin when the crank turns the centre, and if compression can be carried so far that the cushion pressure is as high as the boiler pressure, the whole of the surplus energy is recovered.

Now if the engine exhausts to the atmosphere the steam remaining in the cylinder may have a pressure of about 2·3lbs. higher, or 17lbs. absolute, which will rise in pressure to 68lbs. when compressed into one-fourth of the space. But if the engine exhausts into a condenser the pressure remaining in the cylinder will be only about 2·3lbs. above the vacuum in the condenser, or say 5lbs. absolute; and when compressed into one-fourth of the space will rise in pressure only to 20lbs. per square inch, which will provide a very poor cushion to bring the piston to rest.

Nor in this instance is the economy obtainable by using a condenser very great. The temperature of steam at a boiler pressure of 120lbs.—say 135lbs. absolute—is 350°, at 68lbs. 300°, at 20lbs. 228°, at 17lbs. 220°, and at 5lbs. 162° Fah.—absolute pressures in each case. Steam then entering the cylinder of an engine exhausting to the atmosphere finds the piston, cylinder cover, and port in contact with steam at a temperature of 300° Fah., while no portion of the cylinder has been exposed to a temperature below 220° Fah. But steam entering the cylinder of an engine exhausting into a condenser finds the piston, cylinder cover, and ports in contact with steam of only 228° Fah., while parts of the cylinder have been exposed to a temperature as low as 162° Fah. In the case then of the condensing engine initial condensation will be considerably greater, and more steam must be taken from the boiler to fill the clearance spaces. Consequently a condenser, though increasing the power of such an engine, increases also the weight of steam used, so that the consumption per horse-power will not be much less, but the wear and tear will be much more.

To reduce the range of temperature compound engines are sometimes employed. Suppose that between the boiler and each 48in. cylinder of a reversing engine we place a 30in. cylinder, into which the steam from the boiler is first admitted. With the simple engine, at the moment of reversal, the full boiler-pressure can be thrown on to the 48in. piston, which has an area of 1,810 sq. in., but with the com-



pound engine this pressure can be thrown only on to the 30in. piston, which has an area of only 707 sq. in. Consequently the margin of power necessary for quick reversal is wanting. To ensure as prompt starting as in the case of the simple engine the cylinders would need to be nearer 40in. and 64in. diam., and this would nearly double the cost of the engine and its maintenance.

Methods are in use for banking up the steam in the receiver between the high and low pressure cylinders of a compound reversing engine for use at the moment of reversal, but such devices are not very effective. The economy of the compound over the simple reversing engine has not been very marked, and has been largely due to the fact that every time an engine is reversed a cylinder full of steam is thrown away. In a compound engine the steam from the low-pressure cylinder is wasted, but that from the high pressure cylinder is caught and used up in the low pressure. When the steam can be used up in this way in a turbine the compound engine would not seem to afford a saving of steam sufficient to justify its additional cost and complication.

* Paper read before the Iron and Steel Institute. May, 1912

While, therefore, it is not advisable to exhaust from a reversing engine direct to a condenser, the same objections do not apply to exhausting at about atmospheric pressure into a turbine, which can utilise this exhaust steam and itself discharge into a condenser, extracting from the exhaust steam about as much power as the engine has already got from the live steam. This becomes possible because the heat in the steam is the cause for, and the measure of, its power to give out mechanical work, the energy from it being due and proportionate to the fall in temperature which occurs when steam is expanded in the engine, whether of the piston or turbine type.

Now steam at 120lbs. boiler pressure has a temperature of 350° Fah., and if rejected by the piston engine at just over atmospheric pressure, or 230° Fah., the engine cannot possibly convert into work more than 120° fall in temperature. If this steam is then passed through a turbine which can further expand it down to the temperature of the condenser, which is about 130° Fah., the turbine is then turning to account a further range of 100°, which otherwise would have to be wasted because no piston engine can usefully expand steam much below five-sixths of atmospheric pressure. To do so the pistons would have to be of impracticable size and cost, while the friction caused by them, together with the loss of heat when such enormous surfaces were subjected to wide variations in temperature, would neutralise any gain theoretically obtainable by such high grades of expansion.

The turbine, on the other hand, has only one rotating part carried in two bearings, so that the mechanical friction is very low, the flow of steam through it is always in one direction, and therefore there are no losses induced by alternate heating and cooling; there are no clearance spaces to be filled up, there are no reciprocating pieces to set up inertia or momentum stresses, and therefore the speed of the blades is not limited to a maximum of 1,900, but may reach over 19,000ft. per minute. This materially reduces the size and cost of the apparatus.

Still the turbine is not usually as efficient at high pressures as the piston engine. A well-fitted piston allows very little steam to pass it at any pressure, but the percentage of leakage through the clearance which must be left between the tips of the blades and the casing of a turbine is a serious matter at the high-pressure end, where the blades are short, though much less at the low-pressure end, where the blades are long and the pressure lower. Hence the piston engine is most efficient at high pressures, but the turbine at those below the atmosphere, the combination comprising the best qualities of both types of prime mover. The exhaust turbine removes the only objection to the simple reversing engine, namely, its high steam consumption, but leaves its good qualities, its simplicity, and low first cost, and its amenability to prompt handling and rapid increase of speed all unimpaired.

Figs. 1, 2, 5, 6, 9, 10, 13, 14, 17, 18, 21, and 22 are the indicator diagrams obtained from such an engine having a clearance space of 10 per cent. of the volume swept out by the piston—the smallest obtainable with piston valves—working with a pressure at the steam chest of 120lbs. above the atmosphere, and with the steam cut off at various points of the stroke. The mean speed of the piston is 1,200ft. per minute, and the weight of the reciprocating parts $4\frac{1}{2}$ tons per cylinder—a fair average for such pieces. Figs. 1 to 10 are for the engine when non-condensing, and Figs 13 to 22 when condensing.

To allow for the influence of the inertia and momentum of the reciprocating parts the lines A B are drawn across each diagram; they are curved to allow for the irregularities in velocity introduced by a connecting rod of the common length —five times that of the crank. By taking the difference of pressures shown by the indicator to exist on the two sides of the piston, and deducting from this the height of the inertia curve when above, and adding the depth when below the line, there are obtained the diagrams Figs. 3, 4, 7, 8, 11, 12, 15, 16, 19, 20, 23, and 24, shown cross-hatched below each indicator diagram.

These "equivalent pressure" diagrams are most convenient. On them the resistance induced by inertia is subtracted from, and the assistance induced by momentum is added to, the force produced by the steam. Then by multiplying the "equivalent pressure" answering to any point in the piston's travel by the effective leverage of the crank at the same instant, the tangential twist actually exerted on the crank shaft is accurately known, whatever may be the position of the crank.

The above method is doubtless familiar to all making a serious study of the steam engine, but it may be as well to point out how clearly this graphic method proves that the condenser, by reducing the pressure of the exhaust steam, impairs the cushion required to bring the piston and its attached parts quietly to rest. In Figs. 25 and 26 the equivalent diagrams for a cut-off at one-sixth of the stroke when non-condensing are superposed on the diagram when condensing, and the difference between them is cross-hatched. Instead of the pressure upon the crank pin decreasing, it increases towards the end of the stroke, more particularly on the return stroke, in which, owing to the angle of the connecting rod, the speed of the piston is greater during the fourth than it was during the third quadrant traversed by the crank pin. The motion of the piston of an engine exhausting into a condenser is that of the foot of a cyclist who stamps on his pedals instead of reducing the pressure as his foot nears the bottom of the stroke.

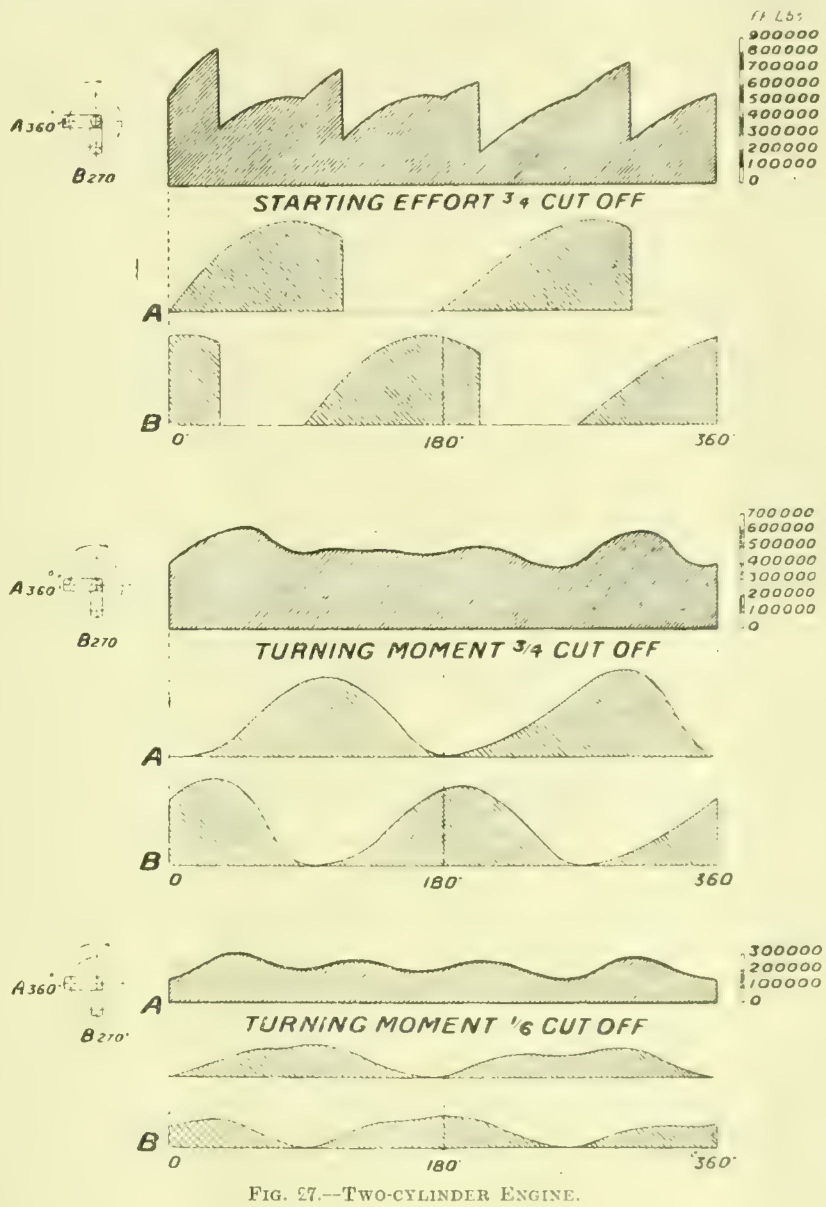


FIG. 27.—TWO-CYLINDER ENGINE.

The earlier in reason the steam can be cut off the less of it will the engine use. But if the valve gear is so arranged that steam cannot be carried very far in the stroke, there must be many positions in which, when the engine is stopped, steam admitted to the steam-chest cannot find its way into the cylinder because the valves block the ports; or, if the steam can get in, the position of the crank is such that there is not sufficient purchase to turn the shaft round.

The case of an engine having two cranks set at an angle of 90° from each other is shown in Fig. 27. The upper part exhibits the effort which the steam can exert on the crank to start the engine from the state of rest in any position, with

valves set to cut off at a maximum period of three-quarters of the stroke. In practice this is found the earliest point in the travel of the piston to which it is possible to limit the admission in an engine with only two cylinders, if such an engine is to start promptly. This allows a minimum starting effort of 190,000ft.-lbs. in any position in which the engine may chance to stand.

Fig. 28 shows that if a third cylinder be added, and the cranks are spaced at an angle of 120° apart, the valves may then be set to limit the admission to half stroke, and yet there will be an effort of 190,000ft.-lbs. available for starting the engine. The saving in steam due to limiting the maximum cut off to half instead of to three quarters of the stroke will be about 30 per cent. at the latest cut off, when the consumption of steam is highest.

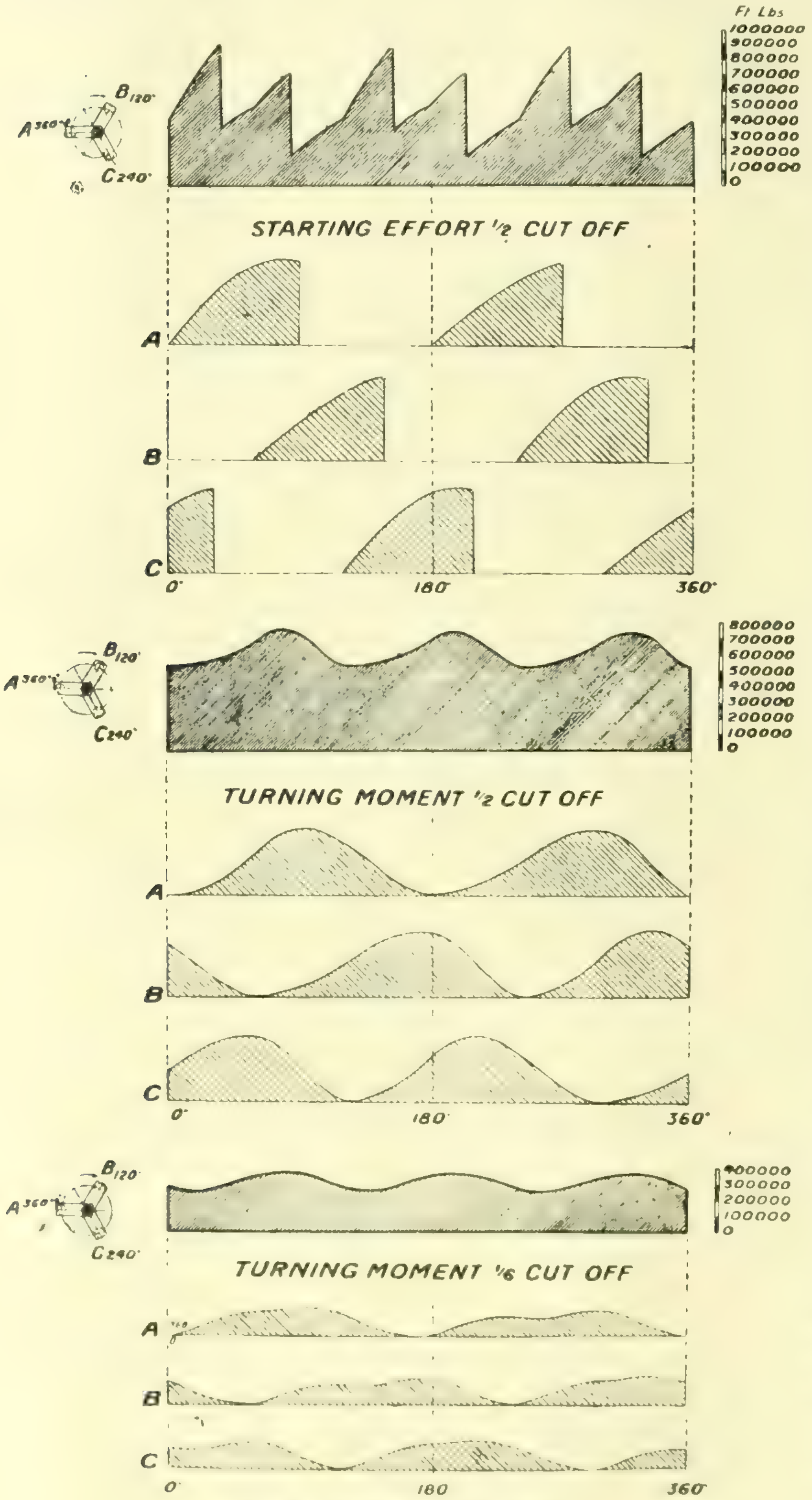


FIG. 28.—THREE-CYLINDER ENGINE.

The turning moment of the 3-cylinder engine when running is also much improved. At high speeds, when shocks are most detrimental, the variation between the maximum and the minimum turning efforts is as 2·2 is to 1 in the 2-cylinder, but only as 1·5 is to 1 in the 3-cylinder type. The running at slow speeds is also better, because the weight of the three cranks balance each other in any position, and there is none of that tendency to "hang" displayed by 2-cylinder engines when both cranks come to the bottom.

With two cranks at right angles the centre of gravity of the cranks, pins, and connecting rods is situated at a considerable distance outside the axis of the crank shaft; at high speeds this sets up a large unbalanced force tending to move the engine as a whole upon its foundations, which must be massive to absorb the vibration. With three cranks spaced equally there is no such unbalanced force tending to move the engine as a whole.

True, both these defects of the 2-cylinder engine can be counteracted by balance weights, but as these add considerably to the revolving weights, they make the engine more sluggish in starting and less prompt in stopping.

From every point of view, then, the 3-cylinder engine is superior to the 2-cylinder, and its very general adoption of recent years is not therefore surprising.

Reversing engines, which are none too large to start quickly, all have such an excess of power when at full speed that, though the valve gear is linked up, the engines run away unless the steam is throttled down from boiler pressure, involving considerable loss by "wire drawing."

On considering the defects of existing reversing engines it occurred to the writer that by still further multiplying the number of cylinders and reducing their capacity, the starting effort could be increased and the full boiler pressure utilised much later in the run, with a saving of steam both at commencement and finish.

Fig. 29 shows the working of an engine having five cylinders 36in. diam. by 36in. stroke, the combined capacity of which is 44 per cent. less than that of three cylinders 48in. diam. by 60in. stroke, and 15 per cent. less than that of the 2-cylinder engine of that size. Yet the minimum starting effort of the 5-cylinder engine is 42 per cent. greater than that of the three, and 37 per cent. greater than that of the 2-cylinder engines with larger cylinders.

But apart from the saving in steam which this would effect the shorter stroke of the 5-cylinder engine would permit of its being run at 200 revs., without exceeding the piston speed of the larger engines, running at 120 revs., so enabling a larger output to be obtained from the mill. Also the turning moment obtained from the 5-cylinder engine, as shown in Fig. 29, is so nearly constant that the maximum stress on the crank shaft, the spindles, and rolls is 25 per cent. less than with the 2-cylinder, and 29 per cent. lower than with the 3-cylinder engines.

The cranks also balance each other against gravity in any position, just as in the case of a 3-cylinder engine; so that there are no unbalanced forces tending to move the engine as a whole on its foundations, and the local unbalanced force may be materially reduced. By placing the two adjoining cranks, not at 72° apart but at 144°, the weights concentrated at the crank pins go a long way towards balancing each other, the disturbing couple being situated at a distance of only 5·56in. from the centre of the crank shaft, whereas in the 3-cylinder engine the couple tending to shake the bearing between the two cranks will be situated at 15in. from the axis of the shaft; and as the centrifugal force is proportional to the square of the speed, the disturbing force, at the same number of revolutions, with the 5-cylinder engine will be as 31 is to 225 in the case of the 3-cylinder engine—only about one-seventh as great—supposing the weights for both engines were alike, whereas the connecting rods of the 5-cylinder would be appreciably lighter.

In addition to these advantages, the first cost of five engines with cylinders 36in. diam. by 3ft. stroke would not be more than about three-fourths of that of three engines having cylinders 48in. diam. by 5ft. stroke. The cost of the spare parts to be kept in stock in case of a breakdown would also be reduced by about one-half; and if the five sections of the crank shaft were made all precisely alike, as could be easily arranged, only one-fifth of a crank shaft would be needed to ensure immunity against having to wait while a new crank shaft was being made to replace a broken one. Indeed there would probably be very little difficulty in running with four cylinders only for some considerable period if desired.

The most marked advantage, however, would be in the case of a plant containing cogging, roughing, and finishing

mills. In this case the keeping in stock of a complete spare engine, even down to the cylinder and bedplate to renew any one broken, would only add one-fifteenth to the whole cost of the three sets of engines, and by making the parts interchangeable a damaged engine could be literally lifted out and a new one dropped in its place without stopping the plant for more than a few days.

There is one further point to deal with, namely, the steam pressure. The higher the pressure against which the engine exhausts the more efficient is the cushion. There seems no reason why the common pressure of 120lbs. should not be materially increased now water-tube boilers are available. The writer has had several engines, for the design of which he is responsible, working for some years now with steam of 200lbs. pressure superheated 150° Fah., and has experienced no trouble whatever with them. Pressures of 250lbs. and 265lbs. have long been common in the Navy; and there seems no reason whatever why steam of 300lbs. pressure, superheated 150° Fah., up to which temperature no difficulties arise, should not be regularly used in reversing engines.

Fig. 30 shows the theoretical diagrams worked out for a reversing engine with a clearance space of 15 per cent., starting with a boiler pressure of 300lbs. and exhausting against a pressure of 80lbs.; then, allowing for a loss of 15 per cent. in transfer, this steam is shown expanded down in an engine having a clearance space of 10 per cent. (easily obtainable when engines are not required to reverse) expanded three and one-half fold, and exhausted at 17·5lbs. absolute, after

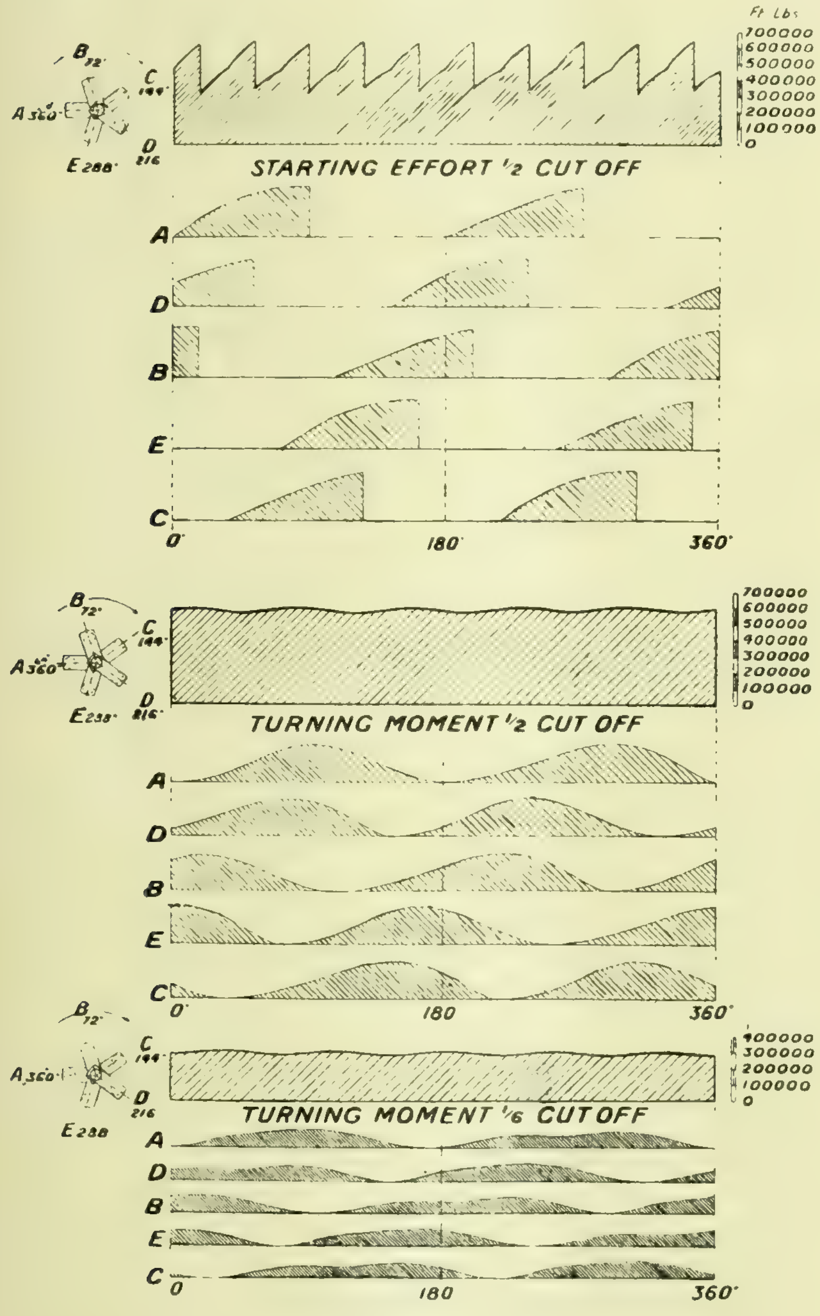


FIG. 29.—FIVE-CYLINDER ENGINE.

which it would be expanded down again in an exhaust turbine.

Consider the case of blastfurnaces consuming 50 tons of coke per hour and yielding 140,000 cub. ft. of gas per ton of coke; the gas given would be 7,000,000 cub. ft. Allowing 45 per cent. of this for heating the stoves there would remain for producing power 3,850,000 cub. ft. of gas per hour. Employing this gas to raise steam at 300lbs. pressure, superheated 150° Fah. in boilers capable of evaporating 50lbs. of water per 1,000 ft. of gas, there would be available 192,500lbs. of steam per hour.

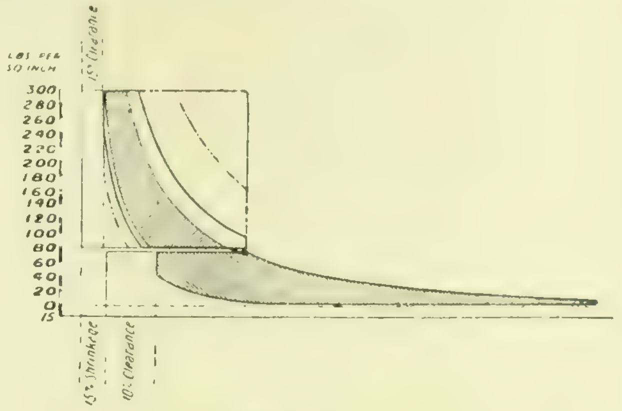


FIG. 30.

This steam taken direct to reversing engines in the mill requiring 30lbs. of steam per indicated horse-power when exhausting against a pressure of 80lbs. per square inch, would afford a continuous output of 6,416 i.h.p. hours.

Allowing that this exhaust steam would lose 15 per cent. in weight by condensation, &c., and drop 5lbs. in pressure, there would be left 163,625lbs. of steam at 75lbs. pressure to supply blast. Engines worked by this steam, which would yield 1 i.h.p. for every 31lbs. of steam when discharging at a little above atmospheric pressure, would provide 5,278 i.h.p. for blowing the blastfurnaces. The blast required would be about 4,875,000 cub. ft. per hour, or 81,250 cub. ft. of free air per minute, to compress which to 8lbs. pressure per square inch would require about 32½ net indicated horse-power per 100 cub. ft., or 2,641 i.h.p. Blowing engines having a mechanical efficiency of 85 per cent. and a volumetric efficiency of 90 per cent. (giving an overall efficiency of 76½ per cent.) would absorb in this work 3,452 i.h.p., leaving a margin of 1,826 i.h.p. to meet contingencies.

Deducting 5 per cent. leaves 155,444lbs. of exhaust steam from these engines, which would produce, in an exhaust turbine capable of generating 1 e.h.p. for 30lbs. of steam, 5,181 e.h.p. for the supply of current for the various purposes for which power is required about a works.

Seeing there would be only one set of boilers and one set of condensing plant for the three departments—the blastfurnaces, rolling mills, and general electric supply—while all the engines would be of simple pattern, the first cost of such plant would be extremely moderate and the working costs very low.

It may be interesting to compare this proposed method of working with that of doing the same work by gas engines, taking 1,000 cub. ft. of gas to produce 11½ i.h.p. The gas-blowing engines, to be capable of producing the same power as before, namely, 5,278 i.h.p., would require 458,956 cub. ft. of gas; to provide electric current equal to 5,181 h.p. would require 7,200 i.h.p., consuming 626,087 cub. ft. of gas; and taking the overall efficiency of an Ilgner set at full load at 60 per cent., or say 55 per cent. average, there would be required 11,665 i.h.p. to drive the mills consuming a further 1,014,434ft. of gas, making in all a total of 2,099,479 cub. ft. This would leave a surplus of 1,750,521ft. of gas available for some other purpose.

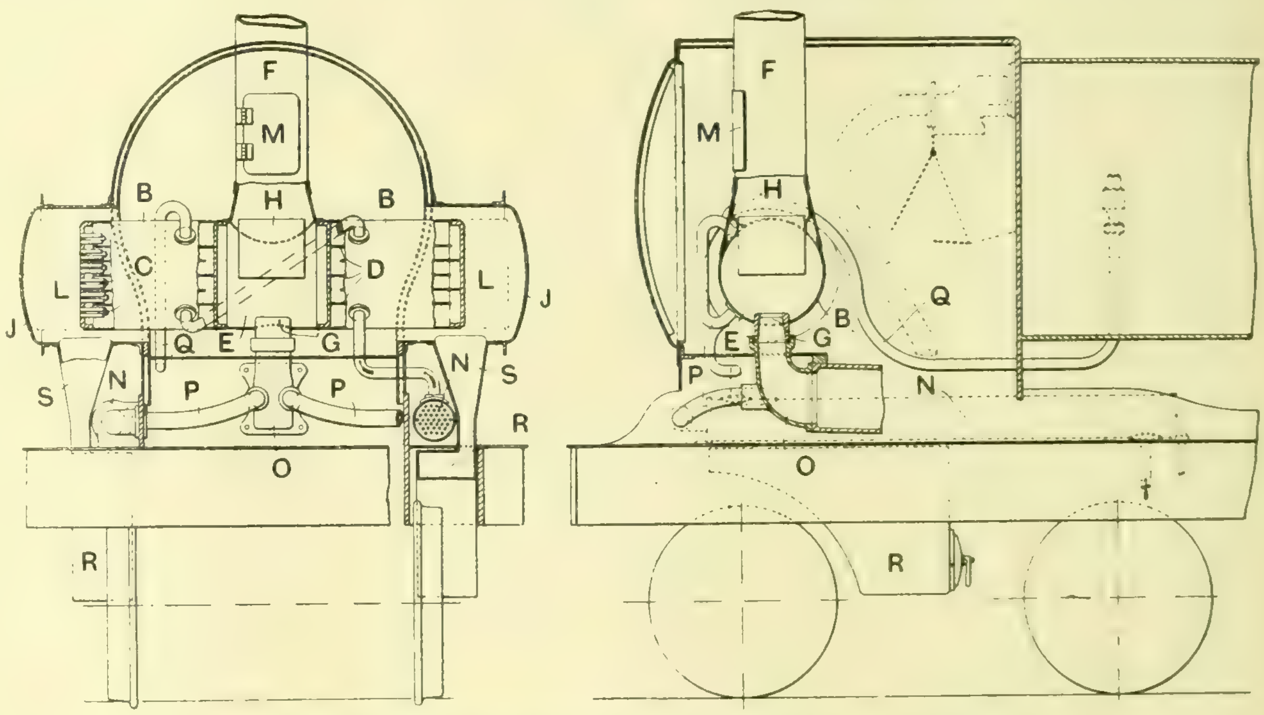
Against this, however, would have to be set the interest, depreciation, and wear and tear of the gas cleaning and electric plant and gas engines, and the higher amount of wages necessary to clean, work, and tend them. Which of the two systems would, on the whole, be the cheaper to run would depend upon the price obtainable for the surplus power.

Electric Towing Locomotives for Panama Canal.—We understand that 40 electric locomotives for towing ships through the Panama Canal are to be purchased by the canal authorities. Before deciding on any particular type, electric locomotive makers are each to be invited to furnish a locomotive, with which experiments will be carried out.

SUPERHEATERS AND FEED-WATER HEATERS FOR LOCOMOTIVES.

WE illustrate herewith an arrangement of steam superheater and feed-water heater applied to a locomotive designed and patented by F. H. Trevithick, Zeitoun, Cairo, Egypt. The arrangement is such that it may be employed: (*a*) As a system of steam superheating by waste gases from the boiler and feed-water heating by exhaust steam; (*b*) as a system of feed-water heating by exhaust steam and by part of the waste gases and superheating by part of the waste gases; or (*c*) as a system of feed-water heating by the exhaust steam from the cylinder and the whole of the waste gases from the boiler with no superheating.

Fig. 1 is a front elevation partly in section, and Fig. 2 a side elevation partly in section of the arrangement. In its application to a locomotive fitted with a high degree superheater there is provided a pair of drums B filled with tubes C amongst which the water or steam to be heated is made to circulate, division plates or baffles D being employed in order to ensure that the water or steam shall be made to assume a sinuous or tortuous path through the heater so that the fluid shall be brought into thorough contact with the tubes C through which the hot waste gases are drawn from the boiler on their way to the chimney. The inner or adjacent ends of the drums B are connected by a tee piece E adapted to form the lower portion of the uptake, the chimney F of the engine being prolonged downwards and connected to this lower portion, the arrangement being such that a chimney of considerable length may be secured irrespective of exterior limiting conditions. The blast pipe G is arranged to eject vertically into the space formed by the tee piece E, the blast thus being directed up the chimney as in ordinary practice with the exception that it is entirely enclosed, and in order to make the interior of E self-clearing there is arranged within the tee piece E a petticoat H which enables a blast pipe protruding only slightly into the interior to be used. The action of the blast in the chimney tends to cause a vacuum in the enclosed space of the tee piece E and uptake and thereby has the effect of drawing the furnace gases on leaving the boiler tubes equally through both the drums B although it will be evident that with suitable arrangements more of the waste gases may be allowed to pass through one drum than the other if thought desirable, or they may be cut off entirely from either drum if required. To facilitate the removal of the heater drums openings are provided fitted with doors J. Any suitable arrangement may be adopted to act as a spark arrester. This may consist of wire gauze in the form of sleeves slightly overlapping the ends of the heaters, or sieves L fitted at their extremities inserted through the side doors J.



ARRANGEMENT OF SUPERHEATER AND FEED-WATER HEATER FOR LOCOMOTIVES.

For the purpose of facilitating the lighting-up of the furnace there is provided a hinged or oscillating door or baffle plate M either above or below the level of the blast pipe orifice which may be operated directly or by a lever situated on the outside of the smoke-box or by means of a crank or connecting rod arrangement, the end of the connecting rod being situated in the cab of the locomotive. The arrangement is such that when lighting up the furnace or at other times when the blast or jet-blower is not in use the baffle plate or hinged door may be opened so that the furnace gases are thereby enabled to pass directly into the chimney thus ensuring for them a freer passage. Except when the heaters are situated very low in the smoke-box, this by-pass or door M may be inserted in the side of the tee piece E or blast chamber, when in addition to the above purpose it may be employed if for any reason it is not found desirable to draw the furnace gases through the heaters.

The exhaust steam heaters N are fed with exhaust steam from the blast pipe G or from an elbow O connected with the blast pipe by way of the pipes P. The feed water traverses the heaters N prior to entering heaters B through which it passes in succession and away by means of the pipe Q to the boiler clack valve. In conjunction with each heater vessel B there is provided an ashbox R into which the ashes collecting in the ends of the heater shell and arrested by the sieves or sleeves L may be led through a chute S, the ash-boxes being fitted with doors so that they may be readily emptied of their contents when required.

WATERTIGHT BULKHEADS: APPOINTMENT OF A TECHNICAL COMMITTEE.

THE President of the Board of Trade has appointed a technical committee to advise him in the interests of safety of life at sea with regard to the internal sub-division of vessels of all classes by watertight bulkheads and other means. The reference to the committee is to advise: (1) As to what in their opinion would constitute efficient sub-division with regard to each of the classes of vessels included in the rules for life-saving appliances made by the Board of Trade under Section 427 of the Merchant Shipping Act, 1894, having due regard to the nature of the service in which they are respectively engaged. (2) Whether independently of the foregoing the committee desire to make any recommendations with reference to the sub-division of vessels already built, or of new vessels, which would in their opinion contribute to the safety of life at sea.

The committee is constituted as follows: Mr. Archibald Denny, LL.D. (Messrs. William Denny & Bros., Dumbarton), naval architect, chairman; Mr. James Bain (late superintendent engineer of the Cunard Line), engineer; Mr. E. R. Champness, M.V.O. (Assistant Director of Naval Construction, Admiralty); Mr. G. B. Hunter (Messrs. Swan, Hunter, and Wigham Richardson, Ltd., Wallsend-on-Tyne), naval architect; Mr. Summers Hunter (North-eastern Marine Engineering Company, Ltd., Wallsend-on-Tyne), engineer; Mr. J. Foster King, chief surveyor of the British Corporation for the Survey and Registry of Shipping; Mr Andrew Laing (Wallsend Slipway and Engineering Company, Ltd.), engineer; Mr T. J. Luke (Messrs. John Brown & Co., Ltd., Clydebank), naval architect; Mr. S. J. P. Thearle, DD.Sc., chief ship surveyor of Lloyd's Register of British and Foreign Shipping; and Mr. J. J. Walsh, M.Sc., professor of Naval Architecture, Armstrong College, Newcastle-on-Tyne.

The Oil-engined Ship "Sembilan."—This vessel established a long distance record for Diesel ships, by running from Aden directly to Sabang (Sumatra) in 18 days, maintaining a speed of 8 miles, and arriving on May 12th

THE HARRISON-HUGHES ENGINEERING LABORATORIES AT LIVERPOOL UNIVERSITY.

THE new engineering laboratories which have been erected at a cost of about £40,000 out of funds provided by Mr. Thomas Fenwick Harrison, Mr. John William Hughes, and Mr. Heath Harrison, shipowners, of Liverpool, were opened on Saturday last, the 18th May, by the Right Honourable Viscount Haldane of Cloan, the representative of the donors, Mr. Heath Harrison, formally presenting the building to the Chancellor, the Right Hon. the Earl of Derby.

The addition of the new buildings has so modified the whole arrangement and equipment of the department as to involve a general account of both the older Walker and the new Harrison-Hughes portions of the building.

The Walker Engineering Laboratories built and equipped by the late Sir Andrew Barclay Walker, Bart., another Liverpool citizen, at a cost of about £24,000, were formally opened on November 2nd, 1889, and originally consisted of a three-storey building attached to another of one storey, the latter containing the Woodworking Department. Another storey has now been added to the Wood Workshop at a cost of about £2,000, by means of a special fund provided by Messrs. Brunner, Mond, & Co., Sir. W. H. Lever, Bart., and the Right Hon. Sir John Brunner, Bart., about two-thirds of the space in this extension being devoted to cloak and locker rooms and a Students' Common Room, the other third being used as an extension to the Wood Workshop.

The new building is in the form of an L-shaped block, four storeys in height, projecting from the north side of the Walker Engineering Laboratories. In the internal angle between the higher buildings is the new boiler and gas producer house, with roof lights.

The plans, Figs. 1, 2, 3, and 4 show the principal rooms in both the Harrison-Hughes and the Walker Laboratories, through communication being made between them at every floor.

In the Harrison-Hughes Laboratories special attention has been given to all problems relating to the utilisation of fuel for power purposes, and especially to work relating to internal-combustion engines and gas producers, the sections of the laboratories which deal with these subjects being unusually well equipped.

Boiler and Gas Producer House.—This house, see Figs. 5 and 6, contains a Stirling water-tube boiler capable of generating 3,000lbs. of steam per hour at a pressure of 250lbs. per square inch, and a marine boiler, 9½ft. diam. by 9ft. long, with two furnaces, built by Messrs. David Rollo & Sons, and capable cf generating 4,000lbs. of steam per hour at a pressure of 215lbs. per square inch. The Stirling boiler has a Green's economiser containing 48 pipes. The Rollo boiler has an air-heater economiser in the uptake, and may be used either with natural draught, or with forced draught, produced by an electrically-driven fan, constructed by Messrs. Matthew Paul & Co. This boiler is also equipped with a live-steam feed-water heater, by Messrs. John Kirkaldy, Ltd.

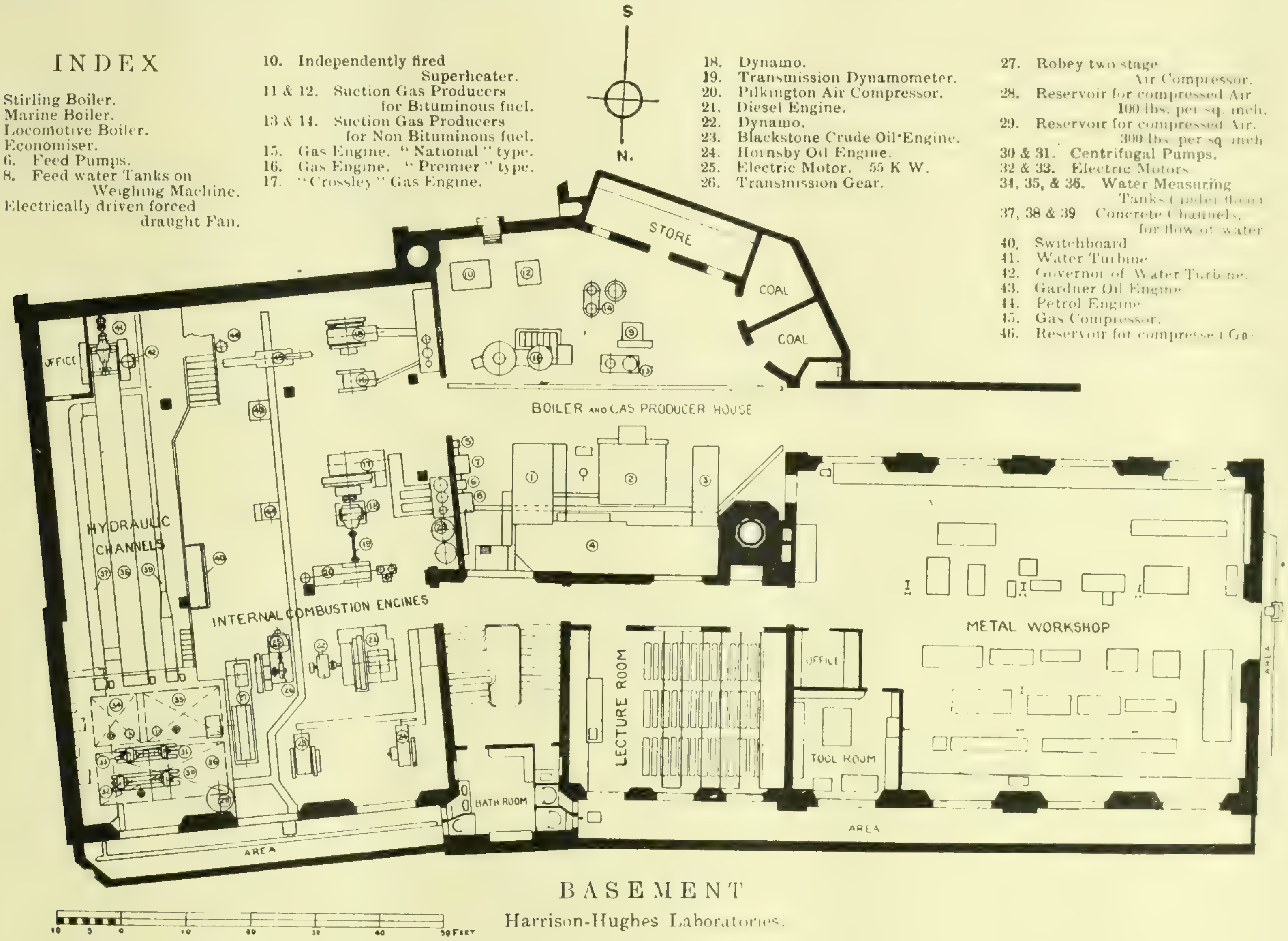


FIG. 1.

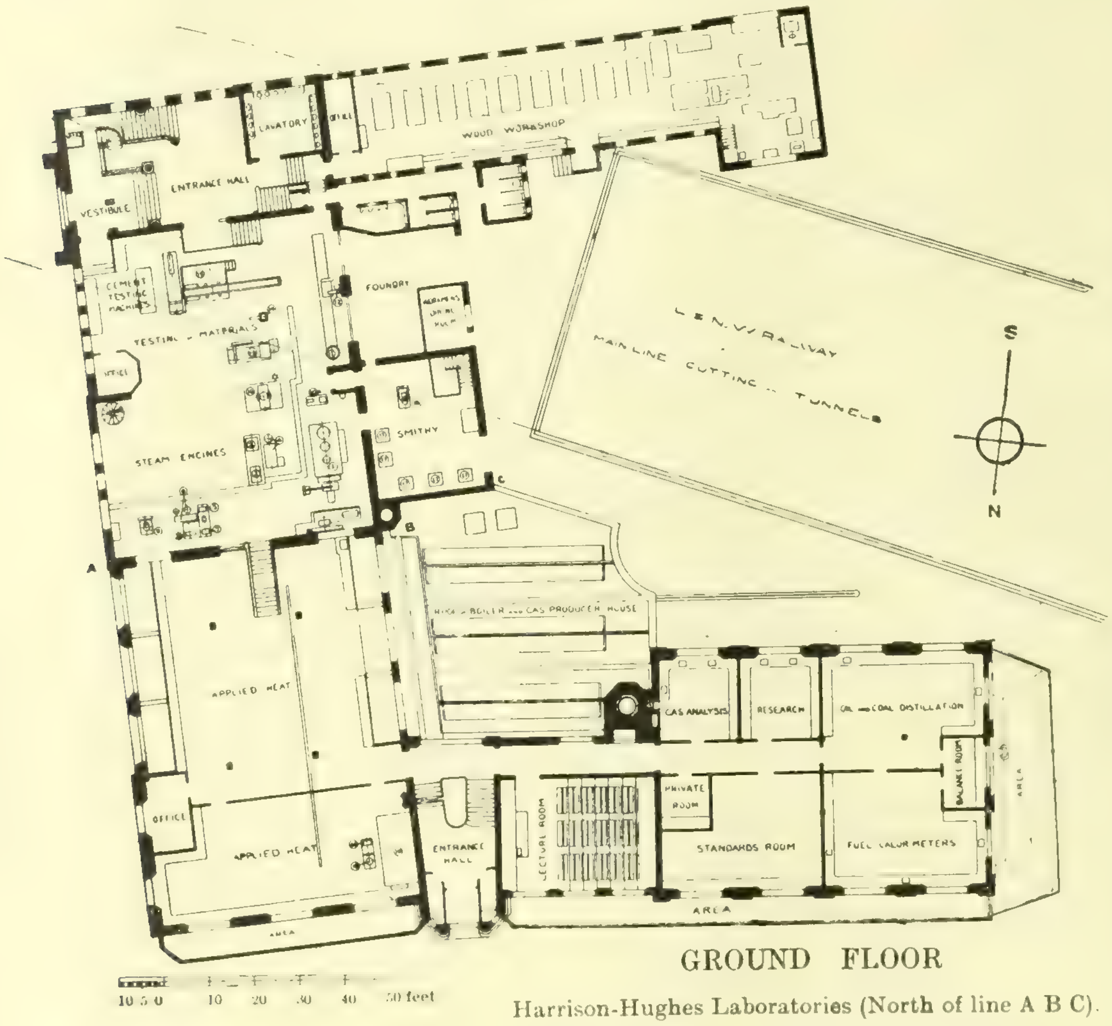
The steam sent to the engines may be either saturated or superheated, an independently-fired superheater, constructed by Messrs. Mechan & Sons, Ltd., being used for superheating the steam. Two feed pumps and an injector are used for supplying water to the boilers. An automatic CO_2 recorder gives continuous indications of the percentage of CO_2 in the products of combustion, and special connections have been made to the chimney on all four floors of the building which enable samples of products of combustion to be withdrawn at these points, and the temperatures and the pressures to be measured. The whole of the boiler plant and auxiliaries have been arranged with a view to enabling the efficiency of every section to be determined separately, as well as the resultant efficiency of each complete unit.

Four different types of gas producers have been provided; the largest of these, of 57 h.p. capacity, constructed by Messrs. Crossley Brothers, Ltd., is their latest type of suction gas producer for gasifying bituminous coal, and it has very complete auxiliaries for removing the tar and dirt from the gas before it is sent to the engines. This producer is also capable of gasifying peat and various kinds of trade refuse. It will,

therefore, enable valuable data to be obtained regarding the fuels which may possibly be used in conjunction with gas engines.

There are two 25 h.p. gas producers for gasifying anthracite or coke—one by the National Gas Engine Company, and the other by the Mersey Engine Works Company; there is also an experimental gas producer of the down-draught type, for experiments on the gasification of bituminous fuel.

Internal-combustion Engine Laboratory: Gas Engines.—This laboratory, see Figs. 7 and 8, contains three gas engines. One of these, by Messrs. Crossley Brothers, Ltd., of 40 b.h.p., is of their latest type for driving dynamos, and is directly coupled by means of a flexible coupling to a dynamo. This machine may also be used as an electric motor. The other end of the shaft of this dynamo is connected, through a torsion dynamometer, to a single-cylinder air compressor, built by Messrs. Peter Pilkington, Ltd., which, under full load conditions, will absorb 30 b.h.p. This gas engine may be used in the following ways: (*a*) For tests of the engine alone, the power then



GROUND FLOOR

Harrison-Hughes Laboratories (North of line A B C).

Walker Laboratories (South of line A B C).

FIG. 2.

INDEX.—1, Triple-expansion Marine Engine. 2, Rateau Steam Turbine. 3, Dynamo. 4, Weir Condenser and Air Pump. 5, De Laval Steam Turbine. 6, Condenser and Air Pump. 7, High-lift Centrifugal Pump. 8, Pelton Wheel. 9, Single Cylinder Vertical Steam Engine. 10, Centrifugal Separator. 10A, Worthington Pump. 11, Vertical Tank for Hydraulic Experiments. 12, Hydraulic Ram Pump. 13, Riehle Torsion Testing Machine. 14, Olsen Testing Machine. 15, 100-ton Buckton Testing Machine. 16, Pneumatic Hammer. 17, Smiths' Forges. 18, Refrigerator. 19, Ice Making Plant. 20, Electric Motor.

being absorbed by a rope brake on a special water-cooled wheel; (*b*) for driving the dynamo only; (*c*) for driving the air compressor, the dynamo circuit being broken. When the engine is disconnected from the dynamo, the dynamo, acting as a motor, may drive the air compressor.

Of the other gas engines, one is of 24 b.h.p., by the National Gas Engine Company; and the other, of 8 b.h.p., was constructed by the students. The National gas engine is fitted with cam disengaging gear for enabling experimental work to be done on the variations of the specific heat of the working fluid in the cylinder, due to variations in temperature and pressure, in the way first devised by Dugald Clerk. All the gas engines are provided with arrangements for varying the volume of the compression space, so that experiments can be made for determining the effect of variation in the compression pressure on the power and the efficiency of the engines.

Oil Engines.—The largest of these is a Diesel engine of [illegible] b.h.p., by Messrs. Mirrlees, Bickerton, & Day, Ltd., and is directly connected to a dynamo by Messrs. Bruce Peebles, Ltd. When it is desired to test the engine alone, the dynamo is disconnected and the power is absorbed by a rope brake on a special water-cooled flywheel.

One of the most interesting engines in this laboratory is a semi-Diesel crude oil engine of 30 b.h.p., constructed by Messrs. Blackstone & Co., Ltd. The power of this engine is absorbed by a dynamometer on a special water-cooled brake drum.

Other engines are a $10\frac{1}{2}$ b.h.p. petroleum engine, by Messrs. Hornsby & Sons, Ltd.; an 8 b.h.p. petroleum engine of the marine type, by Messrs. Gardner & Sons, Ltd.; and two motor-car petrol engines, one of these being of the Knight-Daimler type.

Calorimeters are provided for measuring the amount of heat carried away by the exhaust products of the various gas and oil engines.

Air Compressors.—There are three air compressors, the largest of which is by Messrs. Robey & Co., Ltd. This is a 2-stage tandem cylinder type, with intercooler, and it is capable of compressing 300 cub. ft. of free air per minute to a pressure of 100lbs. per square inch, by gauge. The power required to drive this compressor under full load, at 125 revs. per minute, is 60 b.h.p., which is supplied by a 55 kw. electric motor, running at 760 revs. per minute, supplied by Messrs. The General Electric Company. The power is transmitted through special worm gearing of a very high efficiency, constructed by Messrs. Henry Wallwork and Co. The end thrust of this gearing is taken up by ball bearings, the worm and wheel run in oil, which is kept cool by means of a special radiator through which the oil is forced by a pump. The governing arrangements of the Robey compressor are specially interesting. The governor acts on the admission valves, so that, when the demand for air is below the maximum, the admission valves are prevented from closing during a larger or smaller proportion of the compressing stroke.

The air supplied to this air compressor is measured by a new type of meter, invented by Mr. G. J. Gibbs, of Preston. This meter consists of a thin-lipped rectangular aperture of variable area, through which the air flows under a constant and easily observed head, measured by a water column. The variable quantity in the observation is the area of the slot, which is read by means of verniers or micrometer screws. A box of large capacity is provided between the meter and the compressor for suppressing the more violent pulsations.

The air delivered by this compressor is discharged into a large receiver, from which it may be led to the pneumatic hammer, to other pneumatic tools, and also to a single-cylinder engine.

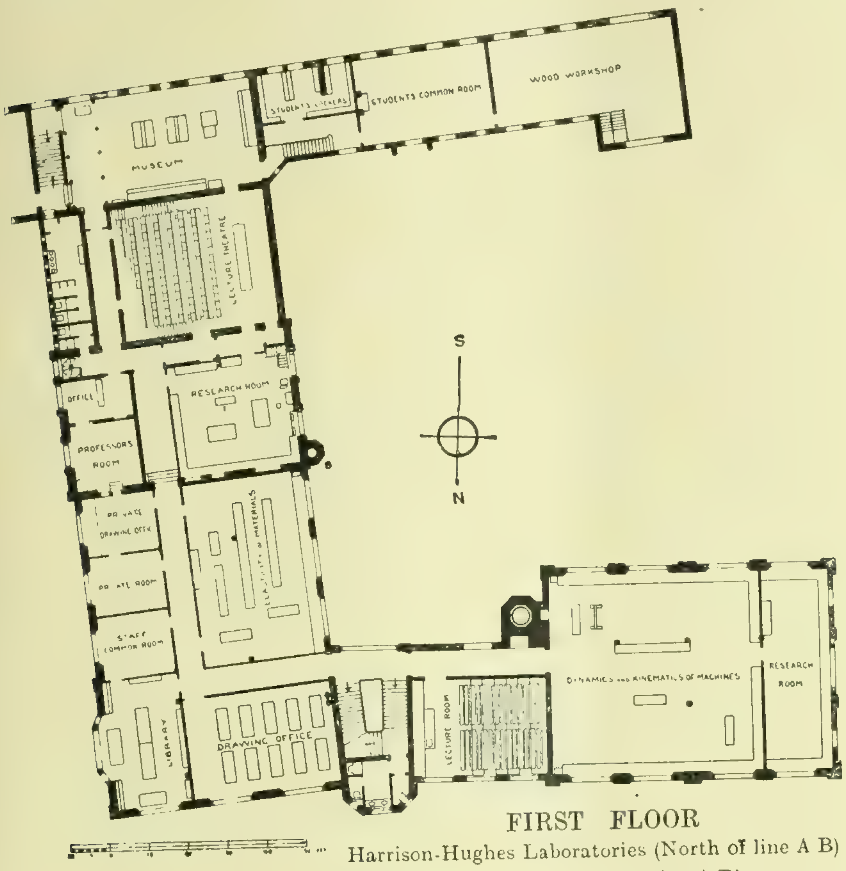
Another of the air compressors is of the double-acting, single-cylinder, 1-stage type, by Messrs. Peter Pilkington, Ltd., and it may be driven either by the Crossley gas engine or by an electric motor, as already mentioned in the section relating to gas engines.

The Robey 2-stage air compressor and the Pilkington single stage air compressor have been proportioned so that the Pilkington machine will act as a third stage for the air compressed by the Robey machine. When the two are worked in series, the air, at 100lbs. pressure, is led from the large receiver to an intercooler fixed near to the Pilkington compressor; and from this intercooler the air flows to the latter machine, which raises its pressure to 300lbs. per square inch, by gauge. The air is then discharged into another large receiver. Connection is made between this receiver and the main steam pipe in the boiler house, so that any of the engines or steam turbines in the Steam Engine Laboratory may be driven by compressed air

The air may be preheated in the independently-fired superheater before being sent to the engines.

A connection is also made between the high-pressure air receiver and the Crossley gas engine, and special mechanism has been fitted to the engine so that it may be started by compressed air.

Steam Engines.—The steam engines, both of the reciprocating and the turbine types are in the Walker Laboratory, see Fig. 9.



FIRST FLOOR
Harrison-Hughes Laboratories (North of line A B)
Walker Laboratories (South of line A B)

FIG. 3.

The largest engine is a triple-expansion marine engine of 150 b.h.p. at 150 revs. per minute. This engine is part of the original equipment of this laboratory, and although it has now been in use about 23 years, it is still in excellent working condition. The engine was built by Messrs. George Forrester and Co., Ltd., of Liverpool, and it is a fine example of good workmanship. Some slight modifications have recently been made with the object of enabling it to use highly-superheated steam. The power of the engine is absorbed by an hydraulic dynamometer. The rate of flow of steam to the engine is shown by a steam meter, the mercury column of which is fixed on the front of the engine. This, and an adjacent tachometer, enable the effect due to alterations of the points of cut-off in the intermediate and low-pressure cylinders to be immediately observed.

Another reciprocating steam engine in this laboratory is a single-cylinder, vertical, reversible engine of 15 b.h.p., by Messrs. Marshall & Sons.

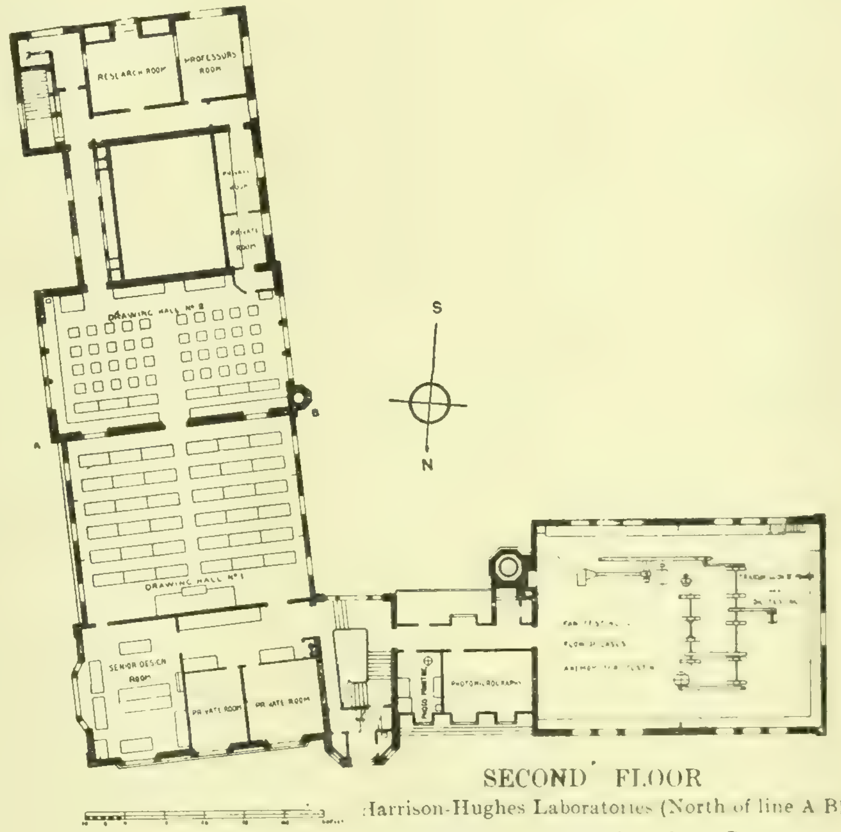
There are two steam turbines; one of these is of the de Laval type, of 15 b.h.p., and it is fitted with two sets of nozzles, one set for working with atmospheric exhaust, and the other set for working with a 28in. vacuum. The other steam turbine is of the Rateau type, of 60 b.h.p., with eight pressure stages. It has been specially constructed for experimental purposes, and it is capable of using highly-superheated steam. This turbine is direct coupled to a dynamo, the field magnet frame of which is mounted on ball bearings, so that, by means of a lever and weights, the torque can be directly measured and the effective power given to the dynamo can be obtained. The pressure gradient of the steam, during its flow through the turbine, is shown by pressure gauges which are in connection with each wheel chamber, and the temperature of the steam at various points within the turbine can be measured. The surface condenser and air pump for this turbine have been specially designed and constructed for experimental purposes, by Messrs. G. & J. Weir, Ltd., and arrangements are made for measuring pressures and temperatures at numerous points. The surface condensers for the de Laval turbine and the Marshall engine are of the "Dripless" type, constructed by the Liverpool Condenser and Engineering Company.

A special portable surface condenser has been provided for making measurements of the amount of steam used by the various auxiliary engines, such as the engine for driving the scraper of the economiser, the boiler feed pumps, and the condenser air pumps. The quantity of condensing water used in conjunction with both the triple-expansion engine and the Rateau steam turbine is measured by means of Venturi meters.

Applied Heat Laboratory.—The Applied Heat Laboratory is immediately above the Internal-combustion Engine Laboratory, and it is being equipped with apparatus for experiments relating to the physical properties of gases and steam, the flow of gases and of steam through nozzles, the determination of the temperature gradient during such flow, and the velocity of efflux from the nozzles. Other apparatus will enable experiments to be made on the flow of heat through metals, "non-conducting" and refractory substances, also on the rate of transfer of heat to and from these substances by convection and radiation. Arrangements have been made, and apparatus provided, for experiments on injectors, steam-jet water pumps, ejector condensers, steam-jet blowers and exhausters. For experiments on combustion, both at constant pressure and at constant volume, a cast-steel cylinder $11\frac{1}{2}$in. in internal diameter, by 5ft. long, is used, and this is capable of safely withstanding a pressure of 2,000lbs. per square inch.

A refractory lining is provided for this cylinder, and it can be readily inserted when required. The cylinder is provided with 12 nipples for the insertion of pyrometers and for the withdrawal of products of combustion for subsequent analysis. It rests in a galvanised iron tank, so that it may, when required, be surrounded with water.

This cylinder is connected by pipes with the air and gas compressors in the Internal-combustion Laboratory. Apparatus has been provided for experiments on the velocity of flow of the products of combustion from this cylinder through turbine nozzles. One object of these experiments is to enable data to be obtained that may be of use in connection with the design of internal-combustion turbines.



SECOND FLOOR
Harrison-Hughes Laboratories (North of line A B)
Walker Laboratories (South of line A B)

FIG. 4.

Another part of this laboratory contains a refrigerating and ice-making machine, of one ton capacity, by Messrs. L. Sterne & Co., Ltd. The ammonia compressor of this plant is driven by an electric motor coupled directly to it. A cold chamber and an air-cooling plant will be added, to work in conjunction with this plant.

In this room there are also a number of glass models for illustrating circulation in various types of water-tube boilers.

Fuel Testing and Gas Analysis.—Four rooms have been provided on the ground floor in the west wing for fuel testing and gas analysis. One of these rooms is equipped with several different types of apparatus for experiments relating to the analysis of products of combustion and of the gases used in internal-combustion engines. Another room is devoted to the experimental determination of the calorific values of solid, liquid, and gaseous fuel.

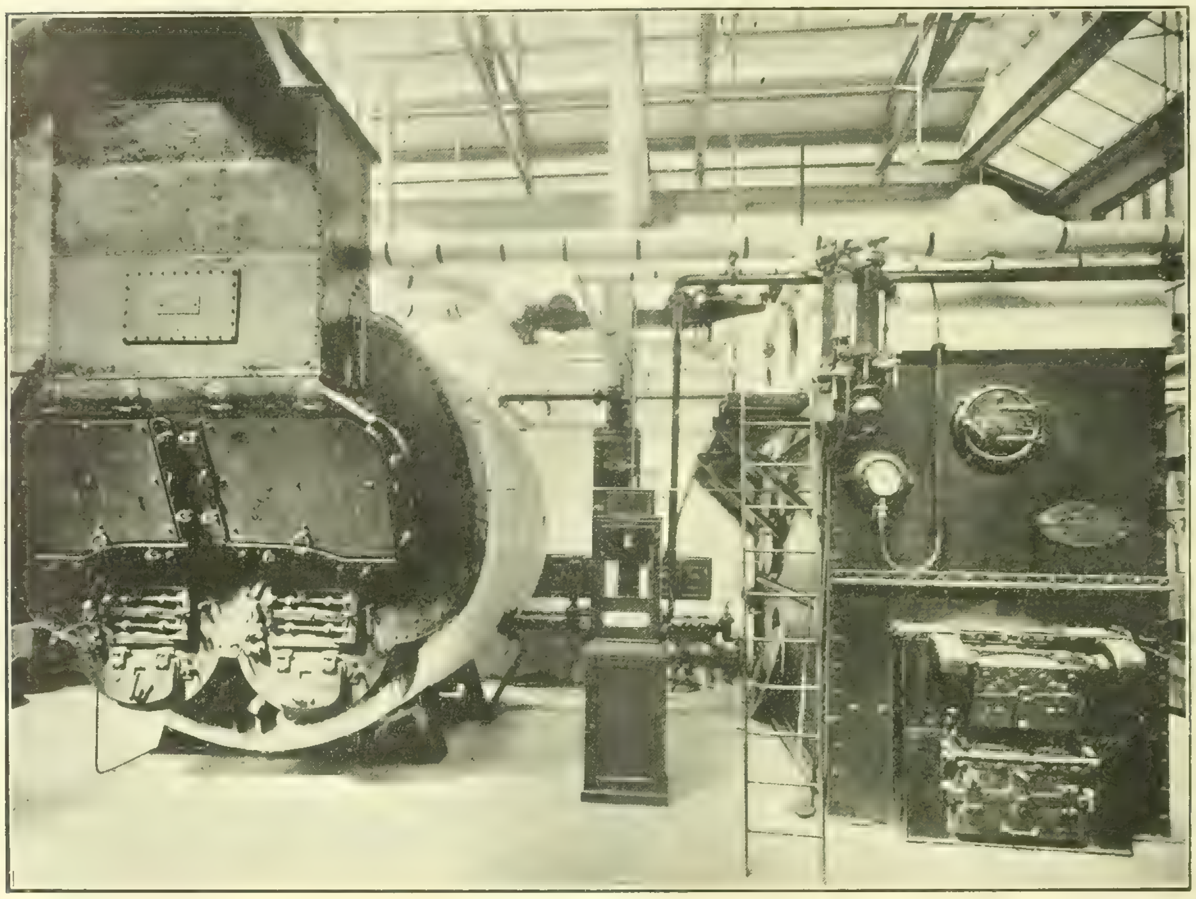


FIG. 5.—BOILER AND GAS PRODUCER HOUSE.

The principal calorimeter in this room is of the Bomb type, by Messrs. Hugershoff, of Leipsic. The water-stirring apparatus connected with this Bomb calorimeter is driven by a small hot-air engine.

In another room are the appliances necessary for making proximate analyses of coal, with the object of determining the percentage of moisture, hydrocarbons, fixed carbon, and ash. Apparatus is also provided in this room for experiments on the fractional distillation of oil, also for the determination of viscosity and the flashpoint.

Adjacent to these rooms are a balance room, a standards room, and a research room; also a private room for the demonstrator in charge of this department.

Hydraulics and Hydraulic Machinery.—On the east side of the Internal-combustion Laboratory, a platform, 5ft. above the level of the floor, has been provided for experiments with water turbines and on the flow of water through channels and over weirs of different kinds, see Fig. 10. This platform is 20ft. wide and 55ft. long, and contains three channels, one 4ft. wide by 4ft. deep, one 2ft. wide by 2ft. deep, and one 1ft. wide by 17in. deep.

The rate of flow of water along these channels is measured by weirs and notches; also by means of measuring tanks under the floor of the laboratory, the water being deflected into one or other of two measuring tanks, or into the sump tank, by means of movable tumbling bays.

The two underground measuring tanks are 8ft. by 8ft. and 8ft. by 12ft. respectively, and the sump tank is 8ft. wide by 21ft. long, the depth in all cases being 13ft. The level of the water in each of the three tanks can be accurately measured by means of special float gauges, while the level of the water in each of the channels is measured by floating point gauges in which the final adjustment is made by means of simple levers which gear frictionally with the stems of the gauges. A Lea recorder is also used for continuously recording variations in the level of the water in the main channel.

The water is pumped from the sump tank to the 10,000 galls. capacity storage tank on the top of the building by means of two centrifugal pumps, each of which has a capacity of 33,000 galls. per hour.

One of these pumps is of the "Rees Roturbo" type, and the other has been supplied by Messrs. Holden & Brooke. Each is driven by an electric motor of 20 h.p., and between each motor and its pump there is a torsion dynamometer for measuring the power transmitted to the pumps.

One of these dynamometers is of the Bevis-Gibson flashlight type, as used for measuring the power of steam turbines on torpedo boat destroyers and other vessels. The other dynamometer is one of Dr. Amsler's latest design, in which the power is obtained by measuring the angle of twist of a high-tension steel rod of square cross section: the measurement of the angle of twist is effected by optical arrangements.

The rate of flow of the water from each centrifugal pump is measured by means of Venturi meters. The main pipes for conveying the water from the centrifugal pumps to the tank on the top of the building, and down again to the hydraulic platform, are each 10in. diam.

At the south end of the hydraulic platform is a water turbine of 14 b.h.p. at 900 revs. per minute, constructed by Jens, Orten-Boving & Co., the speed being controlled by a special automatic oil-pressure governor, which varies the angle of movable guide blades.

FIG. 6.—GAS PRODUCERS.

The head available at the turbine, when the water is taken from the tank at the top of the building, is 65ft.; and when

the water is sent direct from the centrifugal pumps the head available is 80ft.

The water supplied to this turbine is measured both by a Venturi meter and by Pitot tubes, and the discharge is delivered into the 4ft. by 4ft. channel, which has additional means of measuring the rate of flow of water by a new type of float. The interval of time taken by this float between two electrical contacts, at a known distance apart on the side of the channel, is measured by electrically controlled chronographs.

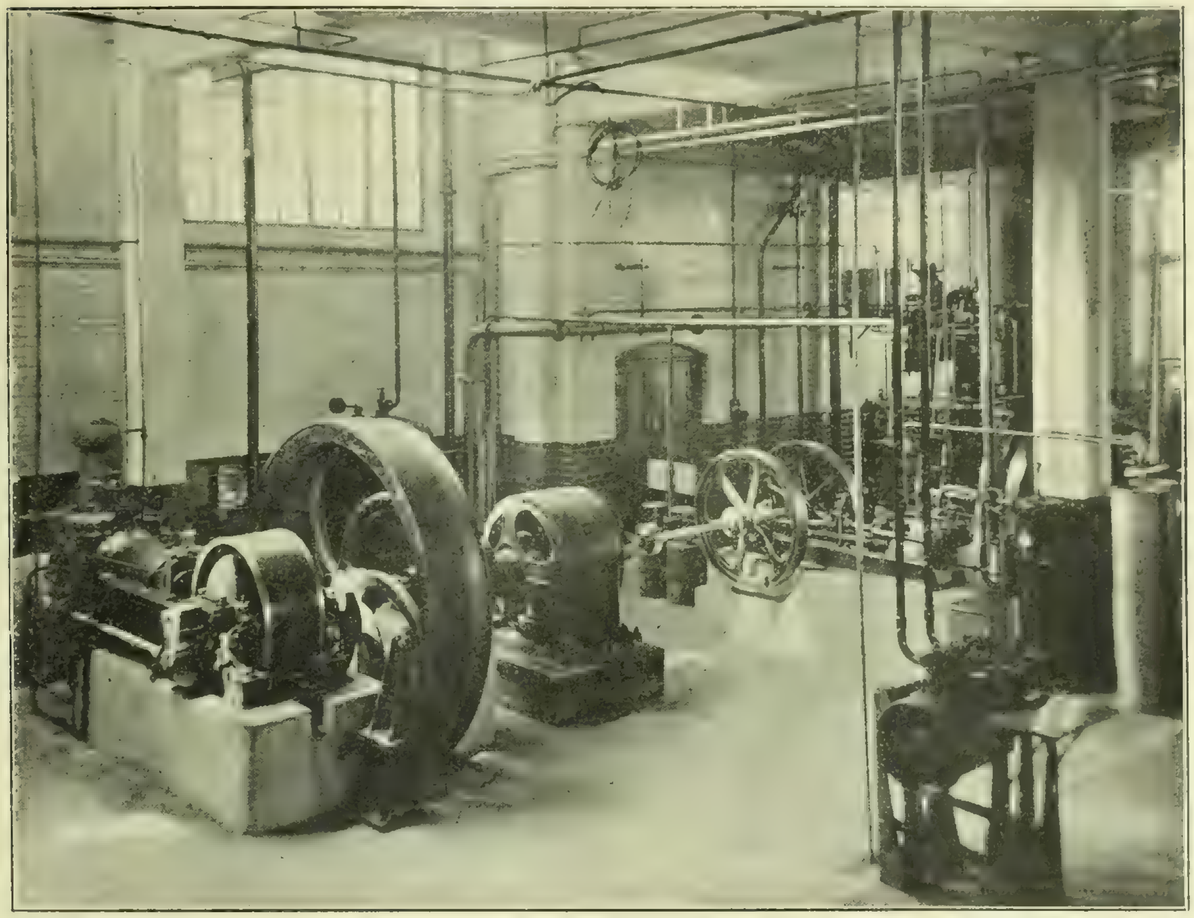


FIG. 7.—PORTION OF INTERNAL-COMBUSTION ENGINE LABORATORY.

The indicating fluid used in conjunction with the various Venturi meters is water, and a deflection of about 5ft. is provided for, so that the pressure difference can be measured with great accuracy. The position of the zero in the gauge glasses is adjusted by means of compressed air, an ordinary bicycle pump being used for supplying the air necessary.

A Humphrey internal-combustion pump of the latest type will shortly be added to the equipment.

For experiments on air-lift water pumps, a pipe, 6in. in internal diameter and 64ft. long, has been sunk 40ft. into the ground. An upcast pipe and an air pipe will be fitted within this, and the water will be discharged into the tank on the top of the building. There is also a large-scale model of an air-lift pump with glass tubes, so that the nature of the action in these pumps can be observed.

Provision has also been made for experiments on the flow of water through pipes of different diameters.

The following hydraulic plant is located in the Walker Laboratory: A vertical tank, 2ft. 6in. diam. and 18ft. 6in. high, arranged for experiments on the flow of water through orifices of various shapes and sizes, in conjunction with which there is also apparatus for measuring the pressure exerted by water jets on surfaces of different kinds.

Adjacent to this plant is a hydraulic ram pump, with arrangements for varying the head of the supply water from zero up to 18ft., and the pressure in the air receiver of the ram may be varied between zero and 250ft. Near this ram is a centrifugal separator, constructed by Messrs. Pott, Cassels, and Williamson, and this is driven by means of a Pelton wheel, the water for which is supplied, at a pressure of 150lbs. per square inch, by a steam-driven reciprocating pump of the Worthington type.

In another part of this laboratory is a centrifugal pump direct-coupled to a 15 b.h.p. de Laval steam turbine. This pump delivers 10,800 galls. of water per hour at a pressure equivalent to 120ft. head. The water from this pump is employed to drive a Pelton wheel, the water being measured between the pumps and the Pelton wheel by means of a Venturi meter.

All the Venturi meters, Pitot tubes, float gauges, and many other measuring instruments and appliances, have been designed and constructed in the laboratory.

Strength and Elasticity of Materials.—The larger machines for testing the strength and other properties of metals, stones, bricks, cement, and concrete, both for teaching, research, and for commercial purposes, are in the Walker Laboratory, while the smaller machines and apparatus are in a room on the first floor of the Harrison-Hughes Laboratories.

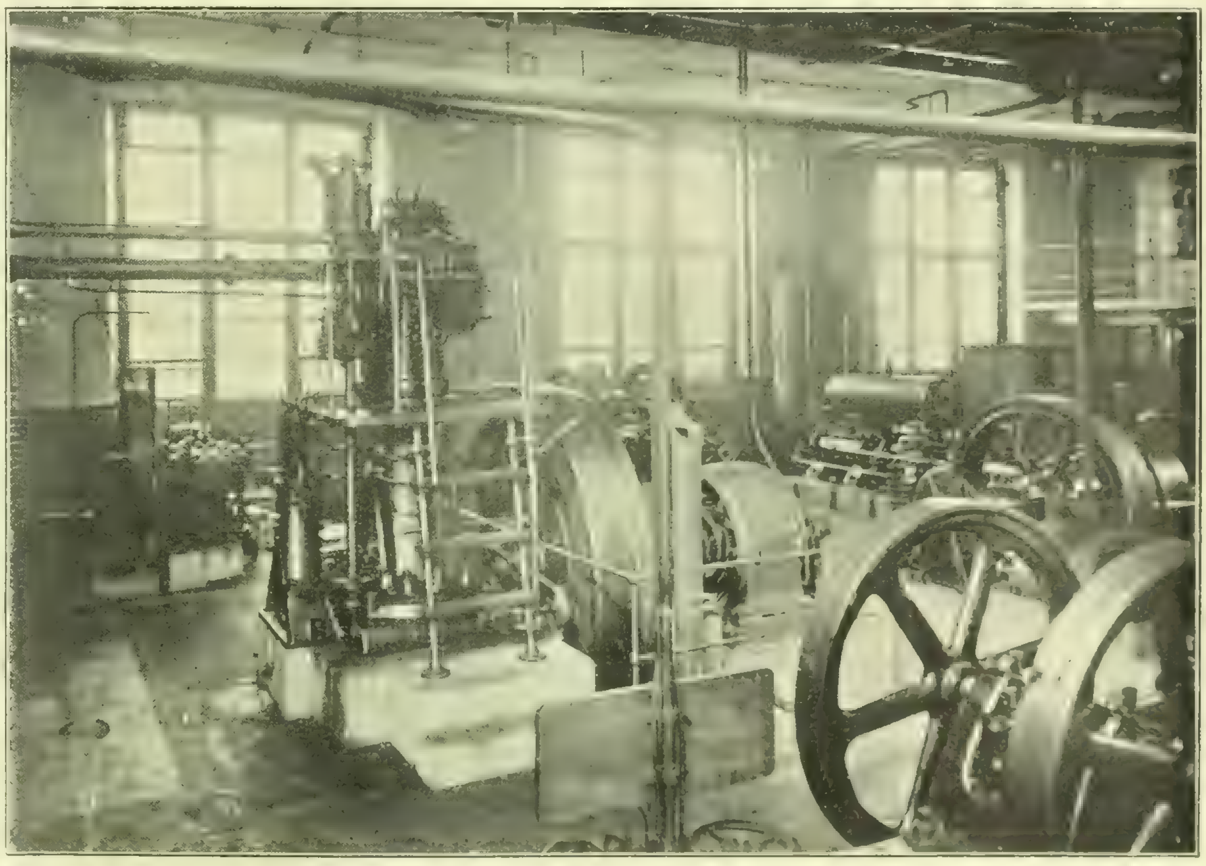


FIG. 8. OIL ENGINES AND AIR COMPRESSORS.

The largest machine in the Walker Laboratory is a Buckton machine, with alternative centres, one for loads up to 20 tons, and the other for loads up to 100 tons. This machine, the pump for which is driven through gearing by an electric

motor, is for tests in tension, compression, bending, and shear. This machine can deal with specimens up to 3ft. long.

A belt-driven Riehlé torsion machine for specimens up to 5ft. long, can apply and measure torque up to a maximum of 60,000in.-lbs. This machine has toggle grips for holding the specimen, and a very sensitive arrangement for measuring the torque.

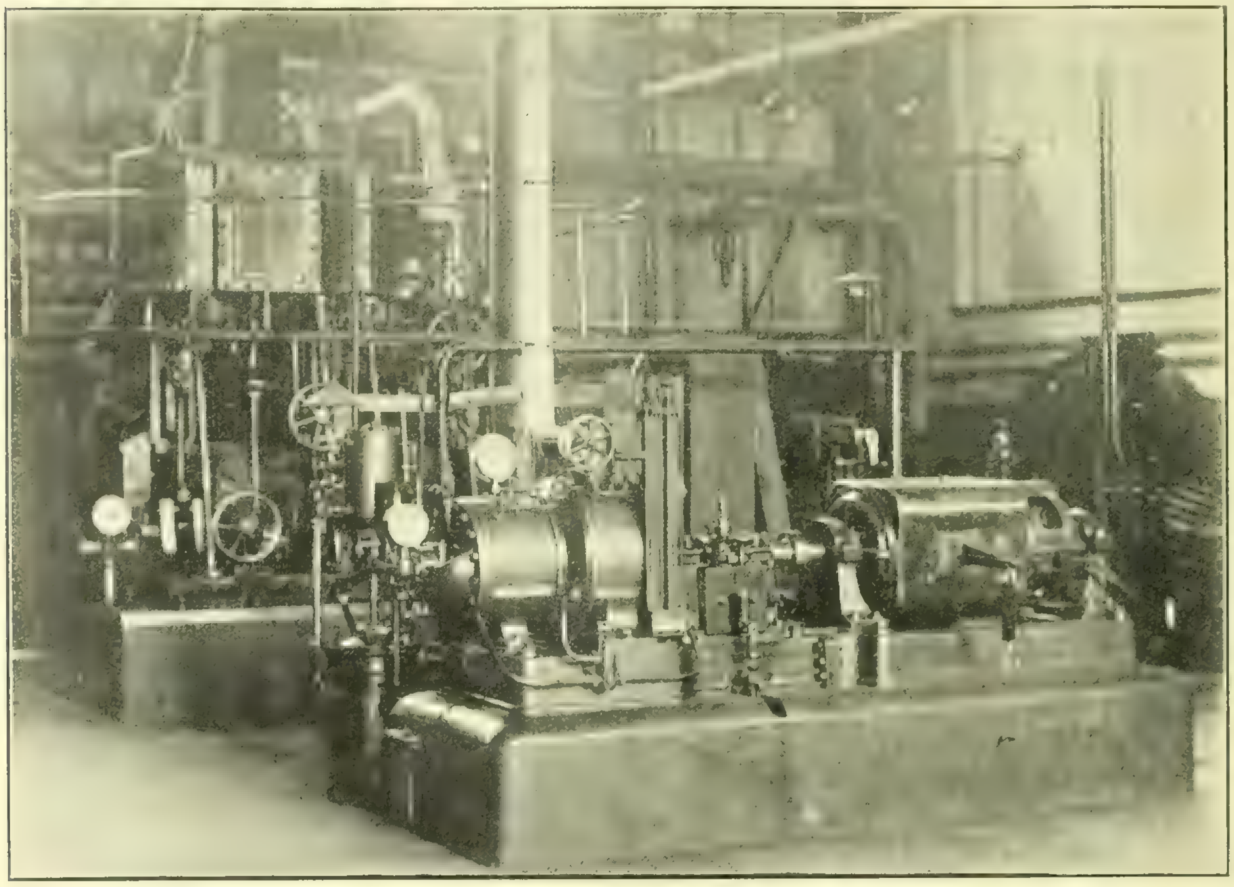


Fig. 9.—Triple-expansion Marine Engine and Compound Steam Turbine.

For applying and measuring tension and compression loads up to 15,000lbs., on specimens up to 5ft. in length, a hand-operated Olsen machine is used.

For experiments on the amounts of energy required to break notched specimens by transverse blows, an Avery impact testing machine is used.

Other machines in this laboratory are an hydraulic press capable of applying loads, in compression, up to 340 tons; a small machine for the determination of the transverse breaking loads on cast-iron and wood; also two machines and other apparatus for testing the properties of cement.

In the Elasticity of Materials Laboratory a considerable variety of apparatus is available for the experimental determination of elastic constants of iron, steel, and other substances. The experiments made with these appliances also provide valuable illustrations and numerical verifications of the lecture work in a subject which the student is apt to regard as difficult and abstruse.

The experimental study of vibrations due to elastic distortion of bodies is also done in this laboratory.

Dynamics and Kinematics of Machines.—The laboratory for experimental work in this subject occupies a large room on the first floor in the west wing of the new laboratories. It is equipped with apparatus for illustrating the application of the fundamental laws of dynamics to machines and machine parts, including experiments on the balancing of rotating and reciprocating masses, and on gyroscopic action. Other appliances illustrate the action of typical mechanisms. Experimental work relating to friction is also done in this room.

Microscopic and Micro-photographic Room.—This room is on the second floor in the west wing. It is being equipped with the latest types of apparatus for the microscopic examination of the structure of metals.

Transmission of Power, Fan Testing, &c.—A room, 70ft. by 52ft., on the second floor of the west wing, is being equipped with apparatus for experiments on various mechanical methods of transmitting power, on fans of various types, and on the flow of gases through ducts and orifices.

The roof immediately above this laboratory is for aerial motor and propeller testing, and general wind experiments.

Design and Drawing Department.—The teaching of drawing and design to all engineering students is essential and of very great importance, and for these purposes exceptionally good provision has been made, both in the Harrison-Hughes and in the Walker Laboratories.

This department occupies the whole of the second floor of the main block of the new laboratories.

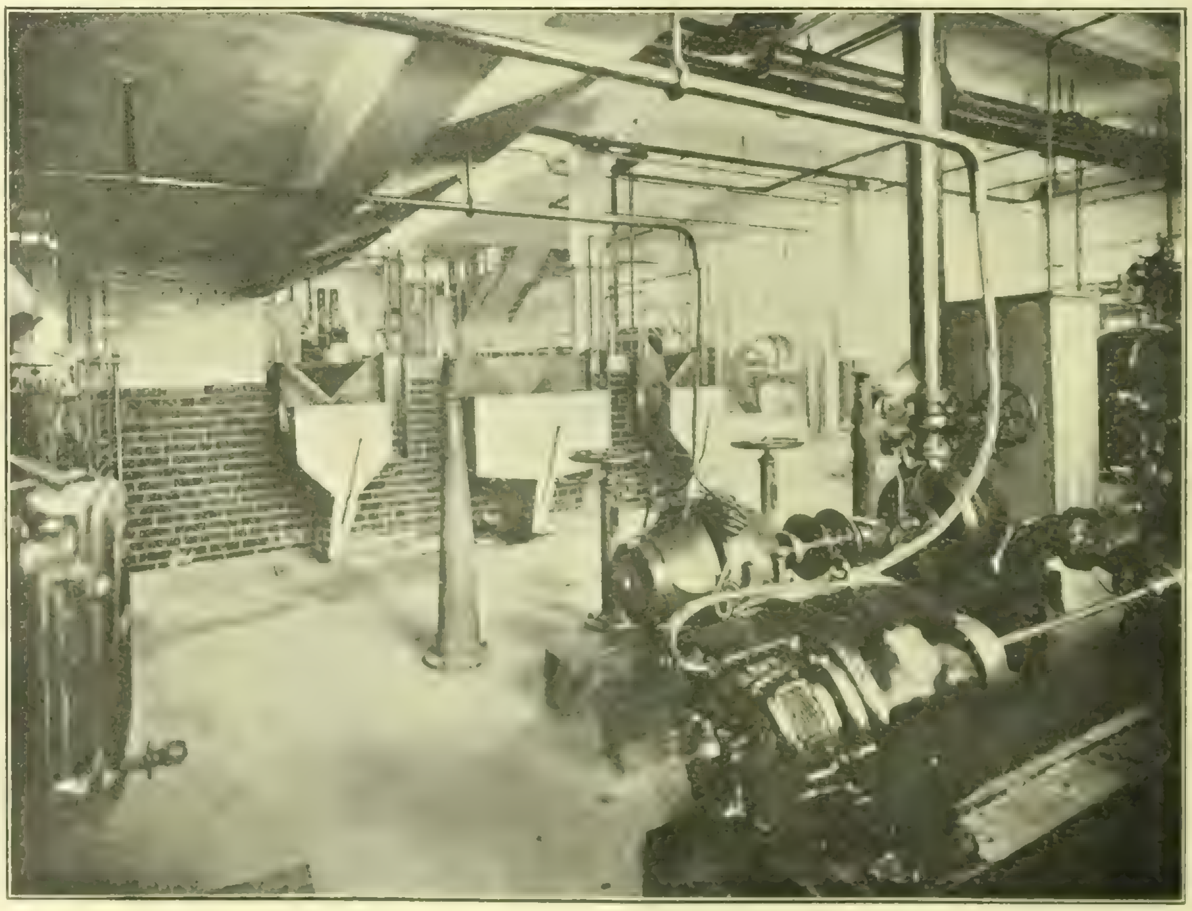


Fig. 10.—Centrifugal Pumps and Ends of Hydraulic Channels.

The main drawing hall is a room 56ft. by 46ft., with northern roof lights. Another room, 33ft. by 23½ft., is reserved for senior students, and also serves the purpose of a

class library. A separate room is equipped with an electric photo-printing apparatus.

Adjoining the main drawing hall, and connected with it, is the drawing hall, 58ft. by 34ft., of the Walker Laboratory.

A valuable collection of drawings and specially constructed models is provided for use in the descriptive geometry and design classes.

Workshops.—The courses of instruction in the workshops of a university cannot, no matter how well these may be equipped, supersede the practical training of a manufacturing works, but the training given in university workshops is of great value, especially to students who have come direct from school to the university. They learn, qualitatively, a great deal in the workshops relating to the physical properties of materials. Systematic instruction in various workshop processes, and in the reasons for the particular methods adopted, is of value to all students.

The metal workshop, 70ft. by 50ft., is a well-lighted room in the basement of the west wing of the new laboratories, and is well equipped with machine tools of the latest types by English and American makers. Amongst these are shaping, planing, milling, and slotting machines, also 13 lathes of various types. The main shafting is supported in ball bearings, and is driven by an electric motor. The benches are fixed along the two longer walls, and are provided with vices of various types and the usual hand tools.

A separate room serves as a tool room, and it is equipped with a tool-room lathe, a Brown & Sharpe milling machine, and a Drummond lathe. The shafting in the tool room is also driven by an electric motor.

Adjacent to the tool room is an office for the superintendent.

The woodworking and pattern shop, which is well equipped with hand and machine tools, is in the Walker Laboratory, which also contains the foundry and the smithy. The smithy contains five forges, the blast for which is produced by an electrically-driven blower, constructed by Messrs. Gibbs and Son; a pneumatic hammer, constructed by Messrs. Peter Pilkington, Ltd.; and a good supply of hand-tools.

Engineering Library.—There are at present three departmental libraries in the Faculty of Engineering—the Engineering Library; the Applied Electricity Library, which is housed in the Applied Electricity building; and the Naval Architecture Library, in the Department of Naval Architecture

The Engineering Library is in a large room on the first floor of the new building. This room is also used as a reading room, and on its tables are provided nearly all the principal engineering journals and magazines.

Engineering Museum.—A large room in the Walker Laboratory is used as a museum, in the cases of which are exhibited interesting models, samples of materials and processes, incrusted and corroded tubes, and appliances of various kinds.

Lecture, Class, and other Rooms.—The principal lecture theatre is in the Walker Laboratory, and in the new building there are three lecture and class rooms, a large room for graphical and computation work, and a staff common room.

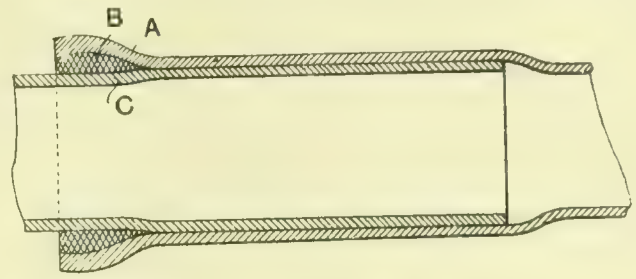
Several private rooms have been provided for the accommodation of the staff.

Ample lavatory accommodation has been provided, also two spray baths, with hot and cold water.

The new building is heated on the low-pressure water circulation system, the water being heated in calorifiers by steam generated in one of the main boilers.

A SIMPLE DESIGN OF PIPE COUPLING.

THE British Mannesmann Tube Company, Ltd., Salisbury House, London, E.C., in conjunction with Mr. J. Gammenthaler, have recently introduced and patented the arrangement of pipe coupling illustrated herewith. The coupling, it will be seen, is of the type in which the spigot is provided with an enlargement, the edge of the socket being enlarged and the outer end thereof contracted, in order to prevent the filling material of the joint from being forced out and the spigot tube from being withdrawn. It has been proposed, in connection with such pipe connections, to provide the socket near its end with a short cylindrical enlargement terminating in an outwardly flared truncated cone with the edge turned in, whilst the spigot is formed at its end with a short cylindrical portion, of the same diameter as the spigot tube itself, extending into a conical enlargement, which is then abruptly reduced to the normal diameter of the spigot tube again by a well-defined shoulder. This form of coupling has, however, the disadvantage that the concentric cylindrical portions of socket and spigot do not afford sufficient guidance, and that the abrupt shoulder on the spigot might displace or shear through the filling material. In the design under notice these disadvantages, it is claimed, are obviated, the spigot being formed with a long cylindrical enlargement of greater diameter than the spigot pipe itself, this enlargement being arranged to fit exactly in a corresponding long cylindrical extension of the socket and merging with a cone of very gradual taper into the spigot pipe, the construction and arrangement of the parts being such that adequate guidance is afforded, and in case of shifting of the coupled pipes relatively to each other, the jointing material may be compressed



A SIMPLE DESIGN OF PIPE COUPLING.

by the tapering cone of the spigot, but cannot be forced out of the socket or be sheared through. The spigot is securely guided in the socket, even if it is drawn some considerable distance partly out of the socket Since the enlargement of the spigot is only slight, and the enlargement merges very gradually in the spigot pipe, the jointing material cannot be broken.

Referring to the illustration, the socket A is contracted or beaded over inwardly at its outer edge, for retaining the jointing material B. The spigot which is to be inserted in the socket A is extended and enlarged in diameter, and this enlarged extension is connected by a conical portion of very gradual taper to the spigot tube, thus forming a conical shoulder C, which bears against the rear of the jointing material B. If the inserted pipe is drawn partly out the jointing material will be gradually compressed, but cannot come out of the socket. The enlarged spigot extension which is made an exact fit in the socket extension is still securely guided in the socket in that movement.

Manchester Steam Users Association.—The annual report for 1911 of the committee of management of this association, just issued, states that the number of boilers under inspection on December 31st last, and the revenue, were the highest on record, and after making allowance for sundry special items of expenditure, a satisfactory balance in favour of the year has been added to the reserve fund. The total investments of the association now stand at £38,202. 2s. 9d., while cash at bankers and other assets bring the reserve fund to £43,084. 19s. The report goes on to say that no explosion occurred during the year from any boiler under the association's care, and at the end of 57 years the committee are glad again to record the fact that no life has ever been lost by the explosion of any boiler inspected and guaranteed by the association. As many as 22,892 boiler examinations were made during the year, of which 9,888 were "Internal," "Flue," and "Entire," a number considerably in excess of any previous year. During the course of their inspections, more especially in the case of boilers newly enrolled, some interesting facts were revealed. Recently on making a first thorough examination of some water tube boilers, working at high pressures, the drum ends were found to be so dangerously grooved in the roots that the end plates had to be renewed. In another case a boiler was found to be working without a pressure gauge, and with the safety valve stuck fast. Other instances might be given, but those referred to are sufficient to show the necessity for the greatest possible vigilance being exercised in the inspection of boilers.

DEVELOPMENT OF THE HEAVY STEEL INDUSTRY.*

BY ARTHUR COOPER.

As the years roll on, the selection of a theme for an address to a society like the Iron and Steel Institute becomes increasingly difficult, and one is forced to choose between a special subject that can be interesting to a portion only of the members, or one of more general interest upon which much has already been said. After mature consideration, I decided on the latter, and propose to review the development of the heavy steel industry during the 40 years I have been associated with a branch of it. By "heavy steel industry" I mean the Bessemer and open-hearth processes and their modifications. Whilst little remains to be said concerning the processes as originally carried out, I am hoping that a brief reference to some of the improvements that have taken place in recent years may be of interest, as these have had the effect of very greatly increasing the output, decreasing the cost, and improving the quality of the products. If, in my review, I do not appear to specially advocate any particular process or form of plant, it is because my sincere wish is to treat the subject in a perfectly fair and impartial manner by giving facts as they present themselves to me, and by leaving it to others to draw their own conclusions.

In the year 1870, when the acid Bessemer process was fully established and the open-hearth process had just been introduced, the make of ingots in the world was about 600,000 tons. These ingots were for the most part acid Bessemer, and the purpose for which they were used was chiefly rails. In those early days, even in works producing their own pig iron, the steel department was operated quite independently of the blastfurnaces and of the rolling-mills; none but the purest hematite pig iron was used. This was carefully selected by fracture, and, where more than one make was introduced, charges of the weight required were made up of a mixture of the different brands, so as to correct variations in any individual brand; and if for conversion by the Bessemer process, each charge was melted down in a separate cupola at a great cost in coke; the ingots produced were allowed to cool down, and afterwards heated horizontally in small coal-fired furnaces preparatory to their being hammered into blooms or slabs, which, after inspection and dressing cold, were again heated and rolled into finished articles.

There was no organised laboratory control of the materials used, and the estimation of carbon by colour in a sample taken from the blow or charge usually constituted the only chemical test. A very large percentage of the ingots made were more or less red-short, often due to the irregular contents of manganese in the spiegel, which would have been detected and the unsatisfactory results prevented with efficient laboratory supervision. Notwithstanding everything, excellent steel was produced from those ingots, that could be coaxed down into respectable blooms. The cost, however, compared with the present practice, in fuel, wages, and waste, was enormous. The output of a pair of acid-lined converters was about 600 tons per week, and this quantity was considered a very fair week's work for a rolling mill.

Early in the decade 1871 to 1880 the blooming or cogging mill took the place of the hammers, and with its aid some steelmakers, recognising the importance of saving fuel, delivered their ingots singly, and as hot as possible, to the mill-heating furnaces, from which they were rolled off at one heat direct into rails; and at works where blastfurnaces existed, molten iron was taken direct to the converters. Other outlets were found for the steel, such as for ship and bridge building and for tinplates; but probably the most important development during this period was the discovery and establishment of the basic process which was destined to render available for steel-making purposes, in all parts of the world, immense tracts of ore beds, which, by reason of their high content of phosphorus, could not be used for steel-making by the acid processes.

Of the 4,000,000 tons of ingots produced in 1880, upwards of 80 per cent were made by the acid Bessemer process, which had been developed very rapidly during the 10 years ending 1880, not only in Great Britain, but also in the United States, Germany, France, and Belgium.

During the period 1881 to 1890 the basic open-hearth process was established, and by-product coke ovens were first put down as adjuncts to blastfurnaces, as it came to be recognised not only that the by-products reduced the coke cost, but also that the waste heat and waste gases could be converted into steam, and turned to useful account at the adjoining iron and steel works.

Mr. Gjers also demonstrated that when the ingot, immediately after casting, was placed in a vertical pit lined with firebrick and allowed to soak, there was sufficient heat in it to enable it to be rolled into blooms and billets or rails. The steel trade is greatly indebted to Mr. Gjers for the economies he introduced in the handling of ingots preparatory to rolling, as undoubtedly from his pits and methods originated the vertical ingot furnaces of to-day, in which the centres of the ingots set whilst in an upright position, thus avoiding the tendency to bleed and cause hollow products, which frequently happened when they were turned on to their sides soon after they were cast, for heating in the horizontal furnaces of former times.

After numerous experiments on the Continent and also in this country it was abundantly clear that the phosphoric slag from the basic converters, when ground into an impalpable powder, had a high manurial value. It must not, however, be imagined that this discovery was immediately turned to profitable account. Considerable difficulties were met with in grinding it satisfactorily, chiefly on account of the shots of steel with which it was interspersed.

The first attempts made with stone mills as formerly used for grinding corn proved utter failures, and it was only after many months of costly and tedious experiments that a satisfactory solution of the problem was arrived at and the slag could be ground regularly into a fine powder at a sufficiently low cost to enable it to compete with super-phosphate and leave a margin of credit to be placed against the ingot. The revenue so derived from this ground slag has aided very considerably in the development of the basic processes.

Captain Jones, in America, and Mr. Gustav Hilgenstock, in Germany, about the same time and quite independently of each other, demonstrated the great advantage of mixers or receivers between the blastfurnaces and the steel-converting plant.

From the years 1880 to 1890 the make of ingots of the world had increased from 4,000,000 tons to 12,000.000 tons, the most notable increases being in the production of acid Bessemer steel in the United States, of acid open-hearth in this country, and of basic Bessemer in Germany.

Between 1891 and 1900 great improvements in appliances, and several important inventions, were introduced, such as the use of electricity for the driving of auxiliary machinery in iron and steel works, and also for driving small rolling-mills: Mr. Saniter's method of desulphurising; Messrs. Bertrand & Thiel's modification of the open-hearth process; and the use of blastfurnace gas as a motive power, first by Mr. James Riley and Mr. B. H. Thwaite, in Glasgow, followed very shortly by Mr. Greiner in Seraing. Mr. Talbot also introduced his method of working the open-hearth process continuously, and the Hon. Charles A. Parsons and Prof Rateau developed their steam and exhaust steam turbines

The output of ingots in the world in 1900 was over 27½ million tons. The most striking features of this output was the large increases since 1890 in the production of ingots in the United States, viz., from 4,000,000 to 10,000,000 tons, of which 6,500,000 were acid Bessemer and 2,500,000 tons basic open hearth, and in Germany from 2,000,000 tons to 6,500,000 tons, of which 4,000,000 tons were basic Bessemer and 2,000,000 tons basic open hearth

Whilst it cannot be said that the ten years 1901 to 1910 were years of invention and novelties as were the 30 years preceding, great improvements have been made both in methods and in the perfecting of plant and appliances introduced during the latter part of the last century. Amongst the former may be mentioned the very important work of the Engineering Standards Committee During the last 10 years this committee, with its 39 sectional and sub-committees, and with the aid of its able secretary, Mr. Leslie S. Robertson, have dealt with a very great variety of subjects, that imme-

* Abstract of Presidential Address delivered before the Iron and Steel Institute May, 1911.

diately concerning this Institute being the standardisation, both for sizes and tests of materials, of all rolled sections as used for constructional purposes for ship and bridge building and boilers, as well as for railway and tramway rails and fish-plates, and for tyres and railway rolling-stock.

The effect has been to reduce enormously the number of sections called for, as, owing to the very representative and influential character of the committees, British standard sections and specifications have been very extensively adopted, notably by the Admiralty, the Board of Trade, and Lloyd's Register. The British Corporation for the Survey and Registry of Shipping and the Bureau Veritas have likewise given effect to the committee's recommendations in their rules, with the result that the cost of roll stocks is being greatly reduced, and the manufacturer may now be content to roll into stock when it suits his convenience to do so, with the certainty that he will not have the material left on his hands as was formerly frequently the case when almost every buyer had his own particular section and specification, which no other buyer could be prevailed upon to take. The advantage to the consumer of the adoption of the standard sections is quicker delivery (small lots frequently from stock) and reduced cost, practically no special rolls being now required.

The output of ingots in the world in 1910 was a little over 57 million tons. A comparison of the production of the three largest steel-producing countries for 1910 with the production of the same countries for 1900 shows that in the United States, whilst the make of acid Bessemer ingots increased from 6,500,000 tons to 9,500,000 tons, the make of basic open-hearth ingots increased from 2,500,000 tons to 15,000,000 tons. In Germany, whilst the make of basic Bessemer ingots increased from 4,000,000 tons to 8,000,000 tons, the make of basic open-hearth ingots increased from 2,000,000 tons to 5,000,000 tons. In Great Britain the only notable increase was in basic open-hearth ingots, viz., from 300,000 tons to 1,500,000 tons, the make of basic Bessemer and acid Bessemer and open-hearth being substantially the same as in 1900.

In these three countries together the make of basic open-hearth ingots in 1910 represents rather more than half the entire make by all the processes, against rather less than one-quarter of the make in 1900.

In the United States the basic open-hearth process is assuredly taking the lead, adapted as it is to produce pure steel of any quality from the softest to the hardest, from ores too low in phosphorus to be utilised by the basic Bessemer process, and too high for either of the acid processes.

In Germany, on the other hand, while the basic open-hearth process is making great headway, very large increases of plant for the basic Bessemer process—by which soft and medium-hard steel can be produced with great regularity and at very low cost—are being laid down, the phosphoric ores of Luxemburg and neighbouring districts producing a cheap iron eminently suitable for conversion into steel by this method.

In France, too, and in Belgium, where similar ores are available, the chief extensions which are being carried out at the present time are in plants for the basic Bessemer process, assisted as it is very materially by the revenue derived from the rich phosphoric slag which it produces. The output of the world of such slag during 1910 was as follows:—

	Tons.
Germany	1,730,000
Great Britain	370,000
Belgium	360,000
France	335,000
Other Countries	105,000
Total	2,900,000

Practically the whole of this was ground and sold for fertilising purposes, and realised on the average about £2 per ton delivered to the farmer, yielding to the steel maker a credit of from 4s. to 6s. per ton of ingots made, and, where the phosphorus in the ore is not paid for, reducing the cost of his ingot by this amount.

In Great Britain the acid processes at present are the largest producers, and whilst there is no reason for supposing that so long as existing works can obtain pure hematite ores at reasonable prices there will be any serious falling off in the make of acid steels, the main and trusted products of this country for so many years, it is, I think, certain that because of the scarcity and of the increasing cost of these ores, future extensions of steel-making plant will be for the basic open-hearth process, which is not only capable of utilising all domestic phosphoric ores, but also foreign ores that can be imported at a low cost, too high in phosphorus for the acid processes and too low to command a value for the phosphorus for the basic Bessemer process—indeed, now that the supply of puddlers' tap is so limited and the owners of the rich phosphoric ores (by no means plentiful) have fully realised the worth of the phosphorus and insist on being paid full value for it, the cost of iron to the basic Bessemer steel maker in Great Britain is becoming too dear to enable him to compete with his open-hearth rival, and it seems probable that he will ultimately be driven to change his process for that of basic open-hearth or some modification of it.

I have thus endeavoured to show the gradual development of the chief steel-making processes in the different countries since 1870. I should now like to draw attention to some of the improvements that have taken place in methods and in plant, particularly during the later years, and which have undoubtedly placed the industry in the position it now occupies.

In the early days it became apparent that an exact knowledge of the composition of all the materials used was essential, and the solitary works chemist of that period, who spent most of his time in estimating combined carbon by colour, has given place to a highly-trained and well-organised staff under a skilled chief, whose duties are to sample, analyse, and report upon incoming raw materials, as well as on all finished goods and waste products, to advise and assist the managers of the different departments in the various manufacturing operations so as to check waste and to ensure that everything possible is turned to useful account, and that nothing leaves the works that does not comply with the specification; and when steel makers realised the great advantages in point of cost of using molten iron direct from the blastfurnaces, and that the utilisation of the waste heat and surplus gases from their coke ovens in their steel-works boilers reduced their coal bills, by-product coke ovens as well as blastfurnaces came to be regarded as necessary adjuncts to the steel works, and most of the recently-built large steel works where conditions are favourable are so equipped.

By-product coke as originally made in this country had a very uphill fight, chiefly because it was much softer than the excellent bee-hive coke then in use. Its density of late years has been much improved by building the ovens of a width most suitable for the coals and by varying the time of coking, and coke makers who have had a lengthened experience maintain that by stamping the coal into a cake or block just large enough to fill the oven when pushed in, coke equal to that from bee-hive ovens can be produced from equal coals—that charging in a cake or block can be effected more expeditiously than by tipping the coal into the oven from the top and afterwards levelling it; that there is less loss of heat and that a greater output per oven can be obtained.

The ovens as originally built provided a small surplus of heat and gas for purposes outside the requirements of the plant, but the modern regenerative ovens with their very economical methods of regulating combustion of the gas in flues, so as to obtain a perfectly uniform heating of the walls, provide a surplus for outside uses of fully 50 per cent. of the gas produced, such as for furnace heating, for lighting, or for power. This from a plant making 5,000 tons of coke per week would mean upwards of 200,000 cub. ft. of spare gas per hour, equivalent to, say, 8,000 i.h.p. if used in gas engines, or to, say, 750 tons of coal per week if used for metallurgical or heating purposes. Great improvements have also been made in the processes for the recovery of the tar and ammonia, giving better yields of by products and reducing the cost of working expenses and repairs.

The chief improvements which have taken place in blast-furnaces during recent years, following the use of larger volumes of air at higher temperatures, have been in the perfecting of the mechanical charging appliances so arranged that the materials can be uniformly distributed in the top of the furnace, at almost any speed required, at a very low cost in labour and in maintenance, and without any loss of gas when

the bell is lowered, and also in the construction of the boshes and of the stacks, both now frequently cooled by water sprays or troughs, or by bronze or some other pattern of water-cooled blocks, by which means the life of the furnace lining, which was shortened very considerably in the early days of rapid driving, has been materially increased; but probably one of the most important developments in connection with blastfurnaces has been the cleansing of the whole of the gases, for, not only has it been proved absolutely necessary to use perfectly clean gas in the gas engine, but it has been found very advantageous to rough clean also that used for stoves and boilers, as with such gas the necessity for laying off the stoves to remove the dust, with the consequential costly repairs, and the periodical stopping of the entire plant for clearing the dust from the flues can be avoided; further, by the use of clean gas the heats can be maintained in the stoves at a higher and more uniform temperature, reducing the consumption of coke, and since the cleaned gas has a higher calorific value less is required, so that more is available for outside purposes.

The two most favoured methods of blowing blastfurnaces to-day are by the reciprocating gas blowing engine using blastfurnace or coke-oven gas, or by the steam-turbo blower, supplied with either high-pressure steam generated in boilers from similar gases, or with exhaust steam from rolling-mill engines—the turbine in this latter case being of the type known as mixed pressure, which can be run with high-pressure steam at times when exhaust steam is not available. Both types of turbine depend for their efficiency upon perfect condensers and an ample supply of cold water.

In a blastfurnace plant producing, say, 5,000 tons of iron per week, with a consumption of 20 cwts. of coke per ton, it has been established that by using modern gas blowing engines and gas electrical generators for driving outside machinery, such as hoists, charging apparatus, and pumps, there would be sufficient surplus gas if used in gas engines to generate, say, 22,000 i.h.p., or, if used for heating or metallurgical purposes, equivalent to, say, 1,600 tons of coal per week.

If, on the other hand, turbo-blowers and turbo-electric generators using high-pressure steam were employed instead of gas engines, on the assumption that the turbine requires, to supply it with steam, not more than double the quantity of gas required by the gas engine, there would be sufficient surplus gas to generate, say, 7,500 i.h.p., or, if used for heating or metallurgical purposes, equivalent to, say, 1,150 tons of coal per week.

It is claimed for the modern gas engine, adopted almost exclusively in Germany, France, and Belgium, to a considerable extent in recent installations in the United States, and in several large works in this country and in Canada, that it can be operated with about 100 cub. ft. of blastfurnace washed gas per effective horse-power per hour, and now that the weaknesses in design and construction, features of the earlier models, have been remedied, it is to-day a perfect machine, and quite as reliable as its predecessor, the reciprocating steam engine—that the quantity and pressure of the blast delivered to the furnace from it is under much better control than from the turbo-blower.

It is claimed for the turbo-blower—used to a considerable extent in this country, and in a few plants only in the United States and on the Continent—that although requiring at least double the amount of gas when burnt under boilers to provide it with steam, it is a cheaper plant to instal, and by reason of its simplicity the cost of stores and maintenance is likely to be lower, that the blast is delivered continuously by it, and not intermittently, as by the reciprocating engine.

At collieries and at blastfurnaces where there are no iron or steel works depending upon heat, the surplus coke-oven gas is now frequently used for generating electricity for power and for light, and any such power and light beyond the actual requirements of the plant is sold outside, thus reducing the coal or pig iron cost. It appears to be the general practice on the Continent, and in the new installations in America and in Canada, where steel works form part of the plant, to use the coke-oven gases for metallurgical and for heating purposes, and the blastfurnace gases for the generation of power; yet there are many instances where blastfurnace gases are also used in mixers, open-hearth furnaces, and heating furnaces with satisfactory results.

Since their introduction in 1889 the use and value of metal mixers has greatly increased. It soon became clear that the single mixer of about 150 tons capacity as originally erected was far too small, for whenever the demand upon it, even for a short time, was increased, or the supply of molten iron was checked, the store was so much reduced that the metal often left the mixer of practically the same composition as it entered it, probably only a few minutes before.

Again, the pig iron made over the week-end when the steel works were standing had always been a difficulty. It caused delay and extra cost when used cold in the open-hearth furnace, and excessive cost and waste when it had to be remelted in cupolas for use in the converters.

The problem of how to ensure more uniform iron for the steel plant, and how to save the cost of re-melting the Sunday pig, has been solved by greatly increasing the mixer capacity, and most large works are now provided with either one or two or more mixers of from 400 to 1,100 tons capacity, some of the simple cylindrical tank type without regenerators, but frequently supplied with coke-oven or blastfurnace gas burned over the top of the bath; the principal function of these—largely used on the Continent and in the United States—is to receive the week-end iron, and to maintain a large store during the week. Very little, if any, cold metal can be melted, and practically no change takes place in the composition of the bath, except that brought about by the admixture of the different ladles of iron from the different blastfurnaces.

Another design of mixer which finds most favour in this country, and which is also used in Canada, and France, and in Germany, is of the gas-fired regenerative tilting open-hearth furnace type. These serve not only the purpose of storing the week-end iron, but they will also melt up during the week large quantities of pig iron or scrap, thus obviating the use of cupolas altogether; and, further, by adding lime and ore, the contents can be refined down to almost any composition required with absolute regularity (a most important condition for the production of uniform steel), thereby reducing the work to be done in the converters and finishing furnaces, shortening the time of the operation, and increasing the life of the linings and the weekly output. This type of mixer, of course, involves extra cost in working over that of the simple cylindrical tank type, but it is held that the extra cost is more than compensated for by the advantages above mentioned.

In the converting and melting departments great changes have taken place. Instead of the pair of 5-ton to 8-ton converters operated by steam-blowing engines from coal-fired boilers, with its wasteful adjunct the cupola plant, turning out from 600 to 800 tons of ingots per week, and instead of the 10-ton to 15-ton open-hearth furnace, with an output of 100 to 200 tons per week, will be found in the most recent plants from three to six 25-ton to 35-ton Bessemer converters, with an output of upwards of 10,000 tons of ingots weekly, operated by gas-blowing engines; and open-hearth furnaces of from 40 to 120 tons capacity, with a weekly output per furnace of from 600 to 1,200 tons of ingots. Indeed, at one works in the United States an open-hearth furnace of 185 tons capacity was recently installed, from which has been obtained over several weeks an average make of 1,350 tons of ingots.

The increase in output has been greatly facilitated by the improvements which have been introduced in recent years in the auxiliary machinery, such as charging machines, cranes, and ingot strippers, now for the most part operated by electricity generated by waste gases, and the arrangements of many of the modern works are such that the same crane which strips the ingot places it whilst still hot in the reheating furnace, from which it can be delivered by another crane to the cogging mill.

In the rolling-mill department the heating furnace now almost universally used is that arranged to heat the ingot in its vertical position, fired with either coal, producer gas, or waste gas from the blastfurnace or coke ovens. The mills themselves have been greatly increased in capacity and power to deal more expeditiously with the larger production; and, for driving reversing mills where steam is used, two-cylinder engines are being displaced by engines with three cylinders, either simple or compound, exhausting into a condenser, or into a turbo-blower or turbo-generator; the former providing blast for the blastfurnaces, the latter electric current for driving outlying machinery.

Another form of drive for reversing mills introduced at Teschen, Austria, in 1906, is by electric motor, on what is known as the Ilgner system, which method has recently been adopted, both for cogging and finishing mills, by many important works on the Continent, chiefly in Germany, and by several in this country, numbering about 30 in all; whilst I understand about 20 more such equipments are at the present time being laid down.

Still, the modern reversing steam engines, as above described for driving reversing mills, have many ardent supporters, both in this country and on the Continent, on the ground of cheaper first cost and simplicity; and although electric motors are very largely taking the place of reciprocating steam engines for driving continuously-running mills both on the Continent, in the United States, in this country, and in Canada, it cannot yet be said that even for this purpose steam has been permanently displaced, for Messrs. James Dunlop and Co., who recently erected a new 3-high plate mill with rolls 28in. diam. and 84in. long, intending to drive it with an electric motor with current generated by steam from existing mills, after careful consideration abandoned the idea of the electric motor, and put down in place of it a mixed-pressure turbine of 750 b.h.p., running at 2,000 revs. per minute, constructed to work either with exhaust steam from their other engines, or with live steam from their boilers, the supply of the latter being regulated automatically by a valve according to the duty required. The speed of the turbine is reduced by gear to run the rolls at 70 revs. per minute, and the power is transmitted through a flywheel of about 100 tons weight. I understand that the mill was set to work at the end of 1910, and that it has in every respect proved satisfactory.

If the experimental surface combustion boiler described by Prof. Bone at the Royal Institution on March 30th and April 6th, 1911, for which an efficiency of 90 per cent. when fired with gas is claimed, can be developed into a commercial success, or if some other more economical steam generator than the present Lancashire or water-tube boiler with an efficiency of about 60 per cent. only can be devised, the economy of steam turbines would, of course, be correspondingly increased.

For several years past the question that has exercised the minds of iron and steel works engineers, particularly on the Continent, perhaps more than any other has been how to obtain most economically the maximum value from their coke-oven and blastfurnace gases, in order to save the coal used for producing power for their iron and steel works' machinery and for their steel and heating furnaces, and with this object in view very large expenditures of capital have been incurred at all the important works. As an instance, I may mention that on a visit, in 1897, to one of the large German works consisting of coke ovens, blastfurnaces, and steel works, I saw a range of boilers and an engine-house containing four pairs of powerful compound steam blowing engines of the latest design and in splendid condition and which at that time were operating their blastfurnaces. At a subsequent visit in 1906 I saw another large engine-house containing a magnificent plant of gas blowing and power engines providing blast and electric power for their blastfurnaces and steel works, and I was told that by the end of the year 20,000 h.p. would be generated in that house, and all from waste gases.

The boiler plant and steam engines were all out of action and kept as stand-bys. I have recently been informed that the consumption of coal in these works has decreased in quantity year by year, and it is expected that very shortly no coal will be required except for the locomotives. This is but an isolated instance of what is taking place in many such works.

My friend, the late Mr. E. P. Martin, in his presidential address from this chair in 1897, referring to a visit he had recently paid to Mr. Greiner, of the Société Cockerill, made use of these words: "Indeed, incredible as it may appear, if it were practicable to apply all the gas made at the blastfurnaces at Cockerills for raising power, they would be able to do away with all their boilers except those of the locomotives.

"If blastfurnace gas can be economically applied as the motive power for driving large engines and for generating electric power, it would almost appear as if pig iron would soon become a by-product, and the chief work of the iron-master of the future will be giving light and power to the country."

It is clear that Mr. Martin, in 1897, regarded this subject as a most important one; but it is far more important to us to-day, having regard to the great increase in the cost of coal which has already taken place, and the certainty of a still further increase in the near future.

During the 15 years that have passed since 1897, it has been demonstrated beyond all question that both coke-oven and blastfurnace gases can be economically applied, not only as the motive power for driving large engines and for generating electric power, but also as fuel for mixers, open-hearth furnaces, and heating furnaces; and I confidently believe the day is close at hand when in the best-managed large works, equipped with modern by-product coke ovens and blastfurnaces, the whole of the converting, heating, rolling, and finishing operations will be carried out with no other fuel than their own surplus gases, and that if any of us fail to utilise our resources to the fullest extent, unless exceptionally situated, we may be left behind in the race.

POWER GENERATION AND DISTRIBUTION IN THE CLYDE VALLEY ELECTRICAL POWER COMPANY'S AREA.*

BY DAVID A. STARR.

In the following paper an endeavour is made to outline the early history, the equipment, and the system of distribution; also to give a general idea of the progress of a company on which a great many of the largest industries in the West of Scotland are depending for their motive power.

Some 18 years ago the Clyde Valley scheme was first discussed by a firm of consulting engineers at Glasgow. The idea at that time was to apply for a provisional order and to obtain the authority of Parliament to erect a power house at or near Motherwell, on a site to be located at one or other of the numerous collieries in the vicinity where fuel could be delivered cheaply from the pit mouth. Their intention was to distribute and sell electrical energy for all purposes in Motherwell and vicinity, and possibly to serve an area within a radius of eight to 10 miles.

Their plans were somewhat hampered by the restrictions imposed by the Board of Trade at that time on the distribution of electricity, and the whole scheme was allowed to remain in abeyance until the Electric Lighting (Clauses) Act of 1899 was passed. This Act considerably facilitated the development of electrical enterprise in Great Britain, removing as it did many of the objectionable restrictions which had previously prevented electrical development on any large scale. In the following year (1900) the matter was taken up more vigorously, and a number of capitalists in and about Glasgow became interested in the promotion of the company.

A much larger scheme than had at first been considered was then decided on, and a Bill was promoted and Parliamentary powers applied for in 1900, in which authority was asked to generate and distribute electrical energy over an area comprising some 750 square miles. In August, 1901, royal assent was given to the Clyde Valley Electrical Power Act (1901). Besides the general powers conferred authority was given to construct three generating stations, and to lay cables and distribute power in 26 parishes in the county of Lanark, 16 parishes in the county of Renfrew, six parishes in the county of Dumbarton, and three in the county of Stirling, an area of 750 square miles in all, excluding the city of Glasgow, the burghs of Partick, Govan, and Paisley, and other burghs within the boundaries of the company's area, where local plants were already established or provisional orders had been granted.

Early in 1902 negotiations were opened with manufacturing companies and contractors for the purchase of plant and apparatus, erection of buildings, &c., and in the summer of the same year a contract was entered into between the Clyde Valley Electrical Power Company and the British Westinghouse Electrical Manufacturing Company, Ltd. The system of generation and distribution decided upon was 3-phase alternating current at a pressure of 10,000 to 11,000 volts between phases, and a periodicity of 25 cycles per second.

It was decided to erect two power stations, and sites were procured—one at Yoker, on the Clyde, opposite Renfrew, and

* Abstract of paper read before the Scottish local section of the Institution of Electrical Engineers.

the other near Motherwell. Construction work was commenced on the buildings during 1902, and in August, 1905, the Yoker power house and generating plant was handed over to the company. In December of the same year the Motherwell power house was completed and taken over, as were also a certain amount of main cables and several sub-stations. The power house buildings were very similar in design, and the plants identical in each, excepting the system of condensing. It was primarily intended to install reciprocating engines in large units, but in view of the rapid progress which had been made in the development of the steam turbine, and the higher efficiency obtainable from this type of prime mover, it was ultimately decided to install turbines.

At the time the plant was handed over to the company the following had been installed in each power house: Four Babcock and Wilcox water-tube boilers, land type, each having a guaranteed evaporation of 16,000lbs. per hour, 88·3 sq. ft. of grate area, and 4,400 sq. ft. of heating surface. These were equipped with superheaters, 750 sq. ft. heating surface, and economisers and feed-water pumps were installed. The boilers in both power houses were equipped with Roney (American) stokers, each pair of stokers being driven by an independent 4 h.p. steam engine. Flues were constructed and stacks erected, the latter being on the Custodis system, having an internal top diameter of 11ft. and 225ft. in height from the top of the foundations.

The boiler houses were constructed large enough to accommodate double the boiler plant originally installed, and coal conveyers and ash-handling plant were installed of sufficient capacity and dimensions to serve the ultimate output of the boiler houses. The framework of the coal bunkers, which were overhead, was completed the full length of the building, but the concrete bunkers were only completed for the boilers then installed.

In the engine room foundations were constructed for four generating units—two of 2,000 kw. and two of 5,000 kw. Two turbo generators with relative condensing plant were installed in each power house; these had a nominal capacity of 2,000 kw. each. The turbines are of the Westinghouse-Parsons double-flow type direct connected to generators of a similar capacity generating 10,000 to 11,000 volts, 3-phase, 25 period current. The generators are separately excited and two 75 kw. direct-current exciters, 125 volts, were installed. One of these is used as a spare. The main and selector E.H.T. switches, as well as some of the auxiliaries, such as coal conveyers and hot well pumps, were formerly operated by current from these exciters, which were direct connected to independent steam engines of Westinghouse compound type with Worthington condensers.

The main condensing plant (owing to physical conditions) was different in each power house. At Yoker surface condensers were used, whilst at Motherwell the condensing was done on the barometric jet principle. At Yoker, where the power house is located on the banks of the Clyde, and where there was a short lift of water, the condensing plant consisted of a Mirrlees Watson vertical surface condenser and a dry air pump for each unit. Suction and discharge pipes of 36in. diameter were laid between the condensers and a well close to the banks of the Clyde. Pipes of 30in. diameter with controlling valves were laid in duplicate between the well and the river below low-water level. Circulating pumps were placed at the head of the pipe line next to each condenser. These were of the vertical centrifugal type directly connected to high-speed non-condensing steam engines.

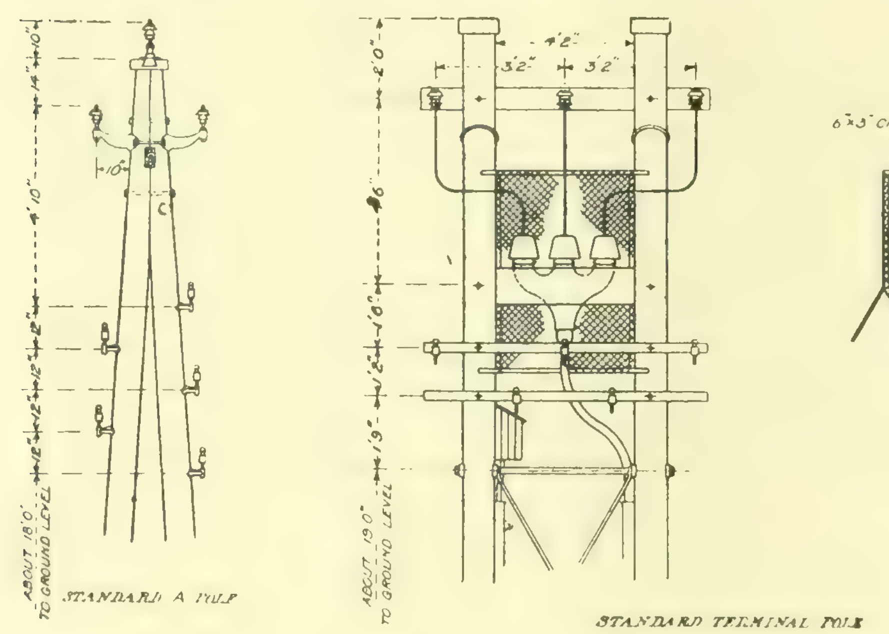


FIG. 1.

At Motherwell, where the power house was located at an elevation of some 150ft. above the level of the Clyde, a pump house was erected near the bank of the river, and a barometric jet condenser was erected at the power house. An exhaust pipe common to both generating units led into this condenser, so that the two turbines exhausted into one main exhaust pipe. This condenser was estimated to be large enough to handle two additional units of 2,000 kw. each.

An 8in. pipe line led from the pump house at the river to a cooling tower, which latter was erected close to the power house. The pipe line was 1,500ft. in length with a rise of 150ft. The pumps were of the 3-throw plunger type, motor driven, their starting and stopping being controlled from the switchboard in the power house. An extension to the main buildings contained the pumping plant for the condensers, and two Alberger 2-stage dry air pumps were installed, together with two hot water and two cold water circulating pumps, these being all steam driven by independent non-condensing engines.

The foregoing is a general description of the generating plant as it was turned over to the Clyde Balley Company by the contractors in 1905. Since that time several additions and alterations have been made to the general equipment with the intention of meeting the increased demands for supply, and with a view of modernising the plant as much as possible, and particularly to accomplish more economical and efficient operations. First it was discovered that the Roney stokers, whilst having a very good reputation in America, with the general class of fuel used there, were unsuited for Scotch coal. These were replaced by chain grate stokers. The steam engines driving the Roney stokers were scrapped and electric motors were substituted. This work had to be done gradually, and the change-over has been justified by the large saving which afterwards took place in the coal consumption. It was next realised that the condensing plant at Yoker could be made much more efficient, and the steam-driven circulating pumps were replaced by motor-driven pumps placed in the well at the river instead of at the head of the pipe line next the condensers. This work soon justified itself by a further reduction in the fuel consumption. It was also found, owing to the fluctuating load and the small amount of power which was used during the night and over week-ends, that it would be advisable to install a smaller generating unit in each power house to handle these small loads. Accordingly a turbo-generator of 600 kw. capacity was installed at Yoker and one of 1,000 kw. at Motherwell. Next, it was found that the day load was increasing beyond the capacity of any one of the generators, and having realised in practical operation that the turbines were of a much greater capacity than their nominal rating, it was decided to increase the capacity of the generators in proportion. The British Westinghouse Company undertook to rewind the generators on site and increase their output by 50 per cent., and this work was satisfactorily carried out. Additional by-pass valves were placed on the turbines, and the whole work was carried out without any interruption to supply. This gave at the beginning of the year 1910 a generating plant capacity in Yoker of 6,600 kw.

and 7,000 kw. at Motherwell. Four additional boilers of a similar size to those first installed had been erected in Motherwell and also a second cooling tower. At this period the maximum load on feeders at Yoker was 2,500 kw. and at Motherwell 4,500 kw. The total connections of consumers' plant to mains aggregated 26,000 h.p.

At the end of 1909 a new line of underground cable was laid between Rutherglen and Renfrew, which connected the Yoker and Motherwell networks together, and in the beginning of 1910 this interconnecting cable was put in commission and enabled the plants in both power houses to be run in parallel. This immediately effected a decided saving, as during periods of light load the supply could be given from either one or other of the power houses. It also had other advantages, as current could be transferred from one area to another when and as required, and the loads could be so adjusted as to keep the plants in both power houses running at their best efficiency. Previous to the interconnecting of the power houses, when it became necessary to clean out flues, arrangements had to be made with the customers in the particular area for a complete shut-down for several hours, and although the time chosen was usually a Sunday during the New Year or fair holidays, when almost all the works were shut down, still it had many drawbacks, and some smaller customers were more or less inconvenienced. The linking up of the power houses permitted of such work being done at any time.

Early in 1910 it became necessary to increase the generating plant at Motherwell, and an order was placed with the British Westinghouse Electric and Manufacturing Company, Ltd., for a 5,000 kw. turbo-generator of the Rateau type, the manufacturers agreeing to take in part payment the 1,000 kw. turbo-generator, as there was now no necessity for the smaller unit. This 5,000 kw. set was installed during the autumn of 1910, and put in commission at the end of that year. On test the steam consumption indicated on the average day's load at least 25 per cent. less than the consumption of the turbines originally installed. The turbine was constructed on the Rateau system, with a Curtis ring for the high-pressure impulse end. The generator embodied all the latest improvements in modern power plant design. The field is energised from an exciter directly coupled on the end of the main shaft. The windings are kept cool by means of an external electrically driven fan. The end windings are specially braced to resist displacements arising from short circuits. The overload capacity is 25 per cent. for six hours and 50 per cent. for 10 minutes. A series of exhaustive tests were taken on site, when it was found that the makers' guarantees were fully met, as shown by the following results, which are corrected to 175lbs. steam pressure, 150° Fah. superheat, and 28½in. vacuum.

Per cent. load	125	200	75	50	25
Steam consumption :—					
(Lbs. per kilowatt hour.)					
Guaranteed	15·00	15·00	15·2	17·5	21·6
Actual	13·45	13·35	13·6	14·5	17·8

Owing to the necessity of maintaining 125-volt direct-current supply, which was mainly used for exciting purposes for the old sets, as well as the operation of switches and auxiliary motors, it was decided to have the field of the exciter on this generator separately excited with 125 volts. This ensured better regulation, especially in the event of any slowing down of the generator, due to temporary short circuits. The field circuits are also so arranged as to be self-excited if necessary.

Two new boilers were installed of the Babcock and Wilcox water-tube type, but of larger capacity than those originally installed. These boilers, each giving an evaporation of 33,000lbs. of steam per hour, have a grate surface of 144 sq. ft., 7,322ft. heating surface, and 1,435 sq. ft. heating surface in superheaters. The flues and economisers were placed behind the boilers; a steel stack was erected common to both boilers, also an exhaust draught system with motor-driven fan. Special chain grate stokers suitable for handling the lower grades of fuel are used, and the boilers are guaranteed to give their contract evaporation with the energy absorbed by the mechanical draught not exceeding 30 b.h.p.

In the original design of the power house it was intended, after the first boiler house was full, to extend the boiler house adjoining the main building, and install additional boilers, flues, economisers, as well as erecting a new stack. On looking into the question, however, it was found that the present coal bunkers, which have a capacity of 1,200 tons, and the conveying plant, would also have to be extended, and it was decided that these boilers, as well as two similar additional sets, could be placed in a building directly opposite the first set of boilers, and in a position where the same bunkers and conveyers could serve the new units. This also brought the boilers nearer to the turbines, and effected quite a large saving in the original estimate for boiler extensions.

The condensing system, due to the poor vacuum obtainable with long lengths of exhaust piping, and the high temperature of water from the cooling towers, next received very careful consideration by the engineers and management, and it was decided to install a system of surface condensing for the

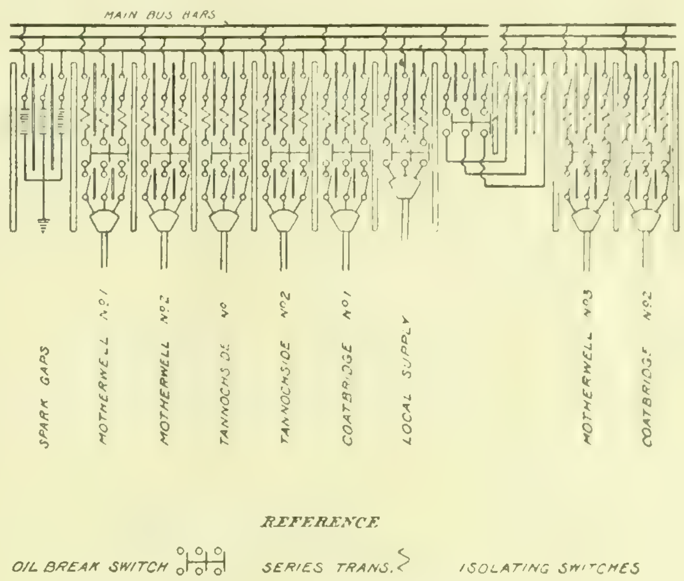


FIG. 2.

new plant. The distance between the power house and the river Clyde, also the difference of levels between the power house and the river, presented many obstacles. Wayleaves had to be secured for the pipe line over an entirely different route than that of the pipe which supplied the cooling towers, and a new pump house and pumping equipment had to be designed. Contracts were eventually entered into with Messrs. G. and J. Weir, Ltd., Glasgow, for all machinery connected with the new condenser plant. Consideration was given to the steadily increasing output of the power house, and it was decided to construct a pipe line of sufficient capacity to supply condensing water for four 5,000 kw. sets or their equivalent. The condenser is of the Weir uniflux type, having a capacity of 80,000lbs. of steam per hour with 7,000 gallons of water per minute and a cooling surface of 6,000 sq. ft. The air pump in the power house is of the Weir dual motor driven type, and two pumping units have been placed in the pump house at the river. These latter consist each of an Allen rotary circulating pump direct coupled to a 3-phase 400-volt 25-period motor, having a nominal output of 350 h.p., but with a guaranteed overload of 100 per cent for six hours. It was found that 650 h.p. was required to drive each of these pumps and supply sufficient water for the condenser, and advantage is taken of the difference in levels already indicated to obtain a certain amount of power from the head of return water. A water turbine is direct coupled to the other end of the pump shaft and the main motor, circulating pump, and water turbine, are erected on one common bedplate. The pipe line is first filled by the motor on its overload, and as soon as there is sufficient head in the return pipe the valves of the water turbine are opened gradually, when the full volume of return water is flowing. A saving of over 40 per cent. is effected in the power required to operate the circulating pumps. In practice it has been found that these pumping units are capable of doing more work than originally specified —viz., to supply one condenser for a 5,000 kw. set on over-

load. It has been found quite practicable to operate the condensers for two turbo-generators of 5,000 kw. each at or near full load, with one of these pumping sets. The pipe line can be filled and the water turbine put in operation within 20 minutes of starting up. To give some idea of the economies effected here, it may be mentioned that in daily operation under the old system of barometric condensing, using water towers for cooling, there were running continuously, in addition to the pump for the make-up water at the river, four circulating pumps, two for hot water and two for cold water, the pumps aggregating 225 h.p. These pumps were steam-driven by direct-current high-speed engines, and were taking approximately 75lbs. of steam per horse-power. By shutting these down and utilising the new plant 100 h.p. to 125 h.p. more was used, but this is electrically driven and does not take more than the equivalent of 15lbs. of steam per kilowatt hour. The results actually obtained with the new turbo-generator and the pumping and condensing plant have shown a saving of 30 per cent. in the fuel consumption at the Motherwell power house. The air pump at the power house, which is motor driven, takes only $12\frac{1}{2}$ h.p. when the turbine is running full or on overload, and no trouble is experienced in maintaining a vacuum of from 96 to $96\frac{1}{2}$ per cent. of the barometer.

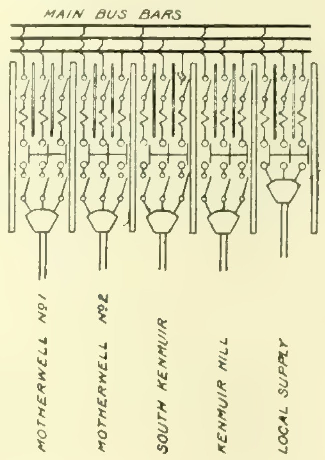


FIG. 3.

The first 5,000 kw. set with the condensing plant was put on commercial load in January, 1911. As the demands on the power house were still increasing, a second 5,000 kw. set with similar condensing plant and to the same specification, was ordered and installed before the end of 1911.

The construction of the Motherwell pump house at the Clyde is worthy of mention. When this was being designed there was a possibility of future subsidence through mineral workings, and this had to be guarded against. Excavations were made, partly through rock, and a solid foundation large enough for the ultimate size of the buildings was constructed of reinforced concrete, 4 by 4 steel angles firmly bolted together were laid crossways about 18in. from the bottom of the foundations. Another layer of similar angles was placed about the same distance below the level of the pump house floor, the whole being embedded in concrete.

The water-circulating pipes, both intake and discharge, were laid in the concrete and connected to the pumps and water turbines, so that in the event of any earth movement taking place, the whole foundation, building, and plant will move in one solid mass. The pipe line is constructed of riveted steel piping 42in. internal diameter both for intake and discharge legs. These pipes rest on brick and concrete piers and the line for the most part is placed above ground. It was necessary, however, to cross two roads and two lines of railway. At these points the pipe line is underground, but both pipes are embedded in concrete: these form anchors for the line, and occur at such convenient intervals that no damage is likely to take place from subsidence or from expansion or contraction. The intake at the river was first provided with grid screens as well as woven wire screens, but trouble was experienced by reason of leaves, twigs, branches, and other material coming down the river when in flood. A removable screen composed of perforated boiler plate was placed in the intake, and scrapers attached to a sprocket chain and driven by a motor have proved effectual in keeping the water clear of foreign material.

At Yoker a new 5,000 kw. set is now being installed, the good results obtained from the operation of the Motherwell plant having decided the company to install similar generators and condensing plant there. The installation of a 10,000 kw. unit is now being considered for the next extension to the Motherwell power house. In a short time the available generating plant at both power houses will consist of the following:—

Motherwell, four units:

Two of 5,000 kw.
Two of 3,000 kw.

Total 16,000 kw.

The two smaller machines are at present kept as reserves in case of an accident to either of the other two sets.

At Yoker there will be three units:—

One of 5,000 kw.
Two of 3,000 kw.

Total 11,000 kw.

For the present the two 3,000 kw. will be kept as a reserve for the 5,000 kw. set. The boiler capacity at present at Yoker is six boilers, each having an evaporation of 16,000lbs. per hour, and at Motherwell eight boilers, each having an evaporation of 16,000lbs. and two having an evaporation of 33,000lbs.

As previously mentioned, the first generators that were installed were separately excited and the exciters driven by independent steam engines directly coupled to 75 kw. exciters. These were in duplicate in each power house, and until the beginning of this year it had been necessary to keep one of these sets running at each power house day and night. It is difficult to estimate the steam consumption of those sets, but it was known that this was very large and that a great deal of fuel was being consumed to keep them running. A storage battery has now been installed in each power house and a motor-driven exciter. These take the place of the steam-driven sets, which are only kept in case of accident. Each battery consists of 60 Tudor accumulator cells of 400-ampere hours' capacity; these are connected in series with a reversible booster.

At the present time there are upwards of 96 route miles of underground cable and 21 miles of overhead lines, all operating at 11,000 volts, with 84 sub-stations and six switch houses. The company have for their own distribution purposes erected 14 of these sub-stations and switch houses, the remainder having been erected at the expense of the consumers, the company supplying the equipment only. All the E.H.T. distribution is at a frequency of 25 cycles and almost all the low-tension distribution is at the same frequency, the only exception being the Burgh of Clydebank, where lighting and small powers are distributed at 50 cycles. The reason of this departure from the standard is somewhat interesting.

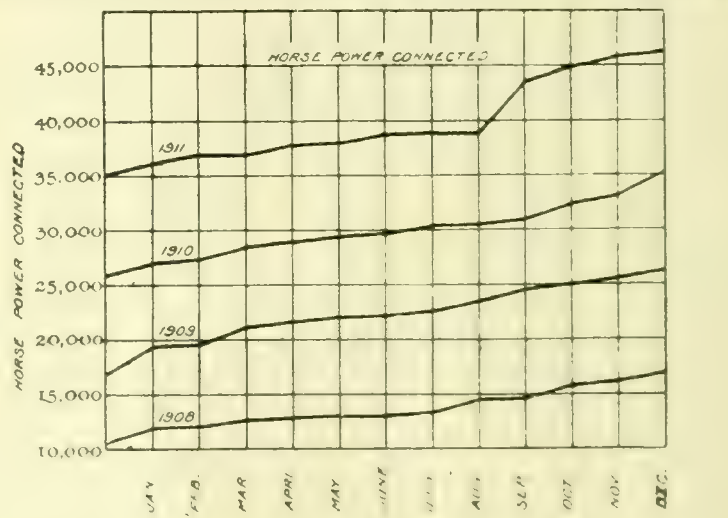


FIG. 4.

The Clydebank Electric Lighting Order (1901) was transferred to and taken over by the company, and at the time of the transference the Burgh stipulated that the supply was to be in the form of direct current. Realising, however, that this would necessitate a rotary converter at Clydebank, with its consequent attendance and other charges, the management effected a compromise with the Burgh authorities by agreeing to give the supply in the form of alternating current at 50 cycles, 25 cycle distribution for lighting being then in its experimental stage. This was accomplished by installing phase-changing plant in the Yoker power house. This plant consists of two units of 150 kw., each composed of one 11,000-volt 25-period synchronous motor direct coupled to a 3,000-

volt 50-period generator. Main feeders carry the 3,000-volt 50-period current to Clydebank and Dalmuir, where it is transformed through street transformers to 400 volt 3-phase and 230 volts between phase and neutral. The phase-changing plant, being placed in the power station, requires no attendance other than can be given by the station staff.

The main E.H.T. network is laid out on the ring main system. The longest ring is upwards of 30 miles in route length, and embraces Motherwell, Hamilton, Blantyre, Cambuslang, Rutherglen, Tollcross, Shettleston, Uddingston, Bellshill, and Carfin. The main cables in the neighbourhood of the power stations are lead covered and are drawn into 4-way or 8-way stoneware conduits, so that spare ducts are available for future extensions. The reason for this is to permit of the sectional area of conductors being increased in proportion to the load, and without having to make excavations each time a reinforcing feeder is laid. On other sections further removed from the generating stations the cables are laid in earthenware troughs. Stamped steel bridge-pieces held the cable in position in the trough, the trough being then filled up with bitumen, and the whole protected with a hard burnt tile 2in. thick. This method of laying, while it probably gives the greatest security from electrolysis or acids, was found to involve rather too much capital outlay, particularly in outlying districts, where the cartage and transport charges on the various materials amounted to quite a large sum. During the past two years armoured cable laid direct in the ground has been used with success and economy. The conductors in cables used in the E.H.T. main circuits are 3-core 0·15 sq. in., constructed for operation with generators having an earthed star-point. Paper insulation is used throughout. On some of the less important sections 0·1 sq. in. conductor is used, and on some branch lines for smaller power supply 0·035 sq. in. is the standard practice. Another feature of the distribution is the use of 11,000 volt street-disconnecting boxes. These are employed in cases of smaller power supplies, where the revenue to be derived from the load is not sufficient to justify the expense of looping in the main ring cables or the cost of erecting a switch house. These boxes are of special design, the distinctive feature being that each phase is brought into a separate porcelain cell to permit of the disconnecting link being oil immersed. Some of these have been in use for four years and have given satisfactory service. The company also have a considerable amount of extra high-tension overhead transmission. Such lines are employed in sparsely populated districts. These serve a very useful purpose in development work; isolated works are thus secured as customers which otherwise would have to be passed over on account of the revenue not being sufficient to meet the heavy cost of underground mains. The general design of pole is as shown in Fig. 1, which represents a creosoted A pole having a malleable cast bracket arms. The main conductors are set 30in. apart, with the telephone and relay conductors carried underneath. The insulators are of the 2-part design. Single-part insulators were first tried, but had to be discarded on account of unequal expansion and contraction during hot weather.

Where it was necessary to cross highways with E.T.H. lines a pole was erected on each side of the road, and the wires were protected by an earthed cage in accordance with the model description of the Board of Trade then in force. Although these cages were of ample size, and made of the strongest possible material, much trouble was experienced during heavy wind-storms by the cages swinging and making contact with the conductors. Within the last year, however, the Board of Trade have been induced to alter their specification, and now a double conductor is strung across the highways on separate insulators close together, and the two conductors are firmly clamped together at intervals of about 3ft. to 4ft., so that in the event of a conductor breaking the strain is taken up by the remaining one. This system of road-crossing has now been adopted by the company, and the cages are being gradually replaced.

The protective system used is that generally known as the Merz-Price balanced protective gear. The pilot wires required for these are laid alongside the main cables in the case of underground work, whilst for overhead work they are carried as separate conductors on the pole line. The relays used are adjusted to operate on a fault current of 60 amperes, and by this means an ample margin of safety is left to allow of one or two branches being tapped off each protected section. Originally each section of overhead line was provided with lightning arresters at points where the overhead line joins underground cables. It was found, however, that these arresters disturbed the balanced protective gear whenever the atmosphere became electrically charged. Trouble from this source became so acute that it was decided to discard the use of these and depend entirely upon the lightning arresters installed on the sub-station bus-bars. Although there have been many severe thunderstorms since this change was made there has been complete immunity from accident or interruption. The sub-station equipments as now installed are the result of a gradual process of evolution. All the original sub-stations had four single-phase transforming units, one of these being kept as a spare. Gradually 3-phase transformers were used, and latterly, when it was found from experience that these were absolutely dependable even under the most severe conditions, their installation has become standard practice. All the transformers are oil-cooled, and are wound for operating on primary 10,000 to 11,000-volt

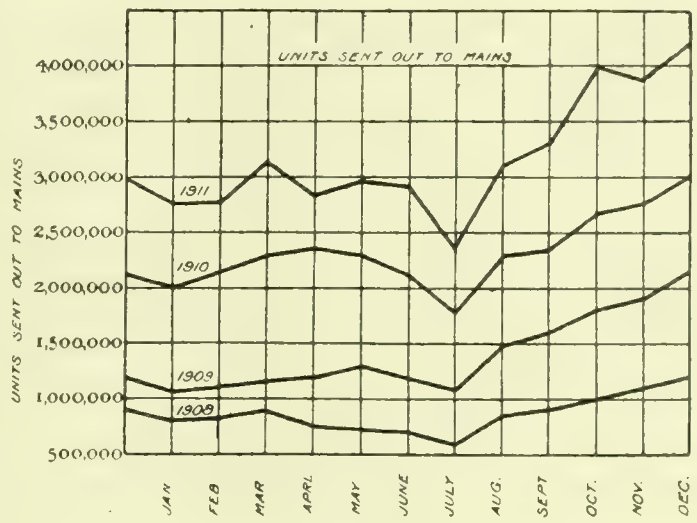


FIG. 5.

circuits mesh connected and with tappings so arranged as to give a pressure of between 400 to 440 volts on the star-connected secondary side. The star-point is brought out and connected to the neutral of the 4-core low-tension distribution cables. Lighting circuits are connected between phase and neutral. As a general rule current is supplied at 25-cycles 400-volt 3-phase. In some cases, however, special conditions have had to be met and current furnished at a different voltage to meet these conditions. Bulk and large supplies at E.T.H. 10,000 to 11,000 volts are given to several of the company's consumers, notably the Coatbridge and Airdrie Electricity Supply Company, Ltd.; Messrs. John Brown, Ltd., Clydebank; Babcock & Wilcox, Ltd., Renfrew; Coltness Iron Company, Ltd., Newmains; Smith & McLean, Ltd., Gartcosh, and several others. In the case of the bulk supply delivered to the Burgh of Wishaw, rotary converters are installed, and the energy is metered as direct current. Similar current is also supplied to the Lanarkshire Tramways Company at Wishaw and Uddingston sub-stations. As a rule where rotary converters or motor-generators are used these are installed by the customers at their own expense and for their own convenience. The general arrangement of two typical sub-station equipments is shown in Figs. 2 and 3.

Referring to the growth of the company's output, at the beginning of 1908, 12,400 h.p. was connected to their mains, and the following shows subsequent development:—

January,	1909	.... 19,500 h.p. connected.
,,	1910	.... 27,000 ,, ,,
,,	1911	.... 36,600 ,, ,,
,,	1912	.... 46,500 ,, ,,

and on the 1st May, 1912, this had been increased by some 6,000 h.p. The 46,500 h.p. which was connected to the com-

pany's mains at the beginning of this year consisted of 43,500 h.p. in motors, &c., and the equivalent of 3,000 h.p. in lighting. About 2,200 h.p. of this latter represents shop and domestic lighting and heating (exclusive of lighting connected with bulk supply), and the remaining 800 h.p. represents lighting used in works where power is supplied. It will be observed that with such a small proportion of lighting (less than 8 per cent. of the whole load) the company have no appreciable lighting peak at any time during the year. Fig. 4 illustrates the connections to mains month by month for four years from the beginning of 1908 to the end of 1911.

The diversity factor is also noteworthy. The highest peak reached by the combined stations during 1911 was 12,500 kw., this being only 27 per cent. of the kilowatts connected at that time. The sum of the highest observed loads on the stations taken separately each week is invariably much higher than the actual demand of the two stations when running in parallel. The difference has at times exceeded 1,000 kw. One reason for this is the different class of works being supplied from each power house, and the different hours of working, stoppages for meals, &c., between the districts. At Yoker the supply is largely to shipyards and engineering works, whereas at Motherwell iron and steel works and collieries are the largest consumers. The night load at Motherwell is, as a rule, not less than 20 per cent. below the day load, and the week-end load is never below one-third of the ordinary day load. The load factor on units generated at Motherwell is frequently 65 per cent. and over during a complete week of 168 hours, whilst at Yoker the load factor on similar conditions is frequently 40 per cent. The combined load factor of the two stations sometimes reaches 58 per cent. over a week. It is remarkable to observe the similarity in rise and fall of the combined outputs over the past four years, and Fig. 5 illustrates the monthly output of the power houses from the beginning of 1908 to the end of 1911. The particular feature is the similarity in contour of these lines. Some notes contrasting the operating conditions in the early stages of the company's career and those existing to-day may be of interest. By referring to some of the old records it was found that at the beginning of 1906 the coal consumption at Yoker was 35lbs. per unit generated, and at Motherwell 49lbs. per unit generated. In the beginning of the year 1907 there was a maximum demand on Yoker of 480 kw. and at Motherwell of 570 kw., and even with a 40 per cent. load factor over the week the coal consumption was between 10lbs. and 11lbs. per unit. At the beginning of this year the coal consumption per unit generated was under 3lbs. per kilowatt-hour for both power houses, and it is confidently expected that a further reduction will take place when the new Yoker plant is in regular commission, and the full benefit is being derived from the installation of the storage batteries and the closing down of the reciprocating engines already referred to.

The company appears to have good prospects for the future. There is no reason to doubt that the same steady rate of progress will be continued for some time. The area served is a good field for the investment of capital, and new works are continually being started, besides which many steam and other plants which have been installed in collieries, iron and steel works, shipyards, &c., many years, are gradually becoming obsolete, and there is a growing tendency in the district, as in fact all over Great Britain, for power users to take their supply (with its many advantages) from a power supply authority.

One of the company's largest bulk consumers is the Coatbridge and Airdrie Electric Supply Company, Ltd. Previous to 1908 they generated their own current by steam, and during the past six years their output has increased by 700 per cent., their revenue shows an increase of nearly 300 per cent., whilst gross profits have increased 100 per cent.

Launch of a Submarine.—There was launched on the 17th inst. by Messrs. Vickers, Ltd., from their shipyard at Barrow, a new submarine, "E 9," built for the British Navy. She is the largest submarine yet put in the water, and has all the latest improvements, including wireless telegraphy and disappearing guns. She will have increased speed and effectiveness.

INDUSTRIAL AND TRADE NOTES.

British Steam Turbine Builders.—There are at the present time close on 40 firms building turbines in Great Britain. Of these 20 build marine turbines only. Of the marine turbines built, all the types but two are reaction turbines, but of the land turbines about 14 are impulse machines of various designs. There are at least two firms specialising in small turbines. On the Continent there are also about 40 firms known to build turbines. About eight are reaction turbines and the remainder impulse.

Govan Shipyard Purchased by Belfast Firm.—Messrs. Harland and Wolff, Belfast, have acquired the site of Messrs. Mackie and Thomson's shipbuilding yard at Govan, and have completed arrangements for taking possession of the ground at an early date. The yard is adjacent to that of the London and Glasgow Shipbuilding and Engineering Company, which the Belfast firm purchased three months ago, and the intention of the new management, it is understood, is to combine the two establishments into one large yard.

A Fast Turbine Yacht.—The turbine yacht "Winchester," built to the order of Mr. P. W. Rouss, of New York, was launched on the 15th inst. by Messrs. Yarrow & Co., Scotstoun. The vessel, which is of special design, measures 205ft. in length, by 18ft. 6in. in breadth. The propelling machinery will consist of Parsons turbines, driving two shafts, steam being supplied by two of the latest Yarrow boilers, fired with oil fuel. The trials of the vessel will be watched with great interest, as the yacht has been designed with a view to attain a speed of 32 knots, and will therefore be one of the fastest pleasure craft afloat.

The Skilled Labour Market.—The "Board of Trade Labour Gazette" states that employment showed a satisfactory recovery in April from the effects of the recent coal dispute, and at the end of the month had nearly returned to the good conditions obtaining in February. Compared with a year ago, there was an improvement in most of the principal industries, particularly in the iron and steel trades. On the other hand, the pig iron industry was considerably worse than a year ago. In the 394 trade unions, with a net membership of 833,010, making returns, 30,222 (or 3·6 per cent.) were returned as unemployed at the end of last month, compared with 11·3 per cent. at the end of March, 1912, and 2·8 per cent. at the end of April, 1911.

International Conference on Wireless Telegraphy.—An international conference on radio telegraphy will assemble in London on June 4th, and is expected to last for four weeks. The object of the conference is to make regulations for wireless telegraphy as carried on by means of ship to shore messages, and its sittings will have no reference to long distance wireless services, nor to the scheme of British Imperial wireless stations which is now being carried out. Existing regulations will be brought up to date in view of the great developments which have taken place since the last conference. The main object of the conference, which will be held at the Institution of Electrical Engineers, is to secure uniformity of working among all vessels licensed for wireless installation and shore stations.

The Engineering Agreement.—At a special delegate meeting of the Amalgamated Society of Engineers, to be held shortly, the following resolution will be proposed: "That the Executive Council shall take an immediate vote of the members in favour of giving the Engineering Employers' Federation three months' notice to end the terms of agreement of 1907. If a majority are in favour of ending them the three months' notice shall be given by the Executive Council to the Federation at once." It is stated that the practice by engineering firms of displacing skilled artisans and training machine operatives whilst members of the union are unemployed has created the desire to throw over the agreement, and that practically all minor wages disputes have been set aside in order that the effort to amend the agreement shall be completed before this special delegate meeting is held. The engineering agreement was drawn up originally at the close of the great dispute of 1897-1898, which lasted for eight months. It has been amended several times, but the main principles on which it was at first based have always remained.

Railway Nationalisation.—On Monday last a deputation from the Amalgamated Society of Railway Servants, and the Railway Clerks' Association waited upon the Prime Minister in regard to the nationalisation of railways. Mr. Asquith said the practical question for the public to consider was whether they would be better off if the change took place. The question was one for experts. Undoubtedly it was serious, and it was one in regard to which they could not expect the Government to make up their minds until they had carefully considered both sides. He should like to have the opportunity of hearing the views of the railway companies. Mr. Asquith pointed out that the paid up capital of the railways in 1911 totalled £1,324,000,000. The

gross receipts were £127,250,000, and the expenditure £78,500,000, making the net receipts a little in excess of £48,500,000. The net percentage on the paid up capital was returned at 3·66. This, the highest figure for the past ten years, was not a very high return for a commercial undertaking. Until the Government had carefully sifted the material they could not dogmatically say which of the two systems was the better. Frankly, he told them that he did not think the burden of proof lying on those who favoured nationalisation had been satisfied.

Galloways, Ltd.: A Receiver Appointed.—The affairs of Galloways, Ltd., the well-known Manchester firm of boilermakers and engineers, have been placed in the hands of Mr. Alfred H. Pownall, chartered accountant, Manchester, who will act as receiver and manager, and carry on the business. The motion was made on the application of Sir Frederick Cawley, Bart., and Mr. C. L. Agnew, on behalf of themselves and all the other debenture holders, who opposed the prospective issue of £50,000 prior lien. It is understood that every effort will be made to reconstruct the company, with the object of continuing the business. The authorised capital of the company is £330,000, in shares of £10, of which £150,000 are 5 per cent. cumulative preference and £180,000 ordinary, of which £100,000 of preference and £164,760 of ordinary have been subscribed and called up. There is also 4 per cent. first mortgage debenture stock for £150,000, the total authorised, £50,000 having been allotted to the vendors and the remainder issued publicly at par, secured by a first mortgage on the company's works and fixed plant. Mr. C. L. Agnew is the chairman of the company, and the other directors are Sir Richard Mottram, Messrs. E. N. Galloway, A. Hewlett, jun., C. Price, and R. F. Riddick. The present company took over in 1899 the business of a company of the same name registered in 1895.

The Ratio of Profits to Wages.—In a monograph recently issued by the Liberty and Property Defence League, the statements often made by Socialist agitators with respect to the general ratio of profits to wages are refuted by putting before the reader the main facts and figures bearing on the subject as shown by an analysis of definite contemporary statistics. The doctrine which dominates the minds of the leaders of the new labour movement that manual labour is the source of all economic values, and that employers appropriate, under the name of profits, from 65 to 80 per cent. of that which rightly belongs to labour is characterised as being as crude as it is childish. This is the doctrine that is now being taught in a "Labour College," the main object of which is the education of Socialists or syndicalists for the business of popular agitation. It is shown in this monograph that out of the total product of industry for one year (1907), the net value of which was approximately £1,450,000,000, profits (including rent of both lands and buildings) amounted to approximately 24 per cent. of the total, and wages and salaries of the employed amounted to approximately 76 per cent. of the total. These figures are in striking contrast to those frequently put forward that profits amount to 77 per cent. and wages and salaries 23 per cent. of the total.

Business Aspects of Engineering.—A lecture on this subject was delivered on May 10th by Mr. Leslie Robertson, M.Inst.C.E., before the students of the Faculty of Engineering at University College, Gower Street, W.C. The lecturer said that the subject of his discourse involved the application of common-sense to technicality. That seemed a simple matter, but the difference between pure technicality and technicality allied to commonsense was enormous. The able technical man might hope to reckon his salary in hundreds, but the able business man who was also a good engineer could command thousands. He recommended his hearers to develop any commercial aptitude they had as far as possible. Engineering was never a matter of technical knowledge alone; it was impossible to divorce it from business. No man could carry out engineering schemes unless he were entrusted with money. Money was the mainspring of all enterprise, and all work must be considered from the financial point of view. An engineer, therefore, wanted a wide knowledge, the more so as he never knew in what branch he would practise. Circumstances might oblige him to undertake work he had never contemplated. But whatever he did, he would be the better for a knowledge of affairs. Mr. Robertson advised his hearers to cultivate business methods. It was most desirable they should be able to write an intelligible letter, and give a clear expression to the ideas in their minds. A knowledge of one or more foreign languages was an immense advantage, as he had proved in his own experience. Some acquaintance with company law and the ability to read and understand accounts were essential.

Bursting of an Emery Wheel: Important Appeal Case.—The Court of Appeal gave judgment on Monday last in an appeal by the defendants, Charles Churchill & Co., Ltd., against a judgment of Mr. Justice A. T. Lawrence in favour of the present respondents, S. Thomas & Sons, Ltd. In February, 1910, the plaintiffs' foreman fitted one of the large emery wheels supplied by the defendants, and after it had been running about ten minutes it suddenly burst, injuring a workman who was sitting down close by. As a result of the accident the plaintiffs became liable to pay compensation to the injured workman under the Workmen's Compensation Act, and they sought in the action to recover that amount, alleging that the defendants were liable for a breach of warranty to be implied from the sale of the emery wheels by defendants, with the knowledge of the purpose for which they would be used by the plaintiffs. Lord Justice Vaughan Williams said the Court was of opinion that the appeal should be dismissed. The real fact of the matter was that in this case the defendants supplied the machinery, and it was not denied and could not be denied that the obligation was thereby thrown upon them to supply machinery which was reasonably fit for the work which they knew the machine was to do. After the wheel had been working for only a short time it flew to pieces, and injured a workman sitting by. The moment that fact was proved and accepted as due to some fault in the wheel, there was a prima facie breach of an undoubted warranty for which the plaintiffs, unless contributory negligence on their part could be proved, were entitled to claim to be repaid the damages they had to pay as compensation to the injured man under the Workmen's Compensation Act. Lord Justice Fletcher Moulton and Lord Justice Farwell agreed. The appeal was accordingly dismissed.

Opening of the Immingham Dock.—The new dock at Immingham, near Grimsby, built by the Humber Commercial Railway and Dock Company, and leased by the Great Central Railway Company, was opened for mineral traffic on the 15th inst. It will not, however, be ready for passenger traffic for a few months. The area covered by the dock and sidings is 1,000 acres. There are 170 miles of running lines and sidings. The central basin of the dock is 1,100ft. square. The south western arm is 1,250ft. long and from 350ft. to 400ft. wide, and the north western arm, to be used as a timber pond, is of the same size. The water area is 45 acres. The southern quay is 2,350ft. long. The entrance lock is 840ft. long and 90ft. wide, with an intermediate pair of gates which gives an outer lock 320ft. long and an inner lock 520ft. long. The height of water over the sills is from 47ft. to 27ft. 6in for spring tides, and from 43ft. 6in. to 38ft. 6in. for neap tides. The adjoining graving dock is 740ft. long and 56ft. wide. It, too, is divided into an outer dock of 320ft. and an inner of 420ft. The depth of water on the sill of the graving dock is 23ft. The depth in the general dock is from 30ft. to 35ft. The graving dock holds 1,215,000 cubic feet of water. Three main pumps, with suction and discharge branches, 20in. diam., can empty the dock in 84 minutes. Each pump is driven direct by a three phase motor of 330 b.h.p., running at 415 revs. per minute. There are also two 14in. centrifugal pumps for draining the dock, each driven by a three-phase motor of 50 b.h.p. The hydraulic and electrical power is generated in a large power house near the western jetty. The equipment consists of nine Lancashire boilers of 180lbs. pressure, fitted with superheaters. There are four hydraulic pumping engines of the horizontal compound surface condensing type, each of which is rated at 630 h.p. They deliver 700 gallons each minute against a pressure of 800lbs. to the square inch. The cylinders are 24in. and 44in. diam. by 36in. stroke. There are two accumulators at the engine house and two at the south quay coal hoists—one at each end. The pressure pipes and return mains are of steel, solid drawn. Rees Roturbo pumps are used to pump water and to raise it to the tank, which is 55ft. above ground level. The electrical equipment consists of two 250 kw. and one 500 kw. Curtis turbo-generators, to which a fourth, of 1,500 kw., is being added, and two 250 kw. rotary converters. The power generated is three-phase at 6,600 volts, 50 cycles, but is converted to direct current on the three-wire system at 460 volts for lighting by a sub station in the power house. There is also a sub-station for the power for the graving dock and another for supplying light to the sidings. A third sub station is at Grimsby for lighting and power there.

Launch of a New Japanese Battle-cruiser.—There was launched from the Naval Construction Works of Messrs. Vickers, Ltd., at Barrow, on the 17th inst., the Japanese battle-cruiser "Kongo." She has been built to a special design, her dimensions being: Length, 704ft.; breadth, 92ft.; draught, 27ft. 6in.; displacement, 27,500 tons; speed, 28 knots at least. She has a coal capacity of 4,000 tons, and oil fuel 1,000 tons. She will be propelled by turbines, having a shaft horse-power approximating 70,000. She will have eight 14in. guns, 16 6in., and 16 smaller guns, with a large number of submerged broadside torpedo tubes. She is very heavily protected with armour.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Rotary fluid pressure machines. Internationale Rotations Machinen Ges. 1862
Valves for fluid-pressure engines. Mercer. 8159.
Rotary engines. Glasgow. 8227.
Valve gear for pneumatic tools. Kann. 10116.
Devices for arresting the motion of pit cages, lifts, and hoists when the hauling rope breaks. Alcock. 10209.
Apparatus for removing boiler scale. Electric Safety Boiler Cleaner, Ltd., and Murray. 10250.
Heating systems. Williamson. 10271.
Condensers. Heenan & Froude, Ltd., Bliss & Cleworth. 10291.
Refrigerating and freezing machinery. Heenan & Froude, Ltd., and Wheal. 10295.
Method of treating antimony and arsenic ores. Trifonoff and Gardner. 10328.
Foundry moulding. Byrnes. 10330.
Self propelled vehicles. Ford. 10362.
Tube rolling mill. Koch. 10556.
Belts and pulleys. Pryor. 10566.
Ore-roasting furnaces. Bracq. 10642.
Washer for locking nuts. Roots. 10762.
Means for locking nuts. Kirton. 10945.
Drain valves for steam engine cylinders. Etchells & Roberts. 10963.
Power installations for the propulsion of marine vessels. Mavor, and Mavor & Coulson, Ltd. 11100.
Process for preserving metals from rust. Lemetre. 11432.
Miners' safety lamps. Prestwich. 11480.
Valves. Foster. 11869.
Acetylene generators. Patrick. 12213.
Metallic multiple packing rings for pistons. Whidbourne and Lishman. 12383.
Belts for the transmission of power. Harris. 12581.
Apparatus for feeding fine fuel to furnaces. Welton. 12752.
Power driven vehicles. Nelson & Bilby. 13158.
Apparatus for automatic analysis of gases. Binz. 13691.
Means for effecting the consumption of smoke in boiler furnaces. Thornton. 14383
Lock and block signalling for railways. Neele & Reed. 14593.
Belt fasteners. Hornby. 15079.
Machines for cutting metal by smooth discs rotating at high speed. Mars Werke Akt. Ges. 15137.
Valveless two stroke internal combustion engines. Johnson, Hurley, & Martin, Ltd., Johnson, and Cantrill. 15298.
Lubricating systems for fluid pressure engines. Poppe. 15883.
Feed water heaters. Marks. 16414.
Burners for drying moulds. Deutsche Luxemburgische Berg werks und Hutten Akt. Ges. 17887.
Safety valves. Lombard. 17960.
Means for controlling inlet and exhaust in internal combustion engines. Kloos. 18520.
Rotary gas scrubbers and washers. Chandler & Waller. 18562.
Safety couplings for railway vehicles. Baggot. 18686.
Rotary pumps for motors. Mendizabal & Bertrand. 19119.
Rotary pumps. Robertson. 19377.
Belting for machinery. Panzetta, and Panzetta Tyre Syndicate. 20103.
Ball bearings. Aktiebolaget Svenska Kullagerfabriken. 21176.
Two stroke internal combustion engines. Hallett & Blackmore 21569.
Liquid level gauge for tanks. Warden. 21651
Apparatus for utilising motor exhaust gases for generating steam. Stradtmann. 26016.
Mechanism for balancing single cylinder engines. Lally. 27071.
Charging apparatus for blast furnaces. Marks. 27139.
Pressure regulators. Schneider. 29190.

1912.

Means for centring irregular articles for turning in copying lathes. Winkle, Winkle & Winkle. 902.
Furnaces for steam generators. Lochner. 958.
Valves. Lowe. 1767.
Differential railway axles. Seabrook. 2330.

ELECTRICAL, 1911.

Automatic telephone exchanges. Welles & Zwietusch. 10238
Controllers for electric motors. Brown. 10364
Incandescent electric lamps. Hubers. 10433, 10434, and 10435.
Apparatus for operating electric motor controllers from a distance. Hirst & Brook. 11045.
Contact conductors of electric traction systems. Duddell and Partridge. 15597.
Automatic control of dynamos. Grafton & Prior. 16007.
Spark plugs. Mackenzie. 16437.
Telephones. Gwozdz. 19011.
Machines for generating electricity and machines driven by electricity. Boyd. 19160.
Incandescent electric lamps. Jahoda & Elektrische Gluhlampen Fabrik "Watt" Scharf Loti & Latzko. 27388.
Arc lamps. Siemens Schuckertwerke. 27699.
Method and device for polarising magneto electrical machines. Volkers. 28715.
Electric furnace. Helfenstein. 29126.

1912.

Alternating-current motors. Bell. 910.
Arc lamps. Way & Thorkelin. 1365.
Rectifier for high tension alternating currents. Siemens and Halske Akt.-Ges. 7467.

LAUNCH OF THE CRUISER "SOUTHAMPTON."

THERE was launched from the yard of Messrs. John Brown and Co., Clydebank, on the 16th inst., the second-class protected cruiser "Southampton." The "Southampton" is one of the "Town" class, 450ft. in length, 50ft. in breadth, 16ft. in draught, and of 5,500 tons displacement in normal load conditions. The propelling machinery consists of two sets of Brown-Curtis turbines placed in separate water-tight compartments. The ahead and the astern turbines are incorporated in one casing. Steam will be generated in 12 water-tube boilers of the Yarrow type, fitted with superheaters, designed to use coal and oil as fuel, arranged in three boiler-rooms, and worked under the closed stokehold system of forced draught. The machinery is designed to develop 25,000 h.p., and to give the vessel a speed of 25½ knots in normal load conditions. The armament includes eight 6in guns. All the vital parts of the vessel are protected by a heavy belt of protective steel, and the coal bunkers have been so arranged as to give further protection to the engines.

METAL QUOTATIONS.

TUESDAY, MAY 21ST.

Aluminium ingot	67/- per cwt.
„ wire, according to sizes, &c. ......from	102/- „
„ sheets „ „ ...... „	120/- „
Antimony .... £27/-/- to	£28/-/- per ton
Brass, rolled	8½d. per lb.
„ tubes (brazed)	10⅞d. „
„ „ (solid drawn)	9d. „
„ „ wire	8⅝d. „
Copper, Standard	£73/15/- per ton.
Iron, Cleveland	54/- „
„ Scotch	60/- „
Lead, English	£17/-/- „
„ Foreign (soft)	£16/10/- „
Mica (in original cases), small	6d. to 2/- per lb.
„ „ „ medium	2/6 to 4/- „
„ „ „ large	4/6 to 8/6 „
Quicksilver	£8/5/- per bottle.
Silver	28¼d. per oz.
Spelter	£25/12/6 per ton.
Tin, block	£208/10/- „
Tin plates	14/9 „
Zinc sheets (Silesian)	£29/[illegible] „
„ (Stettin; Vielle Montagne)	£29/7/6 „

Crane Boiler Explosion at Millwall.—The boiler of a travelling crane employed at the Millwall Dry Docks exploded on Saturday morning last, resulting in injuries to several workmen. The crane in question was being driven alongside the dock wall when the explosion occurred. The boiler, which weighed from 3 to 4 tons, was torn away from its staging on the crane and hurled into the air to a height of between 300ft and 400ft. It crashed through about 80 telegraph wires, and then fell through the roof of a carpenter's shop, about 450ft away. Three men were injured by the falling débris. The driver of the crane received serious injuries to the face and body, while another man who was standing near the crane giving directions as to its movements was hurled into the docks by the explosion and seriously injured by the fall.

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Foreign Travel and its Value to the Engineer.

Whit-week affords an excuse—if any excuse other than possession of the time and means be necessary—for a holiday, and a holiday naturally turns one's thoughts to travel, its pleasures, and its value. Of the pleasures of travel this is scarcely the place to speak, but there are some thoughts on the value of travel, especially foreign travel, to the engineer which may profitably be discussed. A century ago the Grand Tour was almost a necessary part of the education of those who aspired to the highest positions in the State. With the rise to importance of the manufacturing class—among whom one must include engineers—the value of the Grand Tour was somewhat obscured by the obvious financial success of many whose nearest approach to a Grand Tour was the annual inspection and stock-taking. Even in those vigorous, if somewhat narrow, times there were some of the manufacturing class who appreciated and sought the aid of foreign travel. Among such may, perhaps, be mentioned Richard Cobden, who owed much of his public and business successes to the influence of his foreign travels. To-day foreign travel is encouraged by universities and public opinion, but there seems to be lacking any clear conception as to what foreign travel is capable of doing for a man and, through him, the nation, or how to make the best of it. There is a pretty general impression that the man who undertakes an extended foreign tour in his capacity of engineer, business man, or student, is in for a "good time," but, unless he is hoping to achieve some specific commercial or technical object, there is a good deal of scepticism as to the value of it all. The day is gone past when business and pleasure could be kept in separate watertight compartments, and foreign travel ought to yield much pleasure in anticipation and at the time, but even more afterwards. It is a mistake, however, to imagine that a foreign tour is without its petty irritations and greater drawbacks. Indeed, one may go further and say that for the young man with the struggle of life before him it is a mistake

to relieve him altogether of the discipline and training of having to face unexpected and annoying situations and of having to maintain his self-respect and his dignity unsupported in the presence of people of all descriptions. When a man has formed his character it is safe to do all that forethought, introductions to people, and money can do in order to relieve him of unnecessary distractions, so that he may devote his best attentions to the more serious problems before him.

This distinction between the green young man and his elder goes beyond the comforts of travel. A student, for instance, however clever he may be, is but ill-fitted to appreciate the details of a manufacturing process or the factors which have produced a certain organisation. He is capable of recognising certain broad facts, such as the wide adoption of electric driving, the success and non-success of piece work in different branches of the trade, and the tendency to sectionalise into departments and to specialise in many ways. The mere fact of watching for and recognising such tendencies is useful in itself, and brings to his notice a wide variety of information which is useful in other directions. The experienced man can, however, look deeper below the surface than the student. He knows, say, that in his home experience a certain practice has not been a success. In the foreign works it is a success, and he naturally notes the fact, which the student would probably have missed from sheer ignorance of home conditions. If the man is wise and thoughtful he does not stop at merely recording a difference in practice between the two countries. He goes further, and asks himself why one method succeeds at home and a different one abroad. Possibly he never thought about it at home, but he now begins slowly to realise the factors which determine not only the foreign practice, but also that in use at home. Thus his foreign tour not only extends the scope of his outlook, but it deepens it. It would be difficult to say which is the more useful service, but either alone would be sufficient to justify foreign travel.

It may be thought from what has been said above that only experienced men, and not students, should travel. That would certainly be a mistake. Travel helps to form a young man's character—and, unfortunately, sometimes to destroy it —and it tends to make him more observant, more thoughtful, and more receptive than he otherwise would have been. If he is poor material to begin with, it will not make him into a great success, but if he has the qualities necessary for good work these powers of observation, discussion, and recognition will greatly increase his value. It is, however, a mistake to expect that foreign travel will convert a student immediately into an expert; whether in finance, commerce, or technical work. Many engineers and business men do make this mistake, and express their dissatisfaction when they find that a young engineer on his return from a tour in Germany or the United States is unable to recite a catalogue of those details of office and workshop practice in which he considers English firms defective.

On the other hand it is certainly true that the man of experience is specially fitted to benefit by a foreign tour. Presumably he has already demonstrated that he is made of good material. His experience guides him in his observations, and his power of forming a judgment should be better than that of a younger man. Another advantage, which counts for more in some countries than in others, is that his age and experience secure him more interviews, and better ones, with men in important positions, than can be obtained by a student. Thus there is no doubt but that experienced engineers need more opportunities of foreign travel. The giving of the equivalent of a scholarship to a man who has been actively engaged in business for some years is somewhat foreign to British ideas, but it is difficult to resist the conclusion that travelling scholarships for men of experience would confer greater benefits on the individual and the nation than even the present ones. Private firms can help in two or three ways. They can modify their foreign business arrangements so as to permit of responsible members of their home staff making occasional trips abroad, they can send men out specially to study, and they can encourage a man by giving him extended leave or holiday. It is, of course, impossible to prescribe any definite rules for guidance, but it is worth while drawing attention to the good work which can be done by an experienced man sent out by his firm to study foreign methods. Foreign commercial travellers whose business it is to canvass for orders are widely employed, but it is very rare to find a man sent out to study the requirements of a market and the existing methods of meeting them, so that he may return to the home firm and organise a department or design machinery and goods suited to the needs of the market. As a rule a commercial traveller is not of much help to a firm until they have grasped the requirements of the market and produced the class of goods suited to it; and without the assistance of a technical man acquainted with the market the firm will often be quite unable to do this.

It is a mistake to construe the studies of a foreign tour in a narrow sense. We are not now dealing with those cases where a man is abroad for some specific and narrow purpose, such as the obtaining of a contract or the appointment of an agent, but rather with those cases where the issues are wider. Finance, commercial practice, the markets, state of the art, labour supply, politics, social ideals, and natural resources all matter. It is not possible to understand the labour market without studying the social and political ideas that are current and those that are coming to the front, nor is it possible to study the state of the art without reference on the one hand to the natural resources and markets of the country, and the finance and business practice on the other. It is not so long ago that history as written was a catalogue of battles and royal intrigues. Later it was extended to include the doings of Parliament, and still more recently it took somewhat misinformed notice of invention and industry. Similarly, the study of industries was at first limited by the walls of the workshop, and then extended to include the buyer. To-day it has gone further. Labour receives as much attention as the other factors, and the general moulding influences of current ideals and public opinion are recognised as factors that cannot be ignored. The only limit to the breadth of one's studies abroad should be placed by one's capacity to assimilate and to combine into a connected scheme or mental picture. Each section should be a unit with its own clear-cut principles and self-contained logical arrangement, but all should be linked up by elementary yet comprehensive principles into a greater scheme in which each unit plays its part, whether great or small.

Institution of Electrical Engineers.—The summer meeting of this Institution will be held at Glasgow on June 12th, 13th, and 14th next. On the Wednesday the members will meet at the Technical College, when a paper on "The Transmission of Electrical Energy by Direct Current on the Series System," by Mr. J. S. Highfield, will be read and discussed. The afternoon will be devoted to the inspection of works. On the Thursday, a lecture on "The Magnetism of Permanent Magnets" will be delivered at the University by Prof. S. P. Thompson, F.R.S. Works will again be visited in the afternoon. On the Friday there is to be an excursion on the Clyde in the morning and afternoon.

THE PRESENT STATE OF DEVELOPMENT OF LARGE STEAM TURBINES.*

BY A. G. CHRISTIE.

(Concluded from page 641.)

Turbo-generators.—A discussion of the design of turbo-generators is beyond the limits of this paper. In general, European builders of electrical machinery allow less overload capacity than is usual on American machines, but give better guarantees of efficiency and regulation. Practice varies widely in regard to the normal rating and maximum capacities of different turbines. Some European builders guarantee their generators to carry normal full load without undue heating only for two to six hours. Others follow the practice which has been introduced in America of rating their turbines at the maximum load they will carry continuously. Several builders still offer turbines which will carry as high as 25 per cent. overload continuously. Such conditions are very confusing to purchasers. The time seems opportune to fix a standard for the rating of steam turbines, and to define the overload capacity which may be expected of this type of engine.

Commercial Considerations.—When steam turbines are to be installed at high altitudes, the effect of altitude on economy frequently comes up. It can be easily shown that with the same boiler pressure and the same absolute pressure in the condenser, the steam consumption of a turbine at 5,000ft. elevation should exceed that of a similar turbine at sea level by less than 1 per cent.

Each turbine is designed to operate at maximum efficiency at some given vacuum. Owing to uncertainties in design factors for losses and to slight inaccuracies in construction, the most efficient vacuum may vary somewhat from that for which the turbine was designed. Theoretically, the steam consumption should decrease as the vacuum increases, but this rate of decrease will vary for each type of tubine, depending on the blade areas and steam velocities of the low-pressure section. It is, therefore, essential that this rate of change be determined for each individual turbine by actual test.

In the purchase of steam turbines, operating efficiency and costs should be considered together with first cost, and the machine selected should be the one on which the ultimate operating and fixed charges are a minimum. This practice is followed in Europe. In America the bargain-counter idea unfortunately possesses many engineers, and manufacturers have frequently been forced to sacrifice efficiency in order to meet competition.

In Table I. some data are presented in tabulated form regarding various types of steam turbines. This information was gathered during personal visits to the various works and also by correspondence. Designs of steam turbine details are constantly changing, so that many of the items in this table may not correctly represent the latest practice of the various builders.

Results of Tests.—The efficiency of a steam turbine may be expressed in terms of pounds of steam per kilowatt-hour as an efficiency ratio or as the B.Th.U. required per kilowatt-hour. The steam consumption is dependent on the initial steam pressure, its temperature or quality, and the condenser pressure. These factors vary in almost every test, and the effect of a variation in each is not the same for all classes of turbines. Hence, different turbines cannot usually be compared satisfactorily on the basis of their steam consumption alone.

If the steam could expand freely to exhaust pressure in a turbine without radiation, friction, eddy or windage losses, its expansion would be adiabatic and on the Rankine cycle. The "efficiency ratio" expresses the proportion of the heat actually turned into work to that available from such an adiabatic expansion. In other words, it expresses the efficiency of the actual turbine as compared with the ideal turbine, and is independent of the type of turbine.

The B.Th.U. per kilowatt-hour is figured above the heat of the liquid at exhaust pressure. This is not a satisfactory standard by which to compare results, for it is largely dependent on conditions beyond the control of the turbine builder. For instance, if the plant does not contain superheaters, the B.Th.U. per kilowatt-hour will be high. The same will be true of a plant which has a warm cooling-water supply for condensers and consequently carries low vacuum. Yet the turbines may be designed to give a high efficiency ratio under these conditions. In fact, they may be able to utilise the heat available more efficiently than the turbines in another plant with both high superheat and high vacuum.

This can be seen in Table II., in which recent turbine tests have been tabulated. The Brown, Boveri turbine at the Dunstan power plant uses 14,980 B.Th.U. per kilowatt-hour with an efficiency ratio of 68·8 per cent. Yet the Westinghouse City Electric with a lower steam pressure, lower superheat and lower vacuum has an efficiency ratio of 68·9 per cent., though using 16,925 B.Th.U. per kilowatt-hour. The Erste Brünner Vienna turbine requires 16,460 B.Th.U. per kilowatt-hour with 71·8 per cent. efficiency ratio. It is therefore apparent that the efficiency ratio alone will express in the best manner the degree to which the designer has approached ideal results in his turbine.

The test results in Table II. were grouped in order to analyse the relative merits of the different types of turbines on the basis of efficiency ratios. The Curtis-Parsons machines built by Erste Brünner hold first place in the list, but are followed closely by others of the same type built by Brown, Boveri and Westinghouse Machine Company. The Parsons turbines, built by Allis-Chalmers and Brown, Boveri, also show high efficiencies. The second class in the order of efficiency includes turbines of the Curtis-Rateau and Curtis-Zoelly types, among which the turbines of the A.E.G. and British Westinghouse Company show remarkably good results. The next group includes simple Zoelly and Rateau turbines. The last group comprises straight Curtis types.

The superiority of the Curtis-Parsons over the Parsons type is probably due to the reduction in the fluid friction and rotational losses occurring in the first cylinder of the Parsons by the use of a Curtis stage in this section.

The Parsons low-pressure sections evidently utilise the heat in the steam only slightly more efficiently than do the impulse turbines. The great surface areas of all disc type turbines which must be whirled in steam, produce losses which are apparently somewhat larger than the combined whirling losses and leakage in the Parsons drum turbines. Both the Zoelly and Curtis-Rateau types appear to use the steam more effectively in the low-pressure sections than the Curtis alone. Many European engineers hold the opinion that where high economy is to be obtained, the impulse turbine of the Rateau or Zoelly type is superior to the Curtis, though its manufacturing costs are higher. The Curtis-Rateau construction has all the commendable features of impulse turbines and has proved very economical.

The results shown in Table II. are from the best reliable tests that have been made on each type. Objection may be raised that these results do not represent actual operating conditions as under varying loads, nor the average economy of any type of turbine. For instance, the Curtis turbine usually gives a very flat water-rate curve, while the Parsons type is more convex. On the other hand, recent tests on the new Curtis-Parsons types have also shown flat water-rate curves at various loads. It was impossible to compare the various types from this standpoint on account of absence of complete data of such tests. It is interesting to note in Table II. that the best results have been obtained within the past two years, and that these show a considerable increase in efficiency over the earlier tubines.

Low and Mixed Pressure Turbines.—One of the first low-pressure turbines installed was described by Professor Rateau in his paper on "Different Appliances of Steam Turbines." The exhaust steam from various non-condensing reciprocating engines around mines was conducted to a regenerator, from which the turbine drew its steam supply. Many low-pressure turbines have been erected since 1904, and have shown very economical results. In some installations it is usual to provide for operation on high-pressure steam when the supply of exhaust steam is insufficient to meet the power demand. Hence the mixed pressure turbine has been developed. In Europe a Curtis stage is added at the inlet and the live steam passed through this before entering the low-pressure section. The whole of the heat content of the live steam can be effectively utilised by this method. Bleeder turbines are also being built, in which, after partial expansion to some fixed pressure, a portion of the steam is withdrawn from the casing for heating or industrial purposes.

* Paper read before the American Society of Mechanical Engineers.

Low-pressure turbines are frequently installed to use the exhaust steam of reciprocating engines without regenerators. In this case the generators are sometimes tied together electrically and the turbines are only fitted with an overspeed governor. Messrs. Stott and Pigott showed the results that could be obtained from such a combination in their paper, "Test of a 15,000 kw. Steam Engine-Turbine Unit." Such turbines are usually installed in stationary work only when the reciprocating engines are already in service. The high-pressure turbine in a new plant requires less floor space, has less complicated machinery, is cheaper in first cost and in maintenance, and approaches, if it does not equal, the economy to be derived from the combination unit in every-day service. Nevertheless, there have been a number of combined engine and turbine plants recently installed in England which have proved very satisfactory. It is probable that low-pressure turbines will be installed in the near future in large gas engine stations to utilise the waste heat in the gas engine exhausts.

Turbo-compressors.—Turbo-compressors have some decided advantages over reciprocating compressors, such as smaller floor space, absence of inlet and discharge valves, low cost of upkeep, and no internal lubrication. They are being manufactured quite extensively in Europe, and have been introduced in America by the General Electric Company, one of whose turbines was described by Mr. R. H. Rice in his paper, "Commercial Application of the Turbine Turbo-Compressor," read at the Pittsburg meeting of the Society. Turbo-compressors are built either with curved or radial impeller blades, which discharge the air into smooth expanding diffuser channels to convert the velocity energy of the current into pressure. Usually guides are provided to direct the air into the entrance of the next stage without eddies. All passages are made as smooth as possible with no abrupt bends or turns, and all walls are water-cooled. The air is prevented from leaking back from stage to stage by labyrinth packings, such as are used in impulse turbines.

European builders have installed turbines to deliver air at as high pressure as 130lbs. per square inch gauge, and are prepared to furnish them up to 180lbs. discharge pressure. Turbo-blowers have also been built to deliver large volumes of air at low pressure such as are required in furnace work. These units have no water-cooled jackets. The first difficult problem encountered in the construction of turbo-blowers or compressors was the provision of a suitable governing device for the unit. However, several ingenious and satisfactory arrangements have recently been developed, and it is probable that this difficulty will soon be overcome completely.

The efficiency of turbo-compressors with water-cooling is defined as the ratio of the power required to compress the given quantity of gas isothermally to the power consumed at the compressor coupling in the actual compression. This efficiency in well-designed units, with discharge pressure between 60lbs. and 150lbs., should fall within the limits of 60 and 70 per cent. The best results noted up to the present time were obtained in a turbo-compressor built by Pokorny & Wittekind for the Victoria Falls Power Company in South Africa, which, on official test, showed an efficiency of 67·7 per cent.

When there is no water-cooling provided, the efficiency of a turbo-blower is expressed as the ratio of the power required to compress the given quantity of air adiabatically to the power actually expended at the compressor coupling. This efficiency, depending on the size of the blower, should fall between 70 and 80 per cent. as a maximum. An efficiency of 78 per cent. has been obtained on official tests of a Rateau turbo-blower built by Kuhnle, Kopp, & Kausch, and is probably the best result obtained up to the present time on this type of compressor.

It can thus be seen that, in so far as efficiency is concerned, the turbo-compressor is equal to the average reciprocating compressor. It seems probable that turbo-compressors and blowers will be used to an increasing extent, largely on account of their low first cost and operating costs as compared with steam reciprocating units. The high thermal efficiency of the gas-driven blowing engine exceeds that possible in a turbo-compressor unit so that the former will continue to be used in blast furnace work.

Turbo-driven Pumps.—The steam turbine is an ideal source of power to drive centrifugal pumps, especially when it is necessary to lift against high heads. The efficiency of such centrifugal pumps usually ranges from 65 to 80 per cent, so that, in spite of the high efficiency of the turbine itself, the combined set will not give as good economy as a high-grade reciprocating pumping engine. However, its first cost is low, it requires no internal lubrication, takes up very little floor space, and has no valves to require examination or renewals.

Geared Turbines.—Attempts have been made to adopt steam turbines for direct connection to continuous-current generators and other slow-speed machinery. A steam turbine to be economical must be a high-speed machine, and hence its use with slow-speed machinery has not proved entirely satisfactory. Dr. De Laval adopted spur gearing as a means of reducing speeds on his first simple impulse turbines, and builders of this type still use this construction. It is only within the last few years that attempts have been made to apply gearing as a means of speed reduction on other types of turbines. The Westinghouse Machine Company are now manufacturing direct-current turbo-generators with the Melville-MacAlpine reduction gearing between turbine and generator. This gear is also being built for use in marine work to drive slow speed propellers. The gear wheels in this construction are carried on a floating frame so that the teeth may be always in correct alignment. One set of such gearing showed under test an efficiency of 98·5 per cent.

C. A. Parsons & Co. have built several notable reduction gears for steam turbines in which the floating frame idea was omitted. A mixed-pressure steam turbine of 750 b.h.p. is now in use driving a three high set of rolls through gearing at the Calderbank Steel Works, near Glasgow, Scotland. A flywheel is placed on the same shaft as the driven gear and thus takes the shock off the turbine when a billet enters the rolls. In 1909 the Parsons Marine Steam Turbine Company installed a geared turbine of 1,000 h.p. in the s.s. "Vespasian" of 4,000 tons. Extensive experiments were carried out, and it was found that the efficiency of this gearing, which had no floating frame, ranged between 98 and 99 per cent. After a year's operation, in which the ship covered 20,000 miles, tests were again made on the gearing with equally good results. On examination no appreciable signs of wear could be noted on the gear teeth, which were made of mild chrome nickel steel and were flooded with oil.

It is perfectly feasible to adopt the steam turbine through gearing to belt and rope drives when these are required in large powers. Under certain conditions, where fuel costs are high and water for condensation is plentiful, such an installation would prove an economical investment in place of reciprocating engines. The direct turbine drive would then come into competition with the motor drive. The losses in line shafting can be greatly reduced by the use of ball or roller bearings, so that the turbine drive may prove very economical in some instances as compared with individual motor drives.

The use of geared turbines in large sizes has been in the nature of an experiment until quite recently. Judging from the results obtained in recent installations, their commercial success seems now assured. In the design of these units the tendency will be to simplify details. The success of the Parsons gears on the s.s. "Vespasian" should encourage designers to do away with any special devices to secure alignment, and to provide simply accurately cut gears properly meshed and running in a flood of oil.

Marine Turbines.—All the standard types of turbines have now been adopted for marine service in driving screw propellers, either direct connected or through gearing. The design of direct connected turbines is complicated by the fact that the speed of screw propellers must necessarily be low as compared with the most favourable speeds for economical steam turbine operation. Hence these turbines require large spindle diameters and massive construction, and yield correspondingly poor steam economies especially at slow speeds. These units are usually built with the power divided between two or more shafts connected to high and low pressure cylinders. With geared equipments the turbines can be operated at their most efficient speeds, while the gears can be so designed that the propeller also runs at its most economical speed. Reversing is made possible by suitable blading in the low pressure ends of the main units into which live steam is admitted when desired. When the turbine is running forward this blading revolves in vacuum and consumes but little power.

Combined types of turbines are also being introduced in marine

installations. A recent Curtis design includes a drum impulse section. M. Zoelly now uses Curtis stages in his high-pressure section, but with steam velocities not exceeding 1,300ft. per second, obtained by converging nozzles only, and drum impulse construction on the low-pressure ends. Several other European builders have also used Curtis stages in the high-pressure portion.

Reciprocating engines exhausting into low-pressure turbines have been installed in several ships, the most notable of which inexperience with electrical machinery, as the essential conditions of operation in marine work do not differ greatly from those under which many electrical machines operate satisfactorily in land practice.

Turbo-driven lighting sets and other auxiliaries are being used in increasing numbers on shipboard, owing largely to the high efficiencies which may be obtained, to the small floor space required, and to the light weight of the units.

TABLE II.—*Economy Tests of High-pressure Steam Turbines. Efficiency Ratios based on E.H.P. Marks, and Davis Steam Tables Used.*

Maker of Turbine	Type	Date of Test	Load-Kw.	R.p.m.	Steam Pressure Lb. Absolute	Temperature at Throttle, deg. fahr	Vacuum referred to 29.92" Bar	Condenser Pressure, Lb. Absolute	Lbs. of Steam per Kw-Hr.	B.t.u. per Kw-Hr.	Heat Utilized per Lb. of Steam	Heat Available per Lb. of Steam	Efficiency Ratio	Reference
Erste Brünner M. F. G.	Curtis-Parsons	1910	2128	1500	156.2	482	27.89	0.995	13.82	16460	247.0	343.8	71.8	Periodische Mitteilungen
Erste Brunner M. F. G	Curtis-Parsons		6000	960	184.9	573	28.18	0.854	12.56	15570	271.5	380.7	71.3	Zeit. D.V.D. Ing., 12/10/'10
Erste Brünner M. F. G....	Curtis-Parsons	1910	7442	960	192.0	584	28.18	0.853	12.625	15705	270.2	384.4	70.3	Periodische Mitteilungen
Westinghouse Machine Co	Curtis-Parsons	1910	9173	1800	181.7	433	27.81	1.032	14.57	16925	234.1	340.2	68.9	Trans. A.S.M.E., vol. 32
Brown Boveri & Cie....	Curtis-Parsons		3053	1360	150.2	505	29.00	0.456	13.01	15990	262.2	385.5	68.0	Dinglers P.J. 6/17/'11
Erste Brünner M. F. G....	Curtis-Parsons	1910	1416	1260	128.2	482	27.60	1.137	15.18	18060	224.6	326.5	68.8	Periodische Mitteilungen
Brown Boveri & Cie.	Curtis-Parsons	1911	1750	1500	176.4	586	27.08	1.392	14.23	17500	239.5	354.8	67.5	Zeit. F.D.G. Turb., 5/30/'11
Brown Boveri & Cie.......	Curtis-Parsons	1910	3764	1500	161.2	561	28.77	0.562	13.04	16290	261.5	391.4	66.8	Zeit. F.D.G. Turb., 5/30/'11
Westinghouse Machine Co.	Curtis-Parsons		9830	750	192.2	475	27.22	1.322	15.15	17790	225.2	336.0	67.0	Trans. A.S.M.E., vol. 32
Brown Boveri & Cie.......	Curtis-Parsons	1911	1495	3000	200.6	563	26.41	1.720	14.78	17880	230.7	345.5	66.8	Data from Manufacturer
Brown Boveri & Cie.......	Curtis-Parsons	1911	1271	3000	172.1	568	27.31	1.278	14.61	17880	233.5	354.3	65.9	Data from Manufacturer
Westinghouse Machine Co.	Curtis-Parsons		11466	750	191.7	484	28.07	0.910	14.45	17210	236.0	360.5	65.5	Trans. A.S.M.E., vol. 32
Erste Brünner M. F. G....	Curtis-Parsons		1250	3000	184.9	573	27.89	0.996	14.32	17680	238.2	373.1	63.9	Zeit. D.V.D. Ing., 12/10/'10
Brown Boveri & Cie.......	Curtis-Parsons	1910	3320	1500	180.9	525	29.02	0.440	13.50	16680	252.7	401.3	63.0	Zeit. F.D.G. Turb., 5/30/'11
Brown Boveri & Cie.......	Curtis-Parsons		5128	1000	171.2	565	28.52	0.726	14.35	17830	237.7	382.9	62.1	Stodola, 4th ed., p. 149
Breitfield, Danek & Co. ...	Impulse-Parsons	1909	3585	896	160.7	457	28.32	0.782	16.08	19070	212.0	352.4	60.2	Zeit. D.V.D. Ing., 12/10/'10
Brown, Boveri & Cie....	Parsons	1910	6257	1210	203.7	559	29.02	0.440	11.95	14980	285.5	415.0	68.8	Official Test Report
Allis-Chalmers.........	Parsons	1908	4300	1800	186.4	484	27.96	0.960	14.02	16690	243.4	355.7	68.4	Sibley Jour. of Eng., 1/11'
Brown Boveri & Cie..	Parsons	1903	3500	1360	156.4	499	28.84	0.532	13.71	16720	248.5	378.6	65.6	Zeit. D.V.D. Ing., 12/10/'10
Brown Boveri & Cie...	Parsons		3000	1360	165.0	625	27.02	1.420	14.75	18433	231.3	359.5	64.3	Die Turbine, 6/20/'11
C. A. Parsons & Co...	Parsons		5164	1200	214.3	509	28.95	0.473	13.18	16140	258.7	402.3	64.3	Stodola, 4th ed., p. 439
Allis-Chalmers	Parsons	1911	3850	1800	164.7	491	27.91	0.983	15.40	18410	221.3	348.3	63.5	Power, 1/2/'12
A. E. G.	Curtis-Rateau	1911	6518	1220	198.7	601	29.28	0.352	11.43	14640	298.4	434.2	68.7	Official Test Report
A. E. G.........	Curtis-Rateau	1911	6565	1220	200.2	597	29.18	0.406	11.64	14848	293.0	427.7	68.5	Official Test Report
British Westinghouse..	Curtis-Rateau	1911	5066	1500	190.2	552	28.68	0.649	13.00	16100	262.4	391.5	67.0	Electrical Review, 6/23/'11
M. A. N................	Curtis-Zoelly		3584	1500	178.3	569	27.54	1.166	13.99	17190	243.7	361.3	67.5	Data from Manufacturer
Bergmann.........	Curtis-Rateau	1909	1545	1500	188.5	581	28.59	0.654	12.97	16230	263.0	396.3	66.4	Zeit. D.V.D. Ing., 12/10/'10
Bergmann............	Curtis-Rateau	1910	2477	1500	140.0	522	28.81	0.588	13.93	17135	244.8	373.4	65.6	Elec. Zeit., 4/20/'11
A. E. G.	Curtis-Rateau	1908	4239	1500	188.3	662	29.11	0.397	11.97	15620	284.9	439.0	64.9	Stodola, 4th ed., p. 404
British Westinghouse.	Curtis-Rateau	1911	2930	1500	210.2	568	28.18	0.894	13.72	16935	248.7	383.3	64.9	Electrical Review, 4/28/'11
A. E. G.............	Curtis-Rateau	1907	3169	1500	184.7	592	29.11	0.397	12.74	16230	267.7	425.1	63.0	Trans. A.S.M.E., vol. 32
M. A. N.............	Curtis-Zoelly		2507	1500	175.5	460	27.40	1.234	16.24	19020	210.0	334.6	62.8	Data from Manufacturer
Bergmann	Curtis-Rateau	1909	1562	1500	186.8	555	28.33	0.780	14.57	17970	234.1	381.3	61.4	Data from Manufacturer
James Howden & Son....	Zoelly	1909	6383	1000	202.7	520	27.33	1.269	14.305	17150	238.5	353.0	67.5	Engineer, London, 10/29/'09
M. A. N................	Zoelly	1910	1400	3000	180.7	554	27.40	1.237	14.21	17310	240.0	356.2	67.4	Zeit. D.V.D. Ing., 12/10/'10
Escher, Wyss & Co.......	Zoelly	1910	2052	3000	193.9	585	28.39	0.750	13.04	16290	261.5	392.6	66.6	Zeit. F.D.G. Turb., 2/20/'11
Escher, Wyss & Co.......	Zoelly	1910	4189	1000	179.7	557	28.66	0.618	13.30	16520	256.5	391.3	65.5	Zeit. F.D.G. Turb., 2/20/'11
F. Ringhoffer............	Zoelly	1908	3000	1000	170.7	470	27.60	1.138	15.52	18278	219.8	339.2	64.8	Zeit. D.V.D. Ing., 12/10/'10
M. A. N................	Zoelly	1910	1250	3000	182.1	582	28.82	0.540	13.09	16500	260.2	404.5	64.4	Zeit. D.V.D. Ing., 12/10/'10
Oerlikon...............	Rateau	1911	3166	1500	213.9	663	29.25	0.367	11.44	14970	298.2	450.6	66.1	Engineering, 10/20/'10
Escher, Wyss & Co.......	Zoelly		5118	1000	133.7	549	27.55	1.161	15.18	18530	224.6	341.6	65.7	Dinglers P.J., 7/15/'11
Escher, Wyss & Co.......	Zoelly	1908	5000	1000	166.4	539	26.38	1.736	16.13	19350	211.2	330.4	63.9	Zeit. D.V.D. Ing., 12/10/'10
Escher, Wyss & Co.	Zoelly		3540	1500	155.1	469	28.21	0.838	15.07	17940	226.3	349.5	64.8	Dinglers P.J., 7/15/'11
Escher, Wyss & Co.......	Zoelly	1910	1641	3000	221.0	672	27.91	0.985	13.08	16775	260.6	406.5	64.1	Zeit. F.D.G. Turb., 2/20/'11
Escher, Wyss & Co......	Zoelly	1910	1235	3000	176.8	451	28.39	0.750	15.35	18156	222.3	357.8	62.2	Zeit. F.D.G. Turb., 2/20/'11
British Thomson-Houston	Curtis	1911	2987	1500	154.7	505	26.75	1.557	15.96	18960	213.7	321.2	66.5	Engineering, 10/20/'11
Gen. Elec. Co.........	Curtis		3464		210.0	513	28.75	0.575	13.62	16620	250.4	393.4	63.6	Trans. A.S.M.E., vol. 32
British Thomson-Houston	Curtis	1909	2500	1500	126.5	414	28.17	0.711	15.92	18590	214.0	336.1	63.7	Zeit. D.V.D. Ing., 12/10/'10
A. E. G..............	Curtis	1906	3000	1500	191.3	590	29.05	0.427	12.79	16240	266.6	420.4	65.4	Zeit. D.V.D. Ing., 12/10/'10
A. E. G.	Curtis	1909	2236	1500	191.6	654	29.34	0.284	11.77	15450	289.8	455.8	63.6	Zeit. D.V.D. Ing., 12/10/'10
Gen. Elec. Co.	Curtis		8880		192.5	487	28.02	0.933	15.05	17965	226.7	359.5	63.1	Trans. A.S.M.E., vol. 32
British Thomson-Houston	Curtis	1911	1541	1500	149.7	365	27.97	0.956	17.46	19720	195.3	320.2	61.0	Engineering, 10/20/'11
Gen. Elec. Co..........	Curtis		10816	750	190.0	525	29.39	0.260	12.90	16135	264.5	427.3	61.9	Trans. A.S.M.E., vol. 32
Gen. Elec. Co............	Curtis		5095		185.1	554	29.40	0.255	12.71	16090	268.4	436.0	61.6	Trans. A.S.M.E., vol. 32
British Thomson-Houston	Curtis	1911	1221	3000	134.7	448	27.16	1.353	17.75	20690	192.2	314.0	61.2	Engineering, 10/20/'11
Gen. Elec. Co............	Curtis	1910	8775	750	194.0	451	27.95	0.956	15.95	18720	213.8	350.8	61.0	Trans. A.S.M.E., vol. 32

References: Zeit. D.V.D. Ing.—Zeitschrift des Vereines Deutscher Ingenieure. Zeit. F.D.G. Turb.—Zeitschrift für das Gesamte Turbinenwesen. Dinglers P.J.—Dinglers Polytechnisches Journal. Elec. Zeit.—Electrotechnische Zeitschrift.

is the "Olympic," and have shown very satisfactory results. In this case the engines are used for reversing.

Many schemes have been proposed to install turbo-generators of central station type on shipboard and to operate the propeller shafts by means of large slow-speed induction motors. Marine engineers object to this arrangement on account of the dangers accompanying the use of such electrical machinery and auxiliaries in marine service. This objection seems to be due largely to

Recent orders for turbine-driven steamships abroad include some interesting equipments. The Canadian Pacific Railway has ordered two boats with four screws and with Parsons turbines. The two outside screws will have high and intermediate pressure turbines respectively, while the two centre screws will be connected to low-pressure turbines. Two twin-screw passenger boats of 5,000 h.p., with Parsons turbines, have been ordered for the Southampton-Havre service. Each set consists of a

high-pressure and a low-pressure turbine, geared individually to its own propeller shaft. The British Government has ordered two twin-screw destroyers also to use Parsons geared turbines, totalling 11,000 h.p. per ship, or 7,000 h.p. per gear. The United States Government has placed an order with the Westinghouse Machine Company for a gear equipment on one of its colliers. Geared turbine equipments are thus making rapid headway on account of the high efficiency of the combination and the resultant favourable steam consumption obtained.

At the present time about 90 per cent. of the marine turbines built have been of the Parsons type. Here again the inefficiency of the Parsons high-pressure sections has become apparent, so that it is probable that a construction similar to Zoelly's high-pressure end will be introduced in this section. Sir Charles A. Parsons is quoted as saying: "In the low-pressure blades of the 'Mauretania' the leakage was practically nothing, and their efficiency was about 85 per cent.' Under such conditions it does not seem probable that much higher efficiency can be obtained by use of other constructions than the Parsons reaction type in the low-pressure section. It is reported that the low-pressure blading of Parsons turbines in ships of the United States Navy has given considerable trouble, and also that the turbines need more careful handling when starting up than do impulse turbines.

Trend of Turbine Development.—The cost of manufacture is a very important item in determining the future development of the steam turbine. Types such as the original Parsons and the Rateau, while inherently of very high efficiency, have too high manufacturing costs to compete with the newer combined types. The writer offers as his opinion that the combined types, such as the Curtis-Parsons, the Curtis-Rateau, and also the Curtis-Rateau-Parsons, previously described, will very soon supersede the simple types. It is probable that the Curtis turbine will eventually be built only in horizontal units, and will gradually be modified to a Rateau or even a drum impulse construction in the low-pressure sections. The freedom from close adjustment in impulse turbines and the recent improvements in blading materials will greatly increase the use of this type, although Curtis-Parsons turbines are said to be cheaper to manufacture. In actual operation it is an open question among engineers whether the reaction turbine has a higher commercial efficiency than the impulse type, and hence buyers usually consider first cost and personal preference only.

Turbines will probably be made shorter with very stiff shafts. With this construction many of the earlier blading troubles will disappear. But the peripheral speeds will also be increased, and this will involve the development of suitable blading material and methods of holding blades that will satisfy these new requirements. Recent results seem to indicate that improved efficiency may be looked for with increased blade speeds.

Several impulse turbines have been built recently in Europe, where the expansion was not complete in the nozzle, so that a portion of the expansion took place in the first moving blades. Some large Curtis turbines recently installed in America are said to have Parsons blading in the last stage. These developments would indicate a movement to introduce reaction principles in impulse turbines, and further illustrate the tendency to merge types.

The hope of further improvement in efficiency lies in extensive study, particularly of the action of the steam during its passage through the moving and stationary blades, of the effect of form of blades, passages and casings, and of various forms of baffles and balance pistons to prevent leakage. Such research work has not been carried out up to the present time by most manufacturers, largely on account of the extreme care and heavy expense involved in such tests. The present state of development has been largely one of cut and try. The increasing competition of the gas engine and the possible development of a satisfactory gas turbine will force manufacturers to develop their turbines to the greatest degree of economy.

With regard to detail, simplicity will be the leading consideration. With the introduction of Curtis high-pressure stages, nozzle governing will undoubtedly be used to an increasing extent though the results obtained by Westinghouse, by Zoelly, and by Bergmann with simple throttling governors, raise a question as to whether the additional complication of nozzle governing will pay. Oil relays will probably replace all other systems of governing on account of their simplicity and reliability. The simple and efficient centrifugal oil-pump governor of Sulzer appears to be an improvement of considerable moment, and will probably receive extensive use.

With the development of suitable gearing for steam turbines, their field of application has been greatly increased, and turbines will shortly be used for purposes for which engineers to-day would consider them utterly unfit. Low-pressure turbines will continue to be installed in plants where reciprocating engines are still in operation and also where large quantities of waste heat are available. The low and mixed pressure types of turbines will find a very extended use in connection with heating systems, evaporators, &c.

The development of the past ten years has been truly marvellous. No great gain in thermal efficiency seems possible, so that future improvements will be largely along the line of detail construction and modification.

The writer wishes to express his thanks to manufacturers of steam turbines in America and in Europe, who liberally provided him with the information on which this paper is based, both during personal visits to their works and by correspondence.

ELECTRIC REVERSING BLOOMING MILL EQUIPMENT.*

BY BRADLEY T. MCCORMICK.

THE Algoma Steel Company, of Sault Ste. Marie, Ontario, Canada, has recently put into operation an electric reversing mill equipment operating the blooming mill. The mill is required to roll 75 tons per hour from ingots 20in. by 20in. into billets 8in. by 8in. in 15 passes. The electrical equipment, Fig. 1, is in a separate building from the mill, with an opening in the wall to permit connection between the mill motors and the rolls, while in the mill room, in a position convenient to the operator, are placed the operating controller and an instrument column carrying meters showing the current, voltage, and speed of machines.

The rolls are driven by two 600 volt direct-current motors mounted on the same shaft. Each of these motors has a normal rating of 2,000 h.p. at 75 revs. per minute, and their armatures are connected in series across 1,200 volts. The current for the motors is supplied by a flywheel motor generator set consisting of two 1,700 kw., 600 volt, direct-current generators, with their armatures also connected in series, driven by a 25-cycle, 3-phase induction motor of 1,800 h.p. capacity, at 375 revs. per minute synchronous speed. A 150,000lbs. flywheel serves to equalise the load, so that the power drawn from a 25-cycle line is kept practically constant at a value corresponding to the average power required by the rolling mill motors. The flywheel motor generator set is shown in Fig. 3.

As the power demand at the rolls rises and falls, a slip regulator automatically inserts or cuts-out resistance in the rotor circuit of the induction motor, thus providing sufficient speed variation of the motor generator set to enable the flywheel to alternately deliver and absorb energy in such a way as to make the load on the 25-cycle power line practically uniform. When the power demand of the roll motors exceeds the average, the resistance in the rotor of the induction motor is increased. This decreases the speed of the motor generator set, preventing a rush of current from the alternating current line, and at the same time allowing the flywheel to give up part of its stored energy to carry the mill motors over the peak load. When the power demand is light, the resistance is cut-out of the rotor circuit, allowing the induction motor to speed up the set and store energy in the flywheel.

From the plan, Fig. 1, it will be noted that under both the motor generator set and the mill motors, pits are provided in order to give easy access to the under side of the machines where the leads are connected to the terminal boards. These pits also provide a place for locating series shunts, resistances, &c., which would be very unsightly if placed above ground. The opening under the motor generator set is connected to the one beneath the motor by a passageway, and is reached by a stairway leading from the main floor.

* Paper read before the American Institute of Electrical Engineers, April, 1912.

The speed control and the reversal of the mill motors are effected by varying the voltage impressed upon their armatures through rheostatic control of the fields of the generators.

The excitation for both the mill motors and the generators is supplied by a 40 kw., 250 volt induction motor, generator set. Fig. 4 shows the complete connection diagram for the equipment. The direct-current circuit is protected by a relay

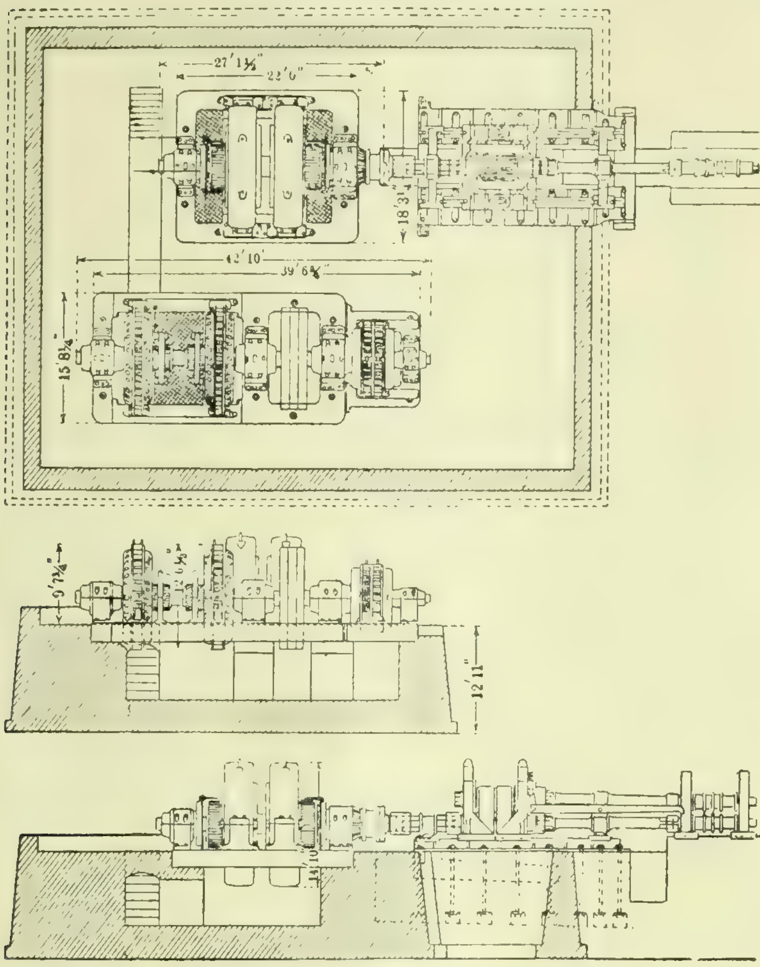


Fig. 1.—Plan of Motor-Driven Rolling Mill Equipment.

in series with the armatures of the generators and mill motors. When the current exceeds the setting of the relay, the latter opens an auxiliary circuit, tripping the circuit breaker in the field of the 40 kw. exciter, thereby killing the excitation on all the direct-current machines.

Since the requirements for a motor drive for a reversing mill demand frequent reversals from full speed in one direction to full speed in the opposite direction in a very short space of time, it is of the utmost importance that the moving parts should be so designed as to obtain the minimum amount of inertia. To accomplish this result, the rolling-mill drive was divided into two units, as shown in Fig. 2, mounted side by side on the same shaft and base. Each unit has a normal rating of 2,000 h.p. at 600 volts and 75 revs. per minute, with a maximum rating of two and one-half times normal, giving a total maximum of 10,000 h.p. available at the rolls for short intervals. This corresponds to a maximum torque of 700,000lbs. at 1ft. radius.

The motors have 16 poles and are of the interpole type. They are also provided with compensating windings in the pole faces of the main poles, in order to reduce the distorting effect of the armature reaction upon the field which would otherwise become quite marked on the peak loads. The yokes are of cast iron, while the main poles and interpoles are of laminated steel punchings. The fields are wound of strip copper on edge in two layers with a duct between to afford an air passage for ventilation. The fields are each separately excited from the 250-volt exciter mains, while a regulating resistance in series with each field circuit gives an adjustment by which the motors may be made to equally divide their load, in case of any slight difference which may exist between the saturation curves of the two machines. The motor armatures are connected in series and are designed for a normal pressure of 600 volts, but by varying the value and direction of voltage impressed across the armatures, the motors can be made to run in either direction at any speed up to 75 revs. per minute.

In order to withstand the severe mechanical stresses set up by the rapid reversals of rotation and the shocks transmitted from the rolls, it was necessary to make the spider and commutator of the most rigid construction. The bearings are protected from end thrust by a thrust collar mounted on the bearing pedestal next to the rolls. One side of the collar is of babbitt and the other of steel. Grease is used for lubricating and is fed by compression grease cups.

The generators each have a normal rating of 1,700 kw. at 600 volts with a no-load speed of 375 revs per minute. The armatures are connected in series, giving 1,200 volts across the two machines. They are capable of carrying an overload of two and one-half times normal, corresponding to the overload of the mill motors. The generators are also of the compensated interpole type, but the magnetic circuit is entirely of a laminated steel, in order that the field may respond quickly to variations in excitation.

The commutators are of the open neck type and are constructed in such a way that the air passes through the spiders of the machines, coming out through the commutator necks, and blows across the face of the commutators. No other source of ventilation is necessary to cool the commutators. As any vibration of the brush rigging is very objectionable on commutators of such high-peripheral speeds, the brush mechanism is supported on a separate yoke mounted on the base-plate.

The fields of the two generators are connected in series and excited across the 250-volt exciter mains, and controlled by a rheostat of such construction that the excitation can be reversed and varied by small steps over any range between zero and the maximum. This rheostat is mounted in the mill room and is under the control of the man operating the rolls

The induction motor has a rating of 1,800 h.p., 2,200 volts, 3-phase, 25-cycles, at 375 revs. per minute synchronous speed. It is of the wound secondary type, in which the current from secondary, or rotor, is carried out through slip rings to the slip regulator. The flywheel is 12ft. diam., and is made of cast steel in three pieces, carefully machined on the rim and held together by fitted bolts passing through reamed holes.

It can readily be seen that the requirements of the bearings for the motor generator set are somewhat more severe than are usually met with in electrical machines of the ordinary type. The heavy weight to be sustained by the bearings on either side of the flywheel requires considerable bearing surface,

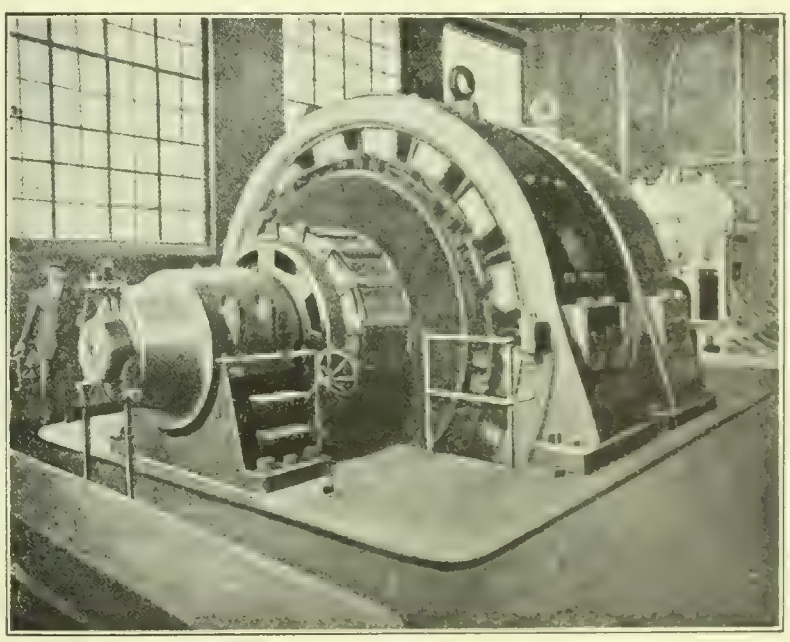


Fig. 2.—2,000 h.p. Mill Motor.

and necessitates a large bearing diameter with correspondingly high velocity of rubbing, in order that the bearings shall not be unreasonably long. The combination of high-bearing pressure and pheripheral speed requires the most careful design to secure perfect lubrication. All of the bearings both on the motor generator set and on the mill motors, are self-aligning, and are provided with water-cooling and three dis-

tinct methods of lubrication, ring-oiling, oil-flooding, and pressure lubrication. Under ordinary running conditions the pressure lubrication can be dispensed with, but it is very useful in starting. When the motor generator set comes to rest the oil film is squeezed out of the bearings, and unless this film can be established again before starting a torque of about 60,000lbs. at 1ft. radius would be required to move the set from rest. But starting the oil pump soon establishes a film

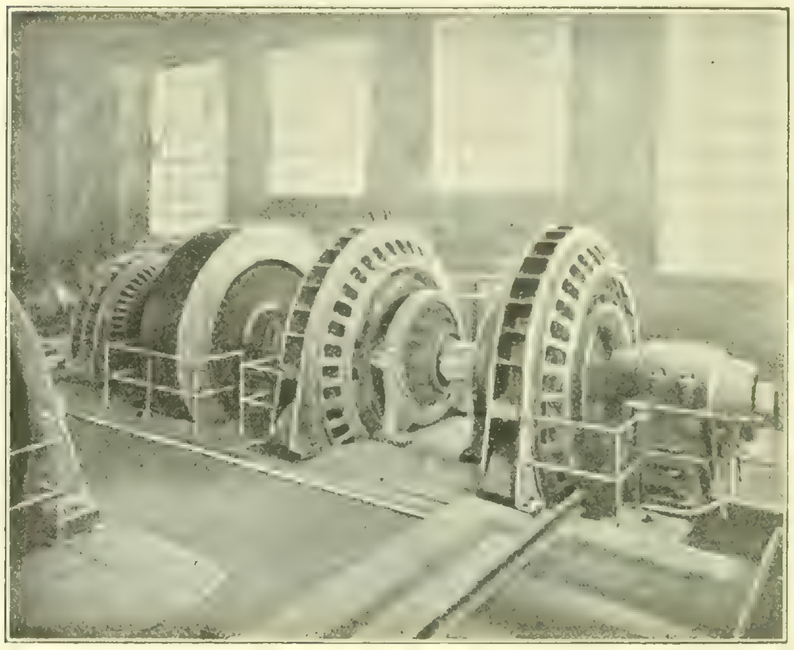


Fig. 3.—Flywheel Motor Generator Set.

again so that the set will begin to revolve on the first step of resistance and come smoothly to full speed without any abnormal demand on the power station.

A small motor-driven oil pump furnishes the oil for both the flooded lubrication and pressure lubrication systems. The overflow from the bearings passes through a cooler and filter and then is pumped up into a storage tank from which it flows by gravity into the bearings. Valves are provided so that the oil can be by-passed around the cooler, filter, and storage tank, and be pumped direct into the bearings under pressure, when starting.

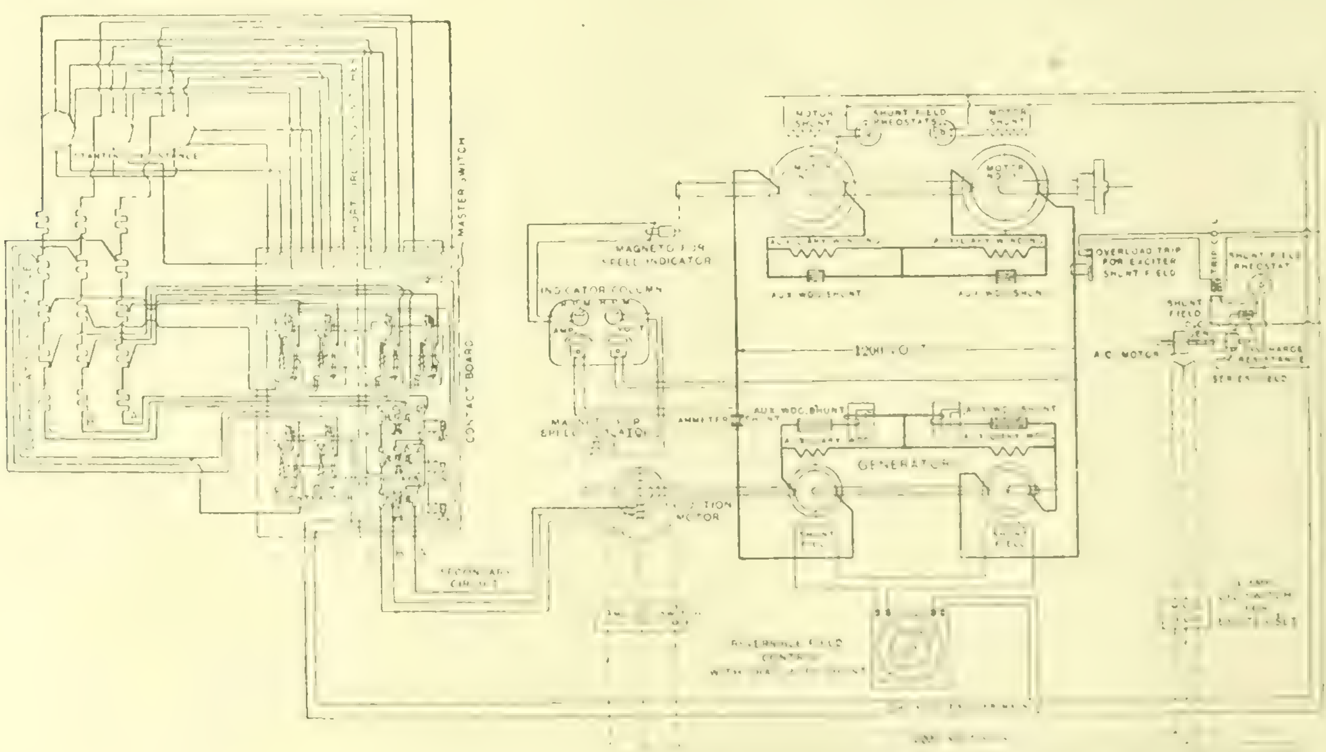


Fig. 4.—Diagram of Connections for Rolling Mill Equipment.

The rotating parts of the motor generator set revolving at 375 revs. per minute have a kinetic energy of 85,000,000ft.-lbs. During the period that the set is being brought to full speed, the resistance in the rotor circuit of the induction motor is required to absorb this amount of energy. In order to dispense with a bulky cast iron grid resistance, a special water-cooled resistance was used. This resistance consists of a boiler iron tank with a water inlet valve at the top connected to the water mains, and a quick-opening gate valve at the bottom for an outlet. The resistance element is immersed in water and consists of a hollow iron tube of helical form, with the taps for the various starting positions, leading out through the top of the case. During the starting period the energy absorbed by the resistance is transferred to the water, after which the hot water can be emptied at the bottom and the tank refilled ready for starting once more. The steps of resistance are cut out by six short circuiting switches, of the manually operated, multiple lever type, mounted on the switchboard.

For the purpose of varying the slip of the motor generator set, cast iron grid resistance is used, made up of three steps automatically switched in and out of circuit by slip regulators. Each element of the slip regulator consists of a series relay and a contractor switch. The contractor switch is operated by direct-current solenoids on the 250-volt exciter main and is actuated by the opening and closing of the series relay. When the current in the rotor exceeds a certain fixed amount, the series relay breaks the current in the solenoid of the contractor switch, allowing it to open and insert resistance in the rotor circuit of the induction motor, thereby reducing the current and increasing the slip. These switches are interlocked in such a way that they will operate one after another in the proper order.

The equipment has been in operation, rolling steel, since December 10th, 1911, and the results obtained indicate that the machines are well within the requirements and that the mill motors are capable of being reversed with sufficient rapidity to easily meet any requirements in rolling. In a rough test made in order to determine the length of time required to reverse the motors, 22 reversals were made in one minute at 75 revs. per minute, with the voltage on the 250-volt exciter mains reduced to 200 volts.

The Driving of Textile Mills.—It would appear from the report of the textile section of the Joint Committee appointed by the Textile Institute and the Institution of Electrical Engineers to enquire into the different systems of driving textile mills, presented at the spring meeting of the Institute recently held at Manchester, that such strong objections have been raised respecting the constitution of this committee that it has been decided not to proceed further with the joint investigation. In view of the large amount of preliminary work that has been accomplished it would have been a pity to have discontinued the investigation, and we are pleased to note that the work is to be continued by a committee of the Texile Institute alone. This committee will be a standing one, and will give continuous attention to all important developments in each of the several systems of driving textile mills, and its reports will be published regularly in the journal of the Institute. As an informal starting point there will be read at the autumnal Congress of the Institute, to be held at [illegible] on September 17th, 18th, and 19th, four papers dealing respectively with driving by steam, electricity, gas engines and oil engines. The paper on steam driving will be by Mr. Stott (Rochdale), that on electrical driving by Mr. Crowley (Manchester), that on gas engine driving by Mr. Wellstead (Manchester), and that on oil engine driving by Mr. Charles Day (Hazel Grove).

PROCESSES IN THE PRODUCTION OF GEARS.*

BY WALTER BETTERTON.

ONE of the most important problems in modern automobile construction, and one which has received a great deal of attention from mechanical engineers during the past few years, is that of obtaining quietness of the running parts. Next to the engine itself, the gears have proved the greatest offenders in this respect. The demand for gears which are accurate, interchangeable, and silent, together with the necessity for producing them both rapidly and at a low cost, has caused a great deal of attention to be devoted to the various processes, tools, and appliances used in their manufacture. We thus find that there are being placed on the market an increasing number of machine tools, steels, and carbonising materials, each of which claims some advantage over its predecessors—such as increased output, greater simplicity, superior generating features, and better hardening results. It is my intention, however, to deal chiefly with the processes of manufacturing gear-box gears by means of a complete equipment of gauges, tools, jigs, &c., with the object of ensuring interchangeability. To a very large extent, fitting is thus dispensed with. After the final machining operation has been performed the parts should be ready to be assembled. When a replace part is wanted it can be supplied from stock, as the methods here to be described ensure that it will fit into its correct position without trouble.

There is probably no part of an automobile that is subjected to greater use—and abuse—than the gears, especially gear-box gears. Carrying, as they do, practically all the power developed by the engine, and receiving at the hands of a careless driver the strains imparted by suddenly applied load, or by rapid changes, it is absolutely necessary that the gears be made of the highest grade materials, and that the very greatest care and the best workmanship should be bestowed upon them. As a saving in weight is an important factor to be considered in the design of transmission, the gears must be made as small and as light as possible, and yet be sufficiently strong to carry suddenly applied loads with no danger of breaking. Owing to the methods by which the speeds are changed, and the clashing and bruising which this involves upon the gears, the transmission mechanism must be made of material which is both hard and tough. Different kinds of steel have been used, and each has been treated by various methods in the attempt to discover the perfect gear material; but although this has not yet been found, so much progress has already been made that the transmission gear of a modern well-made automobile, when carefully handled, will last nearly as long as the car itself.

Of the various kinds of steel which have hitherto been employed, nickel, nickel-chrome, and chrome-vanadium seem to have more advocates than any others. In most factories the gears are case-hardened, and it is to this class of gear that I shall confine my attention. Gears treated in this way have been taken out of cars which have run many thousands of miles, and in some instances the original tool marks on the face of the teeth have been still visible. Treatment by heat requires that, until after hardening (full details of which are given later), sufficient material should be left for supporting the gear during the various processes.

In this paper I shall explain the processes in the manufacture of low carbon nickel steel case-hardened gears, such as the finished gears shown by Figs. 1, 2, and 3. The various processes will be explained in the order in which they are performed.

The composition of nickel steel, suitable for high-speed gears, is as follows:—

		Per cent.
Carbon		·20
Manganese		·65
Silicon	not exceeding	·30
Phosphorus	not exceeding	·04
Sulphur	not exceeding	·04
Nickel		3·50

Nickel steel with 3·50 per cent. nickel rolls and forges well, and when hardened the ratio of the elastic limit to the ultimate strength is very great. The influence of nickel on steel is that it increases the tensile strength and the elastic limit.

Nickel steel of the composition just mentioned should have an elastic limit, after heat treatment, of about 30 tons per square inch. The influence of silicon on the results of quenching is similar in many ways to that of carbon. It is dependent on the co-existing amount of carbon and manganese, and it is difficult to obtain silicon in steel without the presence of manganese. Silicon appears to increase the tensile strength and diminish ductility; but for various reasons it is generally considered objectionable. Phosphorus is the least desirable element in steel, but up to 1 per cent. it appears to increase the tensile strength. Sulphur tends to produce hot-shortness and difficulty in working, but in the presence of manganese the effect is diminished.

Gear blanks for Fig. 1 should be cut from the bar, since it has been proved that steel is not improved by drop-forging, although some steels are less sensitive to injury than others. An investigation into drop-forgings and bar-cut nickel steel gears, details of which were given in a paper read by Mr. John A. Mathews before the Franklin Institute, showed that

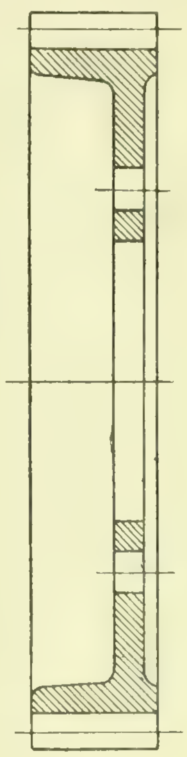


FIG. 1.

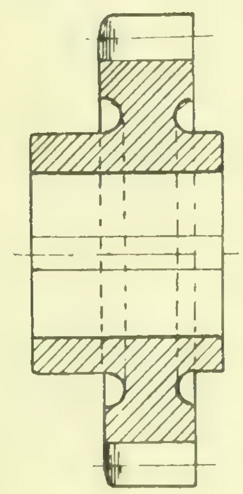


FIG. 2.

under static tests the bar-cut gears were fully 25 per cent. stronger than drop-forged gears, and also that their resistance to shock was greater. Gears shown in Fig. 3 should be made from a drop-forging, as shown by Fig. 4, although when only small quantities are required, it would not pay to make dies. In this case ordinary forgings should be considered. Gear blanks should be annealed previous to machining.

The reasons it is necessary to leave so much extra metal will be explained in the order in which they concern the various operations necessary in the attempt to get a perfect gear—an end which, it is needless to say, is seldom if ever attained. In the case of a gear made from a bar, as shown in Fig 2, it is not necessary to leave any extra metal. Much of the trouble due to distortion in heat treatment is caused by the forging operations being effected at too low a temperature, in which case the metal does not have a chance to flow properly, and is merely forced into shape by the die. This sets up internal strains that will be released when the part is annealed.

We now proceed to rough turn the part all over for the purpose of removing the outer skin, previous to the second annealing, leaving plus one-sixteenth case on the parts required to be hardened, such as the top diameter of the gear, and the sides of the teeth. For the bore minus $\frac{1}{8}$in. only is required in gears where the hole is to be a running fit, or castellated, and has to be hard. Minus $\frac{1}{4}$in., however, is necessary where the gear has to be bolted to a centre, or to another gear, in which case the bore need not be hard, as it is only used for locating the gear centrally. In rough turn-

* Paper read before the Graduates' Section of the Birmingham branch of the Institute of Automobile Engineers, April 25th, 1912.

ing, allowance must be made for the extra metal, and should be machined as shown by Figs. 5 and 6.

When making gears it is, of course, necessary to have the steel carefully and uniformally annealed. The process of annealing is one of great importance, and is better performed in a specially designed sealed furnace, constructed as a muffle; so that the required heat is obtained uniformly by radiation,

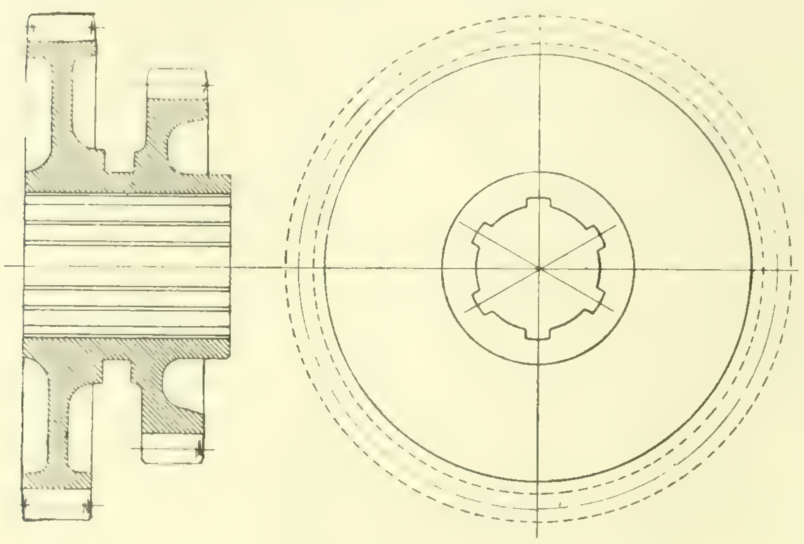


FIG. 3.

without any flame to impinge on the steel. In addition to softening the steel, and rendering it easy to be machined, annealing has the effect of bringing it to a more uniform and homogeneous condition by eliminating the molecular strains which are set up by rolling, hammering, and stamping; so that when the steel is heated preparatory to hardening, equal expansion should follow—also equal contraction when cooled.

It will thus be seen that should the steel not be annealed uniformly throughout, the risks of warping while hardening are considerably increased. The object of rough machining is to break down the scale preparatory to the second annealing, and as the strains set up by the rough machining are released by the second annealing, the metal is then in as normal a condition as possible. This minimises any tendency towards warping in the hardening, which is one of the great troubles encountered in the hardening of gears.

At the present time there are many compounds used for annealing. Whereas a few years ago the ashes from the forge were considered sufficient for properly annealing steel, to-day many special preparations are manufactured and sold for the purpose. The more common materials used are powdered charcoal, charred leather, and hydro-carbonated bone-black. Now, as we shall see, these same materials are used for carbonising, after which they are of very little use for that purpose. Therefore their use for annealing has the additional merit of economy; in fact, they can be used repeatedly, adding each time a little that has only been used for the carbonising process. Air-slacked lime may also be used for this process. The piece to be annealed is usually packed in a wrought-iron box, using some of the previously-mentioned material, or combinations of them, for the packing. The whole is then heated to the proper temperature, which is about 1,750° Fah., and in the case of the gears in question this should be maintained for one hour. The box is then set aside with the cover on in order to cool down to atmospheric temperature. It should be noted that the annealing temperature ought always to be higher than that for carbonising. For certain grades of steel these materials give good results; but for all kinds of steel, and for all grades of annealing, the slow cooling furnace gives the best results, because the temperature can easily be raised to the right point, kept there as long as necessary, and then regulated to cool down as slowly as desired. Gas, oil, or electric furnaces are, of course, the easiest to regulate.

Gears to be broached, as shown by Fig. 3, should be finished bored minus ·015 for grinding after hardening; also faced on the one end true with the bore to take the thrust of the broaching on a La Pointe Broaching or similar machine.

The broaches should be made of carbon steel oil hardened, tempered, and ground, and should be treated as follows. It is necessary to treat the steel with some carbonaceous material until it will harden in oil. It is well known that steel hardened in oil is less likely to spring than if hardened in water. The tendency for steel to crack is almost eliminated, and it has a maximum of toughness—unless, of course, the steel has been improperly treated in the fire. The process consists essentially in supplying the surface of the steel with an additional amount of carbon by some material that will not injure the steel. No form of bone should be used on tool steel for this process, as bone contains a high percentage of phosphorus, and the effect of this is to make the steel weak and brittle. Charred leather gives the best results. The over-all length of the broach, suitable for the gears shown in Fig. 3, is about 26in., the cutting portion about 17in. long, teeth $\frac{5}{8}$in. pitch, cut straight and backed off. The pilot should be about 3in. long. Teeth should never on any account be cut spiral, as this tends to twist the broach while in operation, and consequently the castellation would not be true. To produce an accurate castellated hole, as shown by Fig 3, in nickel steel, it is necessary to use about ten roughing and one finishing broach, especially when this operation is to be performed to very fine limits, as it is necessary in the case of the gears in question. The last four teeth in each broach should be parallel, and then tapered down in equal progression. On the first broach it is necessary that the pilot should be round, and on the same diameter as the hole in the gear to be broached. On the following ones the pilot should be a sliding fit in the hole produced by the previous broach, at the same time locating from the castellations. The finishing broach should have a piece at the rear, and about 3in. long, the exact size of the castellated shaft on which the gear is to be fitted when finished. This will act as a burnisher. The broaches are pulled through the work, and this, in my opinion, is quite a good feature, as it tends to keep them straight while in operation. The cutting portion being so long enables the operation to be performed without previously rough-slotting, which is invariably done when the gears are drifted on to the power press. After broaching the gears should be turned.

Castellated gears should be turned on a mandrel, locating off the castellations, finishing the parts required to be hard, such as top diameter of gears, which should be plus ·005in. for gear cutting purpose, sides of teeth and fork groove, leaving metal as shown by Fig. 6. In the case of Fig. 1, the top diameter should be finished turned plus ·005in., sides of teeth and bore minus $\frac{1}{8}$in., so that they can be bored out again after

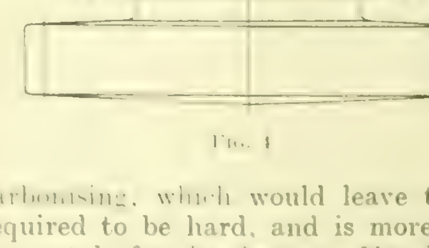


FIG. 4.

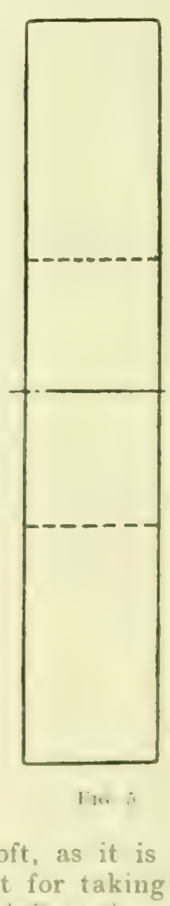


FIG. 5.

carbonising, which would leave the hole soft, as it is not required to be hard, and is more convenient for taking out the metal after hardening. Metal should be left as shown by Fig. 5. Gears shown by Fig 2 can be finished turned and bored complete at this operation.

One of the most important operations is the cutting of the teeth after annealing. The method I am going to de-

scribe is at present in practice and giving very successful results. The teeth should be roughed out on the hobbing machine (see Fig. 7), and, where possible, several gears should be placed on the work arbor at one setting. A great deal of time is saved by placing several gears on the work arbor, which should

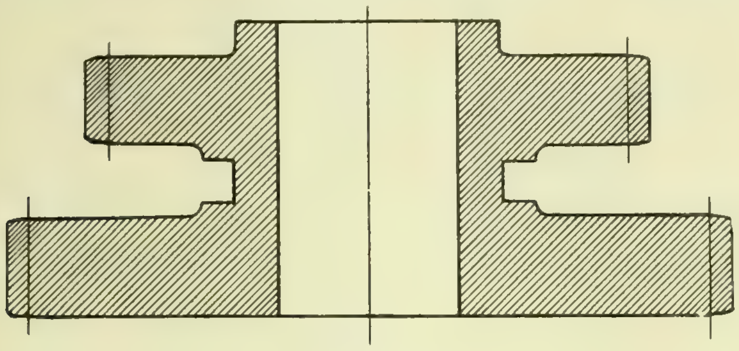


FIG. 6

always be steadied at the top. Suppose six are to be cut at one setting: this would mean that the hob would only have to travel into, and clear, the work once instead of six times, which would be necessary if they were cut singly. When putting several gears on the arbor, they must be faced exceedingly true, or the arbor will be bent. This is especially true when the hole is small and the gears large in diameter. Plenty of lubricant should be applied in this operation, oil being most commonly used. The hob should be made of high-speed steel, 6-pitch, 3in. diam., 5-pitch, $3\frac{1}{2}$in. diam. On account of the accuracy required, single threaded hobs are preferable, as this does away with any possibility of error in making the hob. For the roughing operation 60ft. per minute cutting speed of the hob, and ·020in. feed per revolution are considered good practice for a nickel steel 6-pitch gear.

For the finishing operation, at least, ·01in. should be allowed for a 6-pitch gear and other pitches in proportion. If the finishing cut is merely a scraping cut, and not enough stock is removed to let the cutter get a real chip, the cutter may glaze over the work, especially if the cutter and the work arbor are not held rigidly. The gears should be finished one at a time, excepting plate gears, in which case several can be placed on the arbor at one setting. For this purpose a Fellows Gear Shaper (see Fig. 8) should be used. The cutter can be made far more accurate than a hob or a rotary cutter. The teeth of this cutter can be ground, after hardening, and this corrects any inaccuracies that may have crept in. On the cutter arbor, at the back of the gear cutter, should be placed a round disc made of high-speed steel, hardened, ground, and backed-off, which will act as a shaving tool, and will take off the ·005in. left on the top diameter as previously stated. This will make the outside diameter true with the pitch line. There is a special reason for this, which I will explain later. The teeth should be cut about ·001in. thin at the pitch line to produce a running fit. The gears should now be tested for centre distance, for which purpose a plate with two pins to locate on the bore, set at the correct centres, should be used.

At this point I may say that, by the courtesy of Mr. Ward, of the Universal Gear Grinding Company, I have had the opportunity of seeing in operation a machine for grinding gear teeth, which has the appearance of filling a long-felt want in the automobile industry. If it is, and I believe it is, what the makers claim for it, it would not be necessary to finish-cut the teeth as, with the exception of the gear shown in Fig. 3, they could be ground after hardening. This would obviate the final process of grinding in with emery and oil, a process which at present is so unsatisfactory. In the case of the gear shown in Fig. 3, the grinding-wheel would foul the large gear when grinding a small one, to overcome which it would be necessary to re-design the gear and make it in two parts. The machine has many good features, the main one being that the shape of the wheel is maintained by three diamonds which dress the wheel, and which are controlled by one former. One is used for trueing up the top diameter of the wheel, and one on each side for trueing the curvature.

The tooth-rounding should be performed on an automatic tooth-rounding machine. Several gears should be mounted on the same arbor, and the teeth of the wheels should be rounded in succession at one setting. No doubt you are all quite familiar with the reason for this operation, which therefore requires little explanation, unless it be to say that it is done to facilitate the changing of the gears, and also to prevent the teeth from being chipped when engaging, as would occur if the corners were left square. The sides of the teeth which are not rounded should be frazed before carbonising—which is the next operation.

In carbonising, great care should be taken as, to a very large extent, the life of the gear depends on this. The result of the process is determined by four factors, namely: (1) The nature of the steel. (2) The nature of the carbonising materials. (3) The temperature of the carbonising furnace. (4) The time occupied.

The carbonisers in general use at the present time are animal charcoal, hydro-carbonated bone-black, charred leather, and a few other compositions sold under various names. Owing to the various conditions under which the operation is carried out, experience must largely guide the operator. Theoretic-

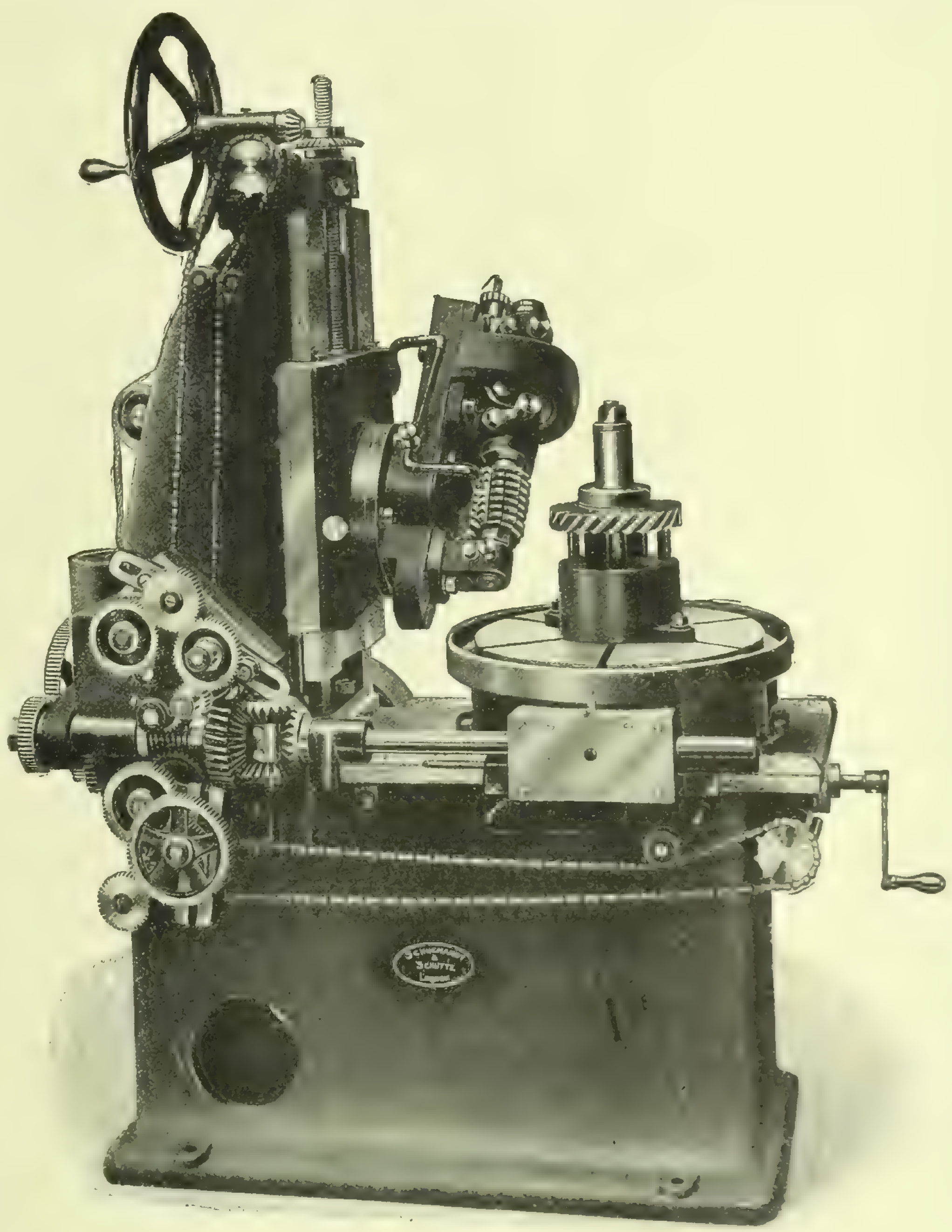


FIG. 7.—GEAR HOBBING MACHINE.

This view shows the differential gearing exposed. In the actual machine this gearing is enclosed.

ally, the perfect carboniser should be a simple form of carbon, and charred leather gives very satisfactory results. Care should be taken to avoid poorly charred leather, or that made from old boots, belting, &c. Good charred leather should contain about 88 per cent. of carbonising matter.

As it is essential that the core of the gears should be left soft in order to withstand the high speed and sudden shocks

to which they are subjected, it is necessary that the carbon content in the core should be low. For this reason preference is given to ·20 carbon steel. The carbonising pots are made both in cast and wrought iron, the former being cheaper in first cost, but the latter bear reheating so many times that they are really cheaper in the end. The carboniser, having

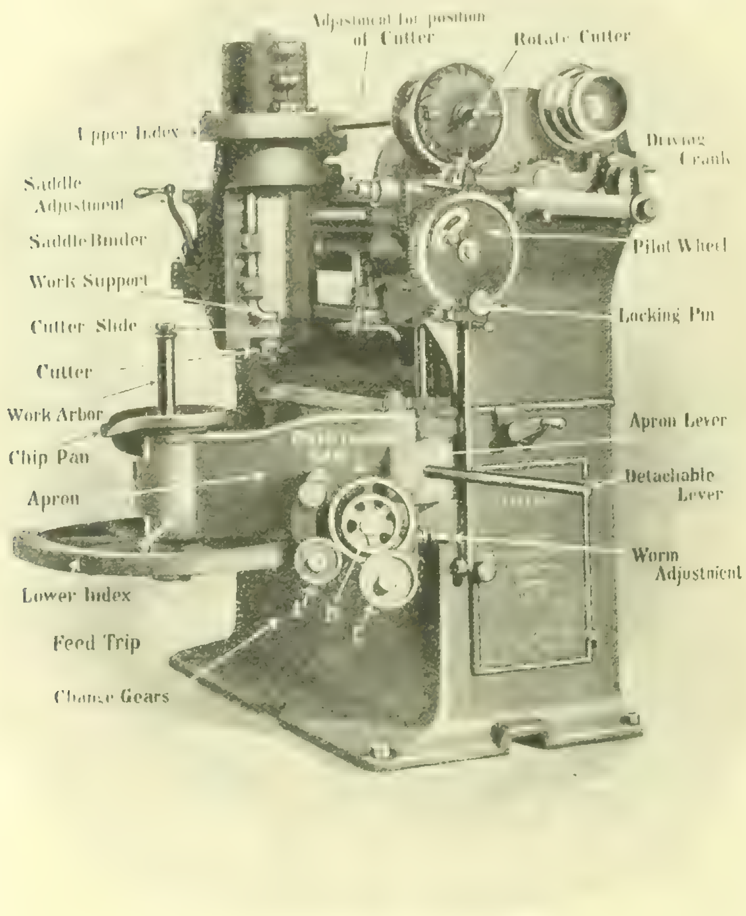


FIG. 8.—FELLOWS' GEAR SHAPER.

been thoroughly dried, and reduced to a fine powder, a layer of not less than $1\frac{1}{2}$in. in depth is placed in the carbonising pot and well pressed down. Upon this are placed the articles to be treated. Care must be taken to have sufficient space all round each piece so as to prevent them touching each other or the walls of the pot; $1\frac{1}{2}$in. is sufficient. Another layer of carbonising material is then put in and well pressed down, taking care not to displace any of the gears. The process is continued until the pot is full, finishing with a layer of about $1\frac{1}{2}$in. at the top. The object in view is to make the contents of the pot as compact as possible, consistent with a sufficiency of carboniser in contact with the gears. The more solid the pot is packed, the more complete the exclusion of air. The lid is then put on, and the joint all round well luted with clay. The pot should be placed in a furnace similar to that used for annealing, and heated to about 1,700 Fah., which heat should be maintained constant six to ten hours. The length of time occupied is regulated, firstly, by the depth of casing required, which should be about three sixty-fourths; and, secondly, by the dimensions of the gear. At the close of the carbonising period, the pot is withdrawn, and put in a dry place where it is allowed to cool to atmospheric temperature. It is then opened and the articles taken out, and the process is completed by brushing to remove all adhering matter. It may be noted here that the case should only be deep enough to resist wear and battering, so leaving the maximum load to fall on the uncarbonised section. If the case is so deep as to form a considerable part of the cross section of the teeth, the teeth may break unless the case is considerably tempered.

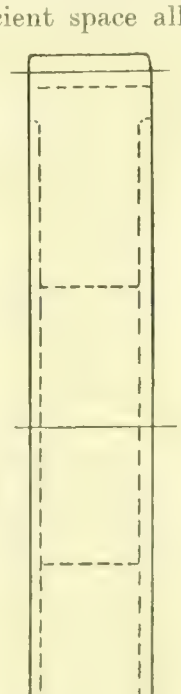


FIG. 9.

The next operation is to turn out the carbon from the parts required to be soft. In the case of the plate gear, shown in Fig. 1, which is to be bolted to another gear or centre, as previously stated, the hole need not be hard, which, for this reason, was left minus $\frac{1}{8}$in. at the previous turning operation. It should now be bored minus ·015in., for grinding after hardening, and faced down on both sides. This refers to both plate and castellated gears, as shown in Figs. 9 and 10. The boring operation should be performed while the gear is held in a collet-chuck, locating from the top of the teeth, which were trued up with the pitch line by the shaving tool used when cutting the teeth, as previously explained. This method has ben found to be more efficient than locating with balls or rollers on the pitch line. The penetration of carbon being only about three-sixty-fourths, it is now removed from the parts which have just been turned. Consequently these parts will not be hardened. This metal is left as shown in Figs. 9 and 10, until after hardening, in order to prevent it from warping, which would undoubtedly happen if the gears were finished as shown by Figs. 1 and 3.

Steel of the composition mentioned in this paper can be hardened as follows. Heat from 1,450 to 1,525 Fah., quench in water; re-heat to about 1,400° to 1,450° Fah., quench in water. The re-heating must be conducted at the lowest possible temperature at which the steel will harden. It will be found that this is sometimes as low as 1,300° Fah. Then, as a safeguard, re-heat to a temperature of between 250° and 500° Fah. in accordance with the requirements of the case; cool slowly in oil. Parts of intricate shape, such as the gears dealt with in this paper, having sudden changes of thickness,

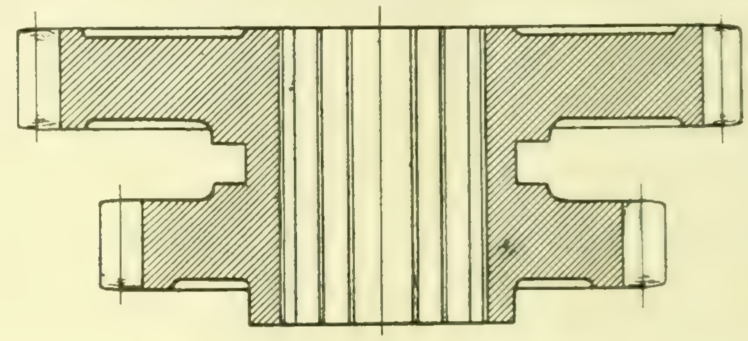


FIG. 10.

sharp corners, and the like, should always be tempered or drawn, in order to relieve internal strains.

Another method of hardening is as follows. Heat from 1,450° to 1,525° Fah.; quench in hot brine. Re-heat from 1,400° to 1,450° Fah.; quench in oil. The temper need not be drawn when the gears are quenched in oil. The final quenching should be done at the lowest temperature at which the piece will harden, as stated in the first-mentioned method.

A small gas muffle should be used for hardening gears, and indeed for all kinds of hardening work. A properly constructed gas muffle can be regulated with the greatest nicety, and in hardening this is most important. It is known that when steel is gradually heated, there is a certain point at which a great molecular change takes place, and that perfect hardness can only be obtained by quenching at this critical point. This should lie between 1,300 and 1,450 Fah. When steel is cooled, whether slowly or not, it bears in its structure a condition representative of the highest temperature to which it was last subjected. From this it will be quite clear that, in case-hardening, as in all other methods of hardening, the steel must be quenched on a rising heat. Steel which is over-heated previous to the final quenching, is very brittle, and liable to easy fracture, and although quenched and subsequently hardened, the metal has little or no cohesion and readily wears away. Steel so hardened breaks with a very coarse crystalline fracture, in which the limits of the case are badly defined. If quenching takes place below the critical point previously mentioned, the steel is not sufficiently hard. If above, though full hardness may be obtained, strength and tenacity are lost, in part or completely, according to the degree of heat by which the critical temperature is exceeded. It may be asked why it is not sufficient, when the pieces are heated at the first re-heating to about 1,500 Fah., to place them in another furnace and reduce to the critical temperature, and quench, instead of quenching twice. To this the answer is that the high temperature has already created a coarse crystalline condition in the steel and that,

until it has cooled down below the critical point, and re-heated to the critical temperature, a suitable molecular condition cannot be obtained. As a further means of illustrating what is meant by the critical point, Fig. 11 shows a curve plotted from results obtained by a recording pyrometer, in which the

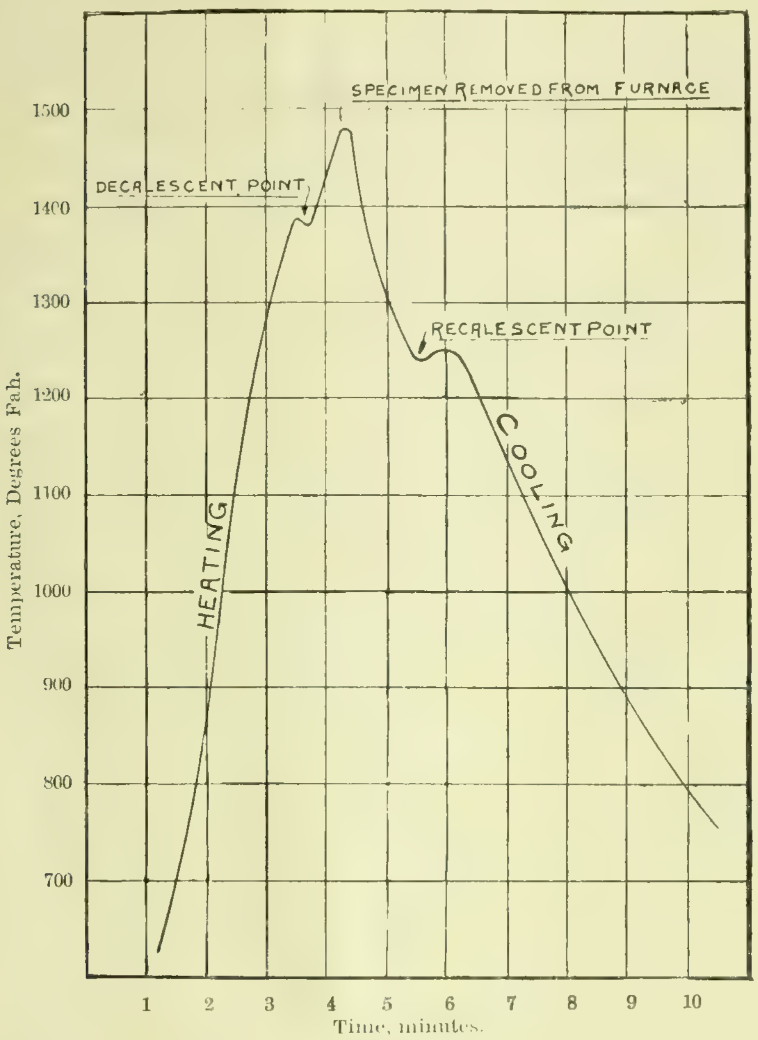


FIG. 11.

decalescent and recalescent, or critical points, are well developed. From this it will be seen that the absorption of heat occurred at a point marked 1,375° Fah. on the rising temperature; and the evolution of heat at 1,250° Fah. on the falling temperature, which was allowed to fall slowly. The relation of these critical points to hardening is that it cannot take place unless a temperature sufficient to produce the first action is reached in order to change the pearlite carbon to hardening carbon; and also, unless it is cooled with sufficient rapidity, to eliminate the second action. The temperature should, of course, be gauged with a pyrometer.

Sand-blasting, which serves to scour off any roughness or stains which have been left on the surface during heat treatment, &c., is best conducted in a building separated from the remainder of the shop. The sand should be kept in a bin in one corner, and sucked up by a centrifugal blower and forced by air pressure through a blow-pipe, which terminates in a nozzle. The sand, being forced out by the air at a high velocity, may be directed at all parts of the piece to be cleaned. This is one of the most efficient methods of polishing and cleaning the gears, and it does not injure the hard surface in any way.

The gears should now be tested for hardness. The Scleroscope (see Fig. 12) appears to be the best instrument for doing this. If a gear shows a considerable drop in hardness, a file should be used to determine whether the cause is due to the piece not being hard or to crystallisation. If the parts can be scratched with a file, it shows that it is not hard enough. If, however, the file will not bite on the spot where the scleroscope reads low, then it is positively known that it has been overheated and is crystallised.

A good method of testing the teeth is the drop test. By this method a 2lbs. weight with a 56in. drop is directed at one tooth. The number of blows necessary to break the tooth should be noted. This test should only be applied occasionally, say, on one out of each batch of gears. A gear which has given satisfaction should be tested, and the result used as a standard for future comparison.

We now proceed to turn out the metal left for supporting the gear while undergoing heat treatment. This operation should be carried out while being held in a collet-chuck, and care should be taken that the outside diameter runs true before commencing it. The hole having been bored ·015in., after carbonising, is now soft. The metal can be turned out on both sides, or on one side, as the case may be, leaving plus ·005in. on the face of the web for grinding. This operation should come next, and it is most essential in order to get a true running gear when in position. The castellated gears which were finish bored minus ·015in. before carbonising are now hard, this being necessary as they have to be a sliding fit on the shaft. The bore which locates on the lands of the castellated shaft, is all that requires grinding. Unfortunately no method has yet been devised for grinding the castellations themselves, and these therefore have to be lapped separately by hand, which is most unsatisfactory. While grinding the bore, the gear should be held in a collet-chuck off the top diameter; hence the trueing of the top diameter with the pitch line in the gear-cutting process. Gears ground in this way should be perfectly true, and are now ready to be tested for centres and true running. It should be clearly understood that the web of the gear shown by Fig. 1 is now soft. This brings us to the final machining operation, that is, the drilling.

There are many advantages in leaving this until the last. The bore is now the correct size, this being absolutely essential for locating the drilling jig. Furthermore, in the grinding operation the bore is totally ignored, the top diameter being the most important. The hole has been ground true with the latter, so that if the holes had been drilled previous to the hardening, they would not be concentric with the bore, and would not match up with the gear or centre, to which it has to be bolted. Another advantage is that the holes are now soft and can be reamed with a piece to which the gear is bolted, it being understood that these would also be left soft in the parts in which the holes are required. All these are important points, and this is the reason for leaving the drilling until last. The gears should now be bolted to their respective parts, and finally run in under belt power. The bearings, in these special cases, are set at the proper centres apart, so as to accommodate the various gears of a train, thus wearing in the gears so that all those for similar parts are absolutely interchangeable. The case is made oil-tight, and a mixture of finely powdered emery and lubricating oil is forced through an opening in the top, so that this grinding material will come in contact with all the teeth in mesh in the train. This grinding is continued until each tooth has been worn perfectly smooth and to an accurate fit with the teeth of the other gears with which it comes into mesh. As a further means of thoroughly running in the gears of the transmission to a perfect fit, the motor transmission and driving shaft are installed in the chassis, and the motor is run while the various speeds of the transmission are thrown into mesh. During this run an electric dynamometer, by means of which a variable load may be applied, is connected to the end of the driving shaft. The gears should now be as perfect as, with the best practice yet known, it is possible to get them.

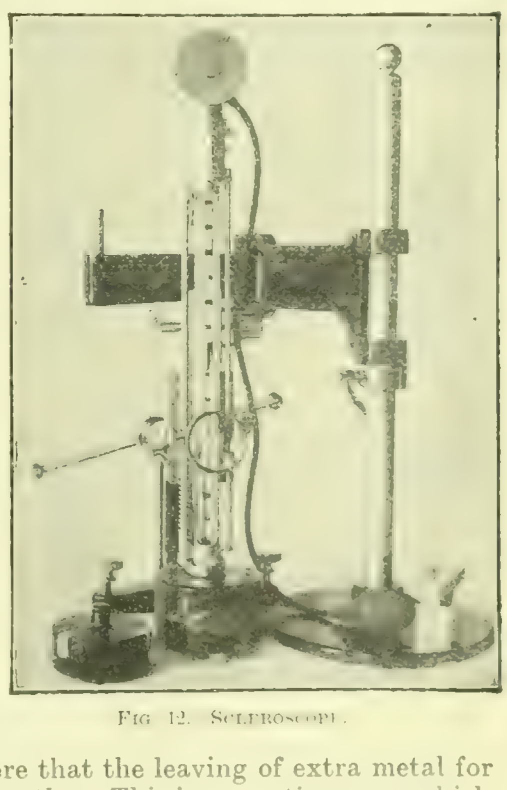


FIG. 12. SCLEROSCOPE.

It may be objected here that the leaving of extra metal for heat treatment is rather costly. This is a question upon which there is room for a considerable difference of opinion. Personally, I am of opinion that if the method of leaving metal which I have described is used with discretion and only in the case of very intricate gears, the most satisfactory results should be produced.

ROTARY DISTRIBUTING VALVE FOR TWO-STROKE INTERNAL-COMBUSTION ENGINES.

THE accompanying illustrations show a design of rotary valve for distributing the charge in 2-stroke internal-combustion engines, the invention of Alfred A. Scott, Mornington Works, Grosvenor Road, Bradford. It has been designed with a view to ensure a better running of the engine under throttle and to enable the engine to develop its full power by preventing it from doing useless work under these conditions. Fig. 1 shows a section through the engine; Fig. 2 shows sectional views of the valve and the cylinder heads; Figs. 3 and 4 are views of the inner rotating sleeve of the valve and outer controlling sleeve respectively; Fig. 5 is a crank diagram illustrating the action of the ports; Fig. 6 shows diagrammatically the location of the ports when the valves are in the positions marked 1, 2, 3, 4, and 5 in Fig. 5, the sections through the transfer and inlet ports being shown one over the other for convenience; Fig. 7 shows the valve in the same positions with the controlling sleeve turned into its half-throttle position.

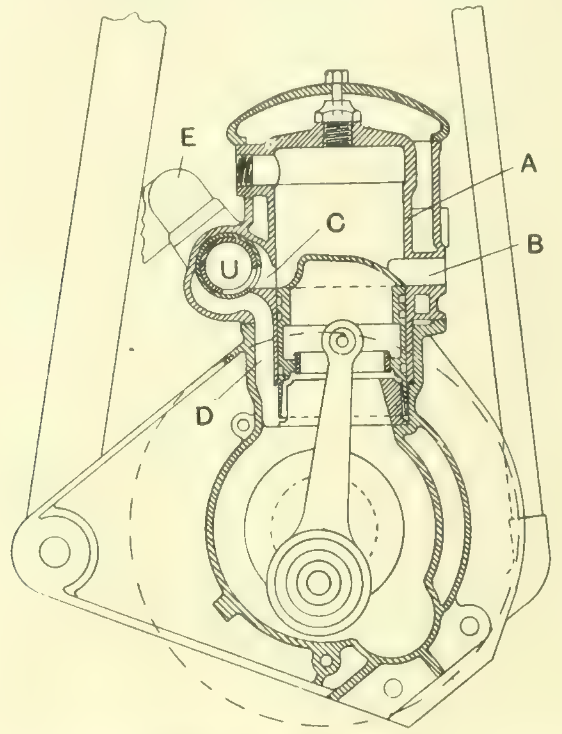


FIG. 1.—INTERNAL-COMBUSTION ENGINE FITTED WITH ROTARY DISTRIBUTING VALVE.

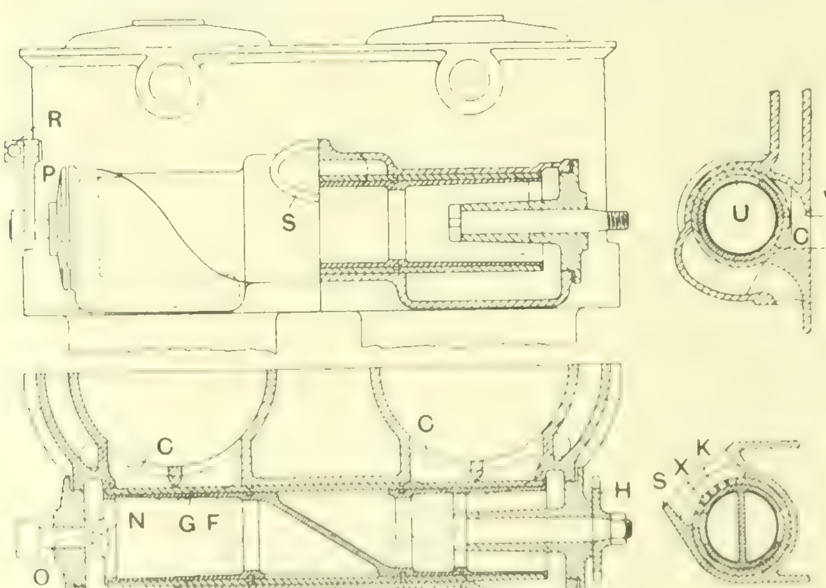


FIG. 2.—ROTARY DISTRIBUTING VALVE FOR INTERNAL-COMBUSTION ENGINES.

The valve is shown by way of example in connection with a 2-stroke engine using crank case compression. The cylinder A is provided with the usual exhaust port B and a transfer port C on the opposite side of the cylinder, the transfer port being in communication by means of the rotary throttle valve with the transfer port D leading to the crank case chamber of the engine. The pipe E is attached to the carburetter and is connected to the seating S of the valve casing. The valve consists of an inner sleeve F and an outer sleeve G. The inner sleeve F is rotated at engine speed by means of a chain running on the sprocket wheel H. The valve F has ports U at each end, located so as to register with the transfer ports C of the cylinders. In the centre the valve has two inlet ports V which communicate with the carburetter alternately. The valve is divided into two compartments by a diagonal diaphragm, so that while one half of the valve is transferring the mixture to one cylinder the other half is admitting mixture from the carburetter through one of the ports V to the crank case of the other cylinder. With this arrangement a single inlet port K in the valve casing is sufficient for a 2-cylinder engine. The controlling sleeve G is arranged around the valve, and piston rings are provided in the valve to prevent leakage between the two. Similarly, rings are provided in the sleeve to prevent leakage between the inlet and transfer ports. The sleeve is provided with ports W adapted to register with the transfer ports C of the cylinder and the ports U of the valve, and the sleeve has also a port X which registers with the inlet port K leading to the carburetter and the ports V in the valve. The port X is provided with a series of bars running longitudinally across them. The time of opening of both the inlet and transfer ports are varied by turning the sleeve G about its axis. For this purpose the outer sleeve is formed with a pair of lugs M on either side of the sleeve, into which fits a pin N attached to a rotatable shaft O. This shaft is turned by means of a crank P attached by a swivel or pin to a controlling rod R.

The ports in the valve, controlling sleeve, and valve casing are so arranged and dimensioned that in normal running the inlet port opens immediately the transfer port has closed,

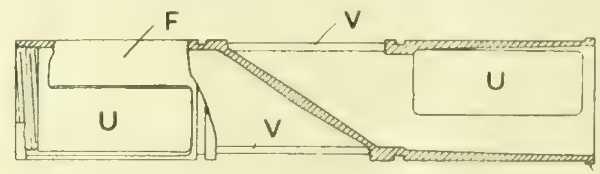


FIG. 3.

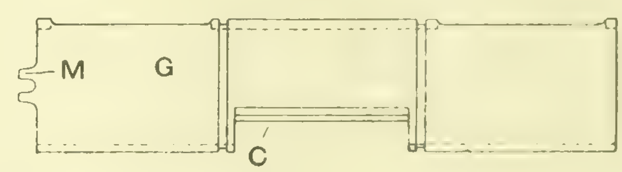


FIG. 4.
ROTARY DISTRIBUTING VALVE FOR INTERNAL-COMBUSTION ENGINES.

the inlet port closes near the end of the suction stroke, and the transfer port does not open until the end of the crank case compression stroke. Then when the throttle is applied the inlet and transfer ports both open later, but close at the same time as on open throttle. The arrangements of the ports and the action of the throttle can be seen readily by referring to Figs. 5-7. In Fig. 6, position 1 shows the transfer port just opening; the exhaust port has already been open some time to allow the burnt gases to escape as far as possible before admitting the fresh mixture. In position 2 the piston has reached the lower end of its stroke, the transfer port is now fully open. In position 3 the transfer port has just been closed by the rising piston, although the ports in the sleeve are still registering. At the same time the inlet port is just opening, so that no negative pressure is produced in the crank case. Position 4, in which the piston is at the top of its stroke, shows the inlet port closing, and position 5 shows it just closed. It will be seen, therefore, that suction occurs from position 3 to position 5, then crank-case compression occurs until position 1 is reached, when the transfer port is opened and the compressed charge is transferred to the cylinder until position 3 is reached, when the piston cuts off the transfer and the suction in the crank case is just on the point of beginning. In this way it will be evident that a much longer effective suction stroke is employed than is usually the case when the closing of the suction valve necessarily does not take place until a considerable time after the upper position 4 of the piston has been reached. Further, the suction valve is opened immediately after the transfer port is closed, so that there is no negative pressure produced in the crank case. Fig. 7 shows the action of the ports when the sleeve has been retarded and is in the half-throttle position. In this case the opening of the transfer port is delayed

and does not take place until the crank is in position 6, a little after position 2, but since the transfer port is always cut off by the action of the piston itself, this port is not open any longer than its normal working. After the transfer port has been closed by the action of the piston, the inlet port between the carburetter and the crank case is not immediately opened, in order to allow the pressure in the crank case which is produced by throttling to fall to that of the atmosphere or slightly below before the crank case is placed in communication with the carburetter. The inlet or suction port does not open until the crank is in position 7, but it is closed at

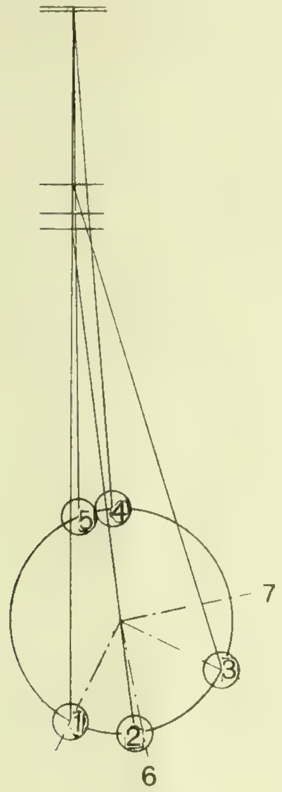


FIG. 5.

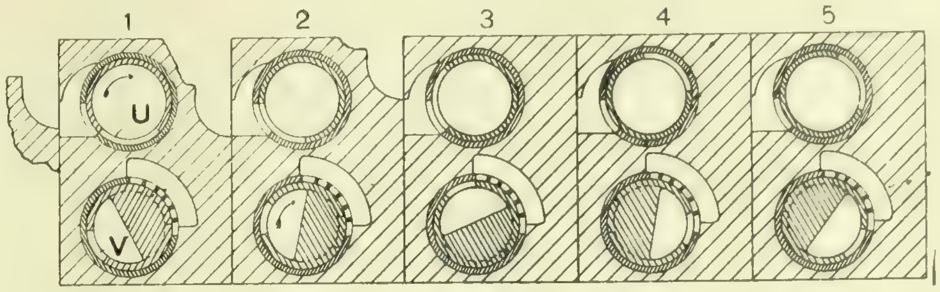


FIG. 6.

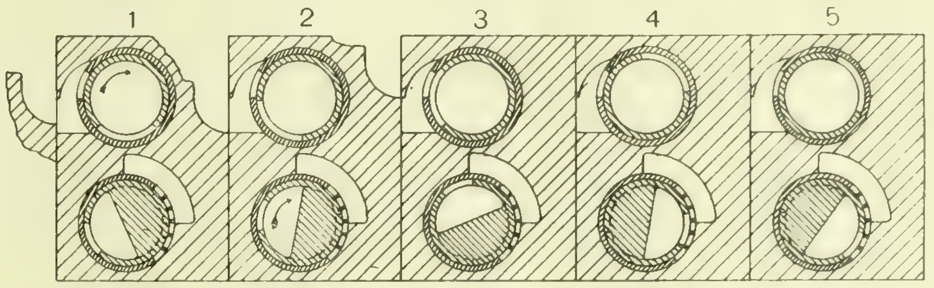


FIG. 7.

ROTARY DISTRIBUTING VALVE FOR INTERNAL-COMBUSTION ENGINES.

approximately the same time as on open throttle on account of the action of the bars X arranged across the port in the outer sleeve. These bars prevent the gases from passing between the inner sleeve and the casing, as is shown clearly in position 5 of Fig. 7.

OIL ENGINES.

IN a paper on "Oil and other Internal-combustion Engines," read before the Minnesota Electrical Association, the author, Mr. E. D. Jackson, divided oil engines into two classes, the instantaneous-explosive type and that in which pure air was first highly compressed and the liquid fuel in atomised form injected during about 10 per cent. of the combustion stroke, the fuel being vaporised and burned, without explosion, owing to the heat of compression. In the first class of engines compression could not be carried beyond 60lbs. or 70lbs. per square inch owing to the danger of pre-ignition, unless water was injected. Hence the term "low-pressure engine" was given to this class. In the second class, however, since only pure air was compressed, compression was carried up to 500lbs. or 800lbs. per square inch, equivalent to 1,000° Fah. Low-pressure engines were, of course, less expensive in construction and less economical of fuel than the high-pressure engines.

Comparisons drawn between the low-pressure and high-pressure oil engines showed that the fuel consumption of the low-pressure engine was from 50 to 100 per cent. greater than that of the high-pressure engine at full rated load, and at light loads this difference became still greater. The low-pressure engines had limitations as to the gravity of the oil suitable, ranging from 39° to 24° Baumé. In other words, the low-pressure engines were practically limited to the distillates, while the high-pressure engines might be operated on the crude oils within the limitations that had been given The weight per horse-power of the low-pressure engines averaged 30 per cent. less than for the high-pressure engines, the cost averaging also about 30 per cent. less. The speeds of the low-pressure engines were higher than the speeds of the high-pressure engines. The low-pressure engines required more cooling water per brake horse-power hour than the high-pressure engines.

In comparing steam, producer-gas, and oil engines, the author mentioned that builders sometimes abused the term "thermal efficiency," which was simply the ratio of output to input in terms of heat units. Thus it was stated that steam plants had a thermal efficiency of 6 to 20 per cent., producer-gas plants an efficiency of 15 to 23 per cent., while oil engines had a thermal efficiency of 30 to 33 per cent. for the high-pressure type. However, the cost of fuel per heat unit, say for coal or lignite in the steam or producer-gas plant, might be widely different from the costs per heat unit of oil for the oil engine, so that such comparisons stated only on a basis of thermal efficiency, with fuels of totally different character, availability, and cost, were misleading for practical considerations.

In comparing liquid fuels, statements as to relative thermal efficiencies obtained with the different fuels were also likely to give false impressions. Thus, when gasolene was used for a liquid fuel in an internal-combustion engine, the thermal efficiency might run as high as 22 per cent., as shown by Government tests, while the same engine using alcohol would show a thermal efficiency of 34 per cent. However, gasolene at a thermal efficiency of 22 per cent., costing 6d. per gallon, was a vastly better proposition than alcohol with a thermal efficiency of 34 per cent. and costing 1s. 10d. per gallon. Thermal efficiencies were therefore of value only when the comparisons were made on the same fuel or when the thermal efficiencies were multiplied by the cost factor of the fuel. The cost of a complete high-pressure oil-engine plant of 500 h.p. rating would average about 25 per cent. greater than a simple Corliss or high-speed compound steam plant, running condensing, with hand-fired, water-tube boilers. The first costs of a low-pressure oil plant would, as a rule, average less than for the steam plant above described.

The high-compression oil engine, with its high fuel economy and high first cost, was, he observed, necessarily a "high-load-factor" machine, viz., it must be operated at a high load factor to obtain better economic results than its less costly and less economical competitors, because its fixed charges, interest, depreciation, insurance, and taxes were relatively much higher than its fuel costs. The high-pressure oil engine therefore showed its best results when used for industrial purposes such as operating factories, mills, &c., or wherever there was a high load factor. As a reserve for water power and as a peak-load unit it frequently could not show the economic results of the low-pressure oil engine. The low-pressure engine more nearly approached steam operation in its economic characteristics, with its lower first cost and lower fuel economy. The proper choice of oil engines should therefore be based on considerations of first cost of the plant, fuel consumption, price, source and stability of supply of the oil fuel, load factor, and percentage of load at which the engine would chiefly run.

MACHINE MOULDING.*

BY WILFRED LEWIS.

THE art of moulding is probably as old as civilisation, and it may have reached a high state of development before any of the events which make up ancient history took place. In fact, the moulder's skill, as exemplified in many antique works of art, has been one of the great civilising forces of the world, and it may be questioned whether we can produce to-day any finer examples of this art than are to be found

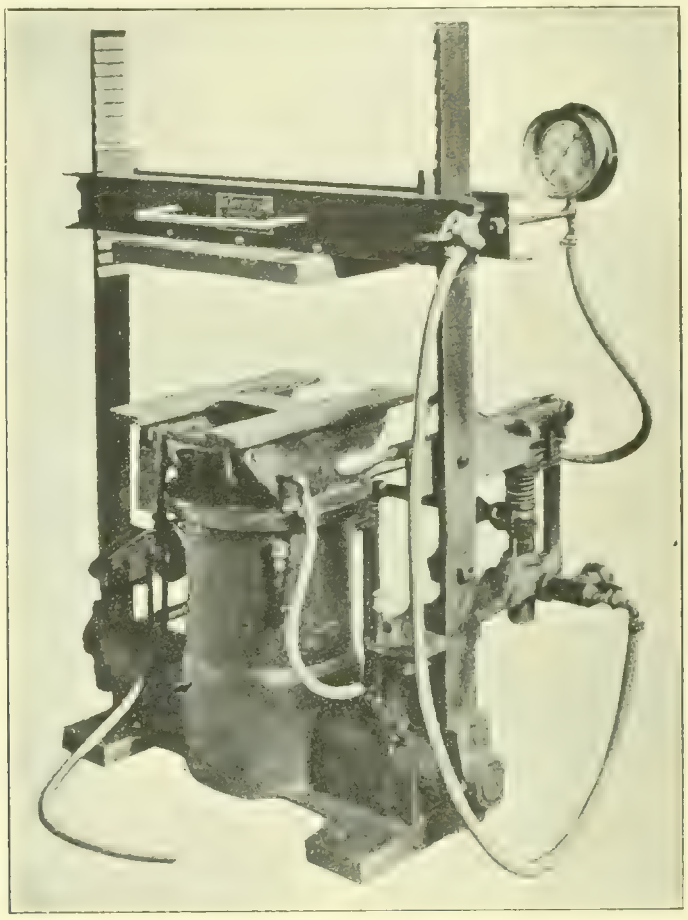


FIG. 1.—POWER SQUEEZER.

among the relics of antiquity. But as civilisation has progressed the demand for the products of the foundry has increased to such an extent as to call for new processes, better methods, and greater efficiency. The printing press, the steam engine, the loom, and, more recently, the internal-combustion engine, have stimulated the activities of men, augmented their productive capacities, and so enlarged the possibilities for commercial intercourse that it is difficult to realise how few of the comforts of life now enjoyed by the masses were within reach of the well-to-do or even the wealthy members of society as it was constituted 200 or even 100 years ago.

Improvements in machinery, combined with power for its operation, have worked wonders in the output of labour, but only a fraction of what can be realised from the same amount of human effort when more intelligently directed and controlled. No labour-saving machine can produce results without human aid in one way or another, and many a machine, good for its purpose, has been abandoned to the scrap heap, not from any inherent defect or inability to effect a saving, but simply as the result of awkward or inefficient handling. We must have efficient workmen as well as efficient machines to obtain the best results, and foundries need both as much as, or possibly more, than any other kind of operating plant to-day.

Although modern industry depends upon the foundry for a large part of its products, and the ingenuity of inventors has been busily engaged for generations in the evolution of labour saving machinery, very little of this effort has been devoted to the improvement of the foundry itself, and it is only within comparatively recent years that machine moulding has developed much importance as an art. In the year 1800 an English patent was granted for moulding screws, the patterns for which were backed out of the sand by lead screws of the same pitch. This was simply a pattern drawing machine of rather ingenious construction, but the English records do not touch again upon machine moulding until 1839, when a very similar patent appears. From this time forward more interest seems to have been aroused, and these patents were soon followed by others for packing sand by mechanical means, including hydraulic cylinders, stampers, and rollers of the road-roller type. Machines for moulding gears and pipes also appear in the first half of the nineteenth century, and in 1843 we find an American patent on the moulding of cannon balls. Later, in 1869, the first jarring machine patent was taken out, and it is not proposed to give a history of the art of machine moulding from patent office records, but simply to point out that the art began in a small way on bench work and continued chiefly in its application to small moulds that one or two men could handle until the end of the last century. Larger work was not generally regarded as applicable to machine moulding until the jarring machine began to emerge from a long period of obscurity and demonstrate its peculiar fitness for ramming large bodies of sand. Its development for large work belongs mainly to the present century, and through its means the art of machine moulding has been extended to embrace nearly everything moulded in sand. But there are, of course, exceptions and peculiar difficulties which will always depend upon the moulder's skill for their proper execution, with or without the aid of machine, and like any other equipment the installation of moulding machines must depend upon the saving to be effected by their use and the outlay needed to effect that saving.

This leads at once to the consideration of foundry costs, the analysis of which should point the way to their reduction These costs are made up of many important elements beyond the scope of the subject, and the effect of one item only need be considered, that of machine moulding, leaving all other items to be treated in the same way by those who are interested in attaining the highest efficiency in every detail of operation. Machine moulding began, as has been said, on small work, and probably one of the best known appliances is the little hand squeezer. This is a very simple and effective machine designed to save part of the time consumed in ramming. Fig. 1 is a little power squeezer adapted to the same class of work as the hand squeezer which saved the work of ramming, but put upon the operator the work of squeezing. There the man still did the work but with greater dispatch, and therefore more efficiently. Here the machine

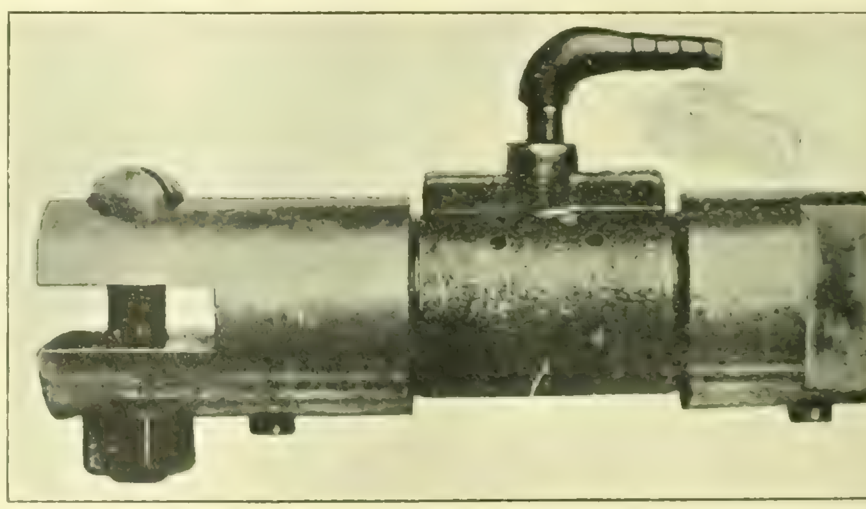


FIG. 2.—TABOR VIBRATOR.

does the squeezing and the operator is less fatigued and can work faster. In support of this statement it may be mentioned that 270 moulds have been put down by one man in six hours, and it is stated that this daily performance has recently been increased to 325 in the foundry of the American Hardware Corporation, where nearly 100 machines of the same type can be seen at work. Of course these performances by expert operators are not to be expected along the whole line, where the average may be in the neighbourhood of 200 moulds a day, but they show what is possible, if not always probable, and it remains to be seen how a proper

* Abstract of paper presented at a meeting of the Mechanical and Electrical Section of the Franklin Institute.

day's work on any given pattern can be fairly estimated. We are frequently asked to say what our machines will do and what production we will guarantee, regardless of the fact that we never know anything about the man operating the

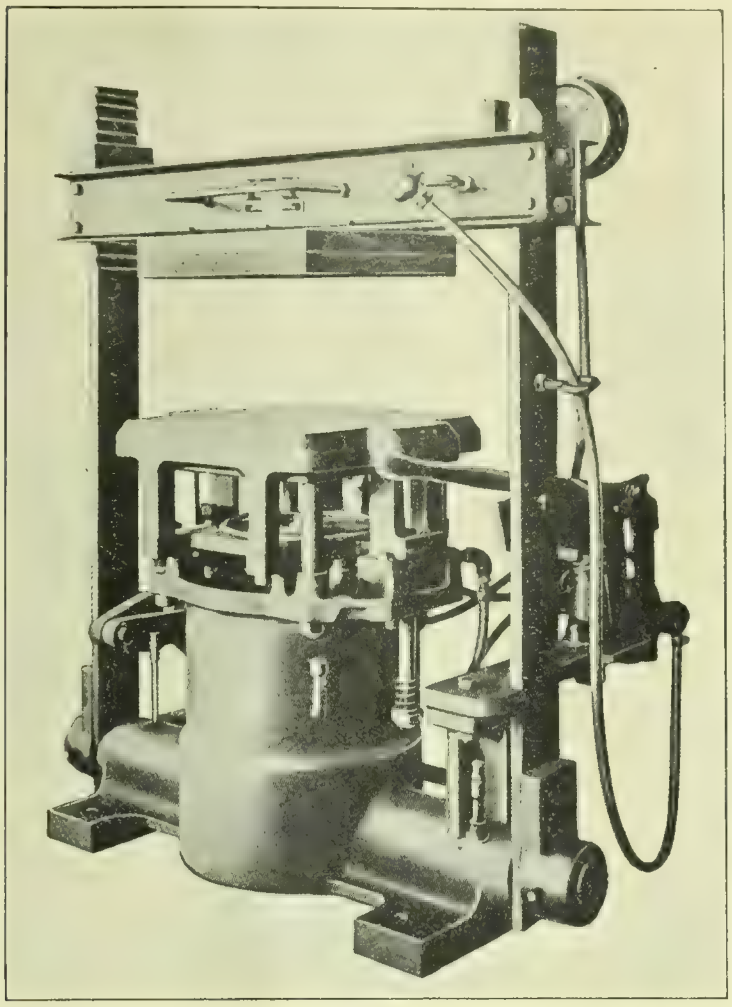


FIG. 3.—SMALL POWER SQUEEZING SPLIT-PATTERN MACHINE.

machine and seldom very much about the patterns to be used, the cores to be set, or the precautions found necessary to ensure success in moulding the same patterns by hand. We know in a general way the type of machine required, but until we have actually made moulds and poured castings, we are at a disadvantage and cannot safely guess at results which should be determined from a careful analysis of the experience gained in moulding by hand. The foundryman contemplating the introduction of machines has had the necessary experience, but he seldom, if ever, has it in a shape available for analysis. Observations should be made in detail and the time required for each and every step taken in the production of a mould recorded.

When patterns are cast in an aluminium match plate both cope and drag can be squeezed at the same time, the number of operations on the machine is reduced from 27 to 25 and the total time from 2·10 to 1·76 min. The snap flasks used are of the usual type. The machine will squeeze moulds as large as 14in. by 20in., but the best production can generally be realised on smaller sizes.

Instead of the aluminium match plate patterns may be mounted on a steel plate, and when split or flat back this is a very convenient method. They may also be mounted on a paraffined board held in a vibrator frame, and when so arranged the moulding time is substantially the same as for the aluminium match plate mounting.

Fig. 2 shows the Tabor vibrator, to which a large part of the saving effected by compressed air, with or without a power squeezer, is due. Power squeezers are made in various sizes, but the smallest size covers by far the largest field. It has been imagined that by increasing the size of flask and putting in more patterns greater production can be obtained, but this is seldom the case, and as previously mentioned the greatest output comes from medium-sized flasks easily handled by one man. Fig. 3 illustrates a small power squeezing split pattern machine with power draft. Machines of this type can be used with or without stripping plates, and are applicable to a great variety of work made in solid or snap flasks. There is less handling time on this machine than on the power squeezer, and since each half of the mould is made separately the strain on the operator is not so great.

It is also possible to cope off, by means of supporting stools, pockets of hanging sand that would be impracticable on a squeezer. It is a very fast machine, but no illustration is as yet available to show where it gains on the squeezer by reducing the number of operations required and the total moulding time. There are some jobs, however, which can be made as quickly on one machine as on the other, and although this is a much higher class of machine than the squeezer it does not follow that it is better for every purpose. On such machines the cope and drag are frequently made from the same set of patterns, and it is therefore a matter of first importance to have them so located on the pattern plate as to match perfectly when the mould is closed.

Split pattern machines have been on the market for many years, and their value is recognised and appreciated, but unfortunately they have to be built for a flask of fixed dimensions, or at least fixed in length or width to fit the flask pins on the machine. They are expensive to build, rather inflexible in their application, and within the last few years they have been superseded very largely by roll-over machines with straight pattern draught to ram by hand or by power. An ingenious hand-ramming roll-over machine, with mechanism for rapping the pattern carrier and dropping the flask from the pattern, was brought out by Teetor in 1889, in which plated patterns are carried in a roll-over frame to which the flask is clamped and rammed in the usual way by hand. When rolled over a support beneath is brought up by a hand lever, the flask is unclamped and the pattern rapped by turning a hand wheel on the trunnion shaft. At the same time the pattern is drawn by lowering the flask. A few of these machines can still be found in use, but the rapping mechanism is not durable, the machine is rather limited in its scope, and other types have displaced it for some time.

The French machine of Bonvillan and Ronceray is a modification of this type, in which the outer trunnion is

FIG. 4.—MOULDING MACHINE WITH ADJUSTABLE SWING FRAME AND SLIDING HEAD.

omitted and power is added for squeezing the mould and drawing the pattern. It has a number of attractive features and is said to be very successful in France, where hydraulic power is more popular than it is here, but the machine has not been so successful in the United States, and it is doubtful

that water can compete with air as a working fluid for foundry use.

The advantage of rolling over to draw a pattern is well known, and in some cases it is an absolute necessity. This has led to the development of a large number of roll-over machines, nearly all of which drop the mould away from the pattern after the manner of Teetor. The one exception is shown in Fig. 4, and this lifts the pattern from the mould in what is generally admitted to be the logical way. Logical because the pattern is generally lighter than the mould, and consequently preferably the part to be manipulated. The machine illustrated is shown as fitted with a grate bar pattern having 140 deep pockets, into which the sand is thrown by hand or settled by jarring the swing frame against its stops before ramming in the usual way by hand. Throwing the sand by hand is preferred, because the jarring process is not uniform, and naturally varies with the distance of different parts of the pattern from the turning centre. The flask used in this case is 14in. by 37in. by 5in. deep, and the time required for a complete cycle of operations was 5·81 min. The cope for this grate bar is almost flat, and requires no machine. It could be made by a helper who would have time enough to spare to assist in rolling over, and probably eight to ten moulds an hour could be made by experienced men. In this machine, which takes a flask 24in. wide and has 7in.

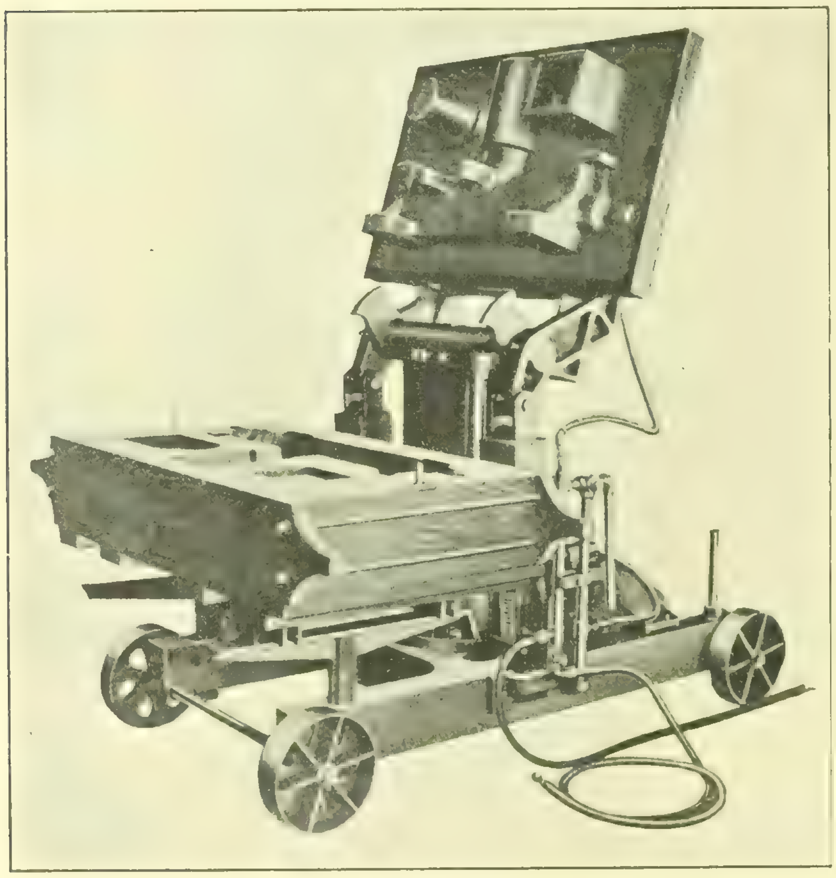


FIG. 5. MOULDING MACHINE WHICH ROLLS OVER AND DRAWS THE PATTERN.

pattern draught the swing frame and sliding head are counterbalanced by helical springs. These can be adjusted to the weights to be carried, and the pattern is drawn by a hand lever at one side.

Since the weight that can be conveniently rolled over by hand is limited to three or four hundred pounds heavier moulds naturally require power, and in Fig. 5 we have a machine which rolls over and draws the pattern by means of a cylinder and plunger, using compressed air on hydraulic oil or water to effect the movements. The illustration shows the pattern drawing and rolling back into position for another flask. In these machines a vibrator is attached to the swing frame, and this materially assists in making a perfect draw, the main object of these roll-over machines. They are designed to save pattern drawing and finishing time, and where patterns are of such a character that the margin for this saving is small the time study will show it and possibly suggest a jarring machine instead. But moulding machines do much more than save time in moulding, and are often worth all they cost in the saving of patterns, the saving in metal and the saving in machine work by reason of the greater uniformity and closer finish of the castings produced. An important feature of these machines is the levelling cradle, of which a number of types have been developed to set the flask with reference to the pattern board regardless of irregularities in the bottom board upon which it rests.

Such machines may be fitted with long patterns overhanging the swing frame for a considerable distance at each end. This possibility indicates the scope of the machine and the advantage of rolling over about an axis parallel to the length of the flask instead of about a normal axis as is done on machines of the French type.

Time study on large work may show that a material saving is effected in finishing, in ramming, or in both, and where ramming time is the principal item a jarring machine is the equipment most needed to reduce costs. There are quite a number of jarring machines on the market, all of them covered by the original claim of Hainsworth in his patent of 1869, which is so refreshing for its simplicity and breadth that it is worth quoting: "The packing of sand, for a mould, in a flask, by raising the same, together with the pattern, and letting them all drop upon a hard bed, substantially as shown and described."

There were no permutations and combinations of elements making an extended series of claims calculated to exhaust the patience of the reader. All he wanted was the whole field, and he secured it in a single claim, but it is not certain that the packing of sand in this way was altogether original with Hainsworth, and there is ample ground to suspect that groceries of all kinds have been packed in paper bags by the same jolting process before the memory of man runs otherwise, and some of these (dried currants, for instance) there is reason to believe have always contained a liberal admixture of sand. The packing of sand by jarring is therefore in all probability as old as the hills, but since the broad claim of Hainsworth no longer troubles us we must look among later improvements within the field that he covered for the development of the art. This patent seems to have attracted very little attention when it appeared, and no further inventions along this line are on record until 1878, when Jarvis Adams gave some impetus to the art, and later followed it by a number of patents. The Adams machines were, however, rather crude, and very little progress in the art was really made until compressed air came into general use as a medium for the transmission of power.

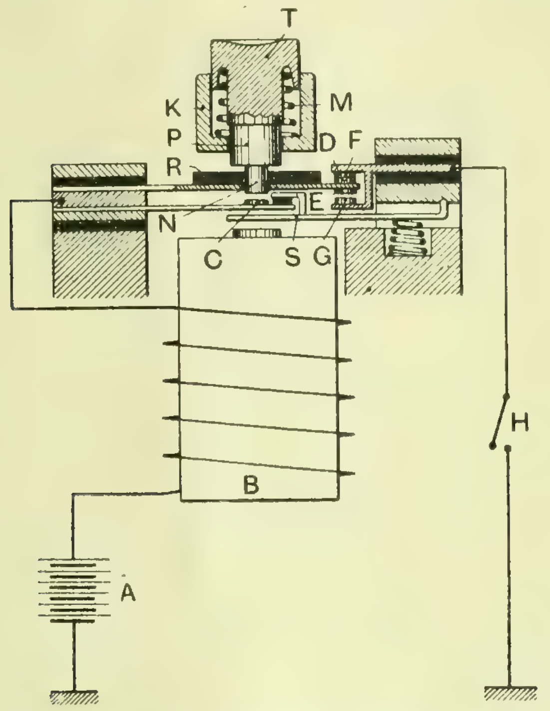
(*To be continued.*)

ELECTRICAL METERS ON VARIABLE LOADS.

A PAPER on this subject was recently read by Mr. David Robertson at a meeting of the Institution of Electrical Engineers. As a result of his investigations the author has arrived at the following conclusions: (1) Meters in which the main control is fluid friction are quite unsuitable for variable loads. (2) Mercury meters run faster than they ought on variable loads, and in some cases this error may be serious. It is necessary to make tests on each separate type to make certain that the fluid friction is kept within limits. The proportional amount of fluid friction at full load should not exceed four or five times the permissible error at that load. (3) Electricity (ampére-hour) meters of the commutator type generally record low on variable loads, but, except when the load is such as to allow the meter to stop frequently, the errors are the same as on steady loads. The proportional solid friction should not exceed the permissible error. (4) Energy (watt hour) meters of the commutator type can be made almost "dead accurate" for variable loads which do not often allow the rotor to come to rest. The compensating coils should be adjusted, not to get the minimum starting current without creeping, but to give a level characteristic above, say, quarter load. When the adjustment is not right the variable load errors are about the same as those with a steady load. (5) The simplest arrangements are the best. Additions made with the object of improving the steady load characteristic may cause serious errors on variable loads. (6) Clock meters in which there is little damping of the pendulums are as accurate on variable as on steady loads except within a small range of load frequency in which resonance effects occur. This type of meter should not be employed on cyclic loads, such as flashing signs, unless the load frequency differs considerably from that of the pendulums (about 80 cycles a minute).

APPARATUS FOR STARTING MULTI-CYLINDER INTERNAL-COMBUSTION ENGINES.

THE accompanying illustration shows diagrammatically a press button switch for starting multi-cylinder internal-combustion engines, the invention of Robert Bosch, Hoppenlaustrasse, 11-13, Stuttgart, Germany. One pole of the battery A is connected with the body of the engine and the other with one end of the primary winding of the ignition coil B, which also serves as the trembler magnet. The other end of the winding B is connected with the insulated ends of two contact springs of which one carries the trembler contact C and the other the switch contacts D and E. The latter are between two stationary contacts F and G which are carried in the frame of the apparatus but insulated from it, and are connected by a lead with the body of the engine over a positively operated interrupter H. The press button T is guided in a stationary socket K connected electrically with the body of the engine and is urged into the normal position by a



APPARATUS FOR STARTING MULTI-CYLINDER INTERNAL-COMBUSTION ENGINES.

spring M. The contact pin N extends through a perforation in the switch spring; the lower part P of the press button is of too large diameter to allow of its passage through the perforation. On the switch spring is fixed an insulating disc R which prevents the press button from making electrical contact with the switch spring when it is pressed. The trembler armature S is insulated from the spring which carries the contact C. In order to bring the trembler into action when the circuit of the mechanical interrupter is opened, the press button must be depressed far enough to bring contact N on to contact C. Current then flows intermittently, being governed by the vibrations of the trembler from battery A through winding B, trembler contact C, and pin N to K.

The distance between contacts N and C is made so small that these contacts are closed before contacts D and F are opened. If therefore the interrupter H has come to rest in the closed position the trembler will not be operated if the push button is depressed merely far enough to close contacts N and C, but not far enough to open contacts D and F. As the depression continues contacts D and F are opened and the trembler starts, but the trembler is again short-circuited when contact E engages with contact G. The trembler can operate therefore only in the very short interval of time in which the switch spring, under pressure of the press button, moves through the distance between contacts E and G, and this distance can be made so short that the engine during that time cannot perform half a revolution.

Launch of a Large German Liner.—There was launched on the 23rd inst. the new Hamburg-American liner "Imperator," 50,000 tons, from the slips of the Vulcan shipbuilding yard. The "Imperator" is now the largest vessel afloat, and is 4,000 tons larger than the "Titanic."

AUTOMATIC CONTROL FOR MOTORS IN STEEL PLANT OPERATION.*

BY STEWART C. COEY.

THE problem of motor control in industrial practice, and especially in steel plant operation, is one in which there is as great a diversity of opinion as in any other problem that presents itself to the industrial engineer. In this paper, it is the intention to take up some of the reasons for the use of automatic control for motors as opposed to manual control, and also some of the tests which have recently been made at the Youngstown Sheet & Tube Company on the new developments in automatic control which have been brought about by the use of the series-wound accelerating switch, and the deductions and standards that have resulted from these tests, in connection with previous experience in automatic and manual control.

The development of automatic control has been carried on for some time for use on both alternating and direct-current motors. In steel plant operation, this is confined for the most part to 3-phase, 25-cycle, 220-volt induction motors and 220-volt direct-current motors. In alternating-current control the practice has been to use wound rotor induction motors with accelerating switches in the secondary circuit, and reverse switches to reverse two phases of the primary circuit. Within the last year the greatest advance has been in the control of direct-current motors, due, as has been said before, to the advent of the series wound contactor switch for accelerating work.

The series switch is in its essential features a switch in which the moving part is so designed that after a certain definite amount of current has been reached in the series coil, the pull on the moving part is reversed due to the saturation of a portion of the magnetic circuit. This fixed locking-out point can be readily changed to suit conditions, and above this point the more the current is increased the greater is the locking-out tendency. After the switch has once closed, any increase in current will only hold it closed more firmly, and the current can drop to about one-tenth of the normal full load current of the motor without the switch dropping out.

However, it is not the intention in this paper to take up the question of the design of the series-wound contactor switch or any other type of switch. The fact is self-evident that the series contactor eliminates a lot of small auxiliary circuits and butterflies, which are necessary when the shunt-wound contactor is used for accelerating, due to the fact that the shunt contactor has to receive its operating current through a butterfly of some kind, which is opened and closed by means of a series coil. In other words, what the series contactor really does is to remove everything from the circuit excepting the series coil, which is necessary in some form when shunt-wound accelerating switches are used.

In considering the problem of the use of automatic or manual controllers in steel plant operation one of the most important considerations is found in the fact that a very large proportion of the operators who handle the various controllers are working on a tonnage or piece work basis. These operators are for the most part under the jurisdiction of the various department superintendents, with the possible exception of the crane operators, and in the Youngstown Sheet & Tube Company even the crane operators come under the department superintendents. It is quite natural that the department superintendents should be more interested in the tonnage output of their departments than in the upkeep of electrical apparatus. The result of this condition is that the various motors are driven to the point of breakdown. Now it is an established fact among operating men that no two men will handle a manual controller exactly alike, and the same man will handle it differently at different times, depending on conditions. This results in some men not giving the motors all they will stand safely and others driving them to the limit and beyond. There are very few men who will give the motor just the right amount of accelerating current and even these men will exceed the safe limit without knowing it at times. It is a recognised fact that after a certain amount of output has been obtained from a motor a point is reached where the saturation of the iron, &c., produces a condition where the increased losses in the motor itself represent practically all of the increase in the in-put to the motor. The fact that, by the use of auto-

* Paper read before the American Institute of Electrical Engineers, April, 1912.

matic controllers, the point of maximum acceleration can be obtained at each operation without running below at one time and above at another, has the effect of increasing the output of the plant.

Another factor that causes trouble, when manually-operated controllers are used, is found in the fact that one man very often has from three to five or more motors which he has to control simultaneously. In our blooming mill we have for instance a man with the control of two approach tables and a screw-down to take care of. It is a physical impossibility to use manual controllers in a case like this and get speed out of the mill without plugging the motors. Exactly the same conditions exist on nearly every crane, and more especially on charging cranes. The result of this condition on cranes is that the crane man watches his hoist controller and pays little or no attention to his trolley and bridge control, while on the charging cranes the condition is even worse. It is quite a usual thing to see a bridge controller completely reversed before the bridge motor has lost its motion in the direction from which it is being reversed.

The effect of these various factors on overload protection is really very serious. Whether this protection is obtained by means of some type of circuit breaker or by fuse, the use of manual control results in a condition where the overload protection of the circuit is invariably set at a point greater than the safety of the motor controlled would warrant. It has been the practice at the Youngstown Sheet & Tube Company to use automatic controllers on reversing motors larger than 50 h.p. This control has been accomplished by means of shunt-wound contactors, with four single-pole contactors for reversing duty, and from three to five of the same type contactors for acceleration. Within the last year a number of different applications have been made of several makes of automatic controllers with series accelerating switches. These applications have all been successful to a marked degree and have been of great value in determining the type of control apparatus that is being installed in the new mills now under construction.

One of the most interesting applications of the series accelerating switch was on the blooming mill screw-down motor. This motor is a 100 h.p. 220-volt mill machine. The mill has been speeded up until this motor carries an average of about 150 h.p., and in order to keep the armature from throwing the solder out of the commutator necks, a fan blows air through the motor continuously. On December 2nd, 1911, a controller of the following description was put on this work as a place giving the hardest possible kind of a test. This controller consists of two double-pole shunt switches, for reverse work, five series switches for acceleration, one lockout coil on the third series switch, one single-pole shunt switch as a line circuit breaker, mechanical and electrical interlocks between the reverse switches, and overload coil to open contactor type circuit breaker and reverse switches, and a two-point master controller.

The series switches on this board are now set to close at 800 amperes. The current is reversed in the motor on an average 20,000 times a day and on account of the speed necessary in operation, dynamic braking can not be used for stopping the motor with success, and the motor is plugged across the line through its full resistance, which is proportioned for the work. This board has given much better satisfaction than was even hoped for and after a few weeks' operation it was found that the lockout point was unnecessary and it has been taken off entirely since then. The copper tips on the two reverse switches last on an average about six weeks and the cost of replacing these is very slight. There has been very little trouble with the series switches and an entire absence of arcing on them. This installation proves conclusively to our minds the value of the series contactor where speed points are not needed.

The places where speed points are needed require careful thought and study. It is easily seen that tables, transfers, and some other motor applications need only one speed, but when we take crane trolleys and bridges it looks at first glance as though speed points were essential. However, by observing carefully it was found that the majority of cranemen seemed to be working only on the last points of their manual controllers and as an experiment a drum reversing switch with a controller consisting of three series switches was put on a 5 h.p. motor on the trolley motion of a 15-ton crane having a 104ft. span. In actual practice it was found that the craneman could "inch" his trolley better with this type of controller than with the old manual type.

These were two of the most interesting points covered by the tests made in the matter of results obtained. Other experiments were made on threading machines with drum reverse and controllers and series accelerating switches. These were very satisfactory, as dynamic braking could be readily used in this case with a great increase in efficiency of operation. The series switch was also found to be of great value in ordinary starting work in place of ordinary hand starters for shears, wet-pans, fans, &c., and has been adopted as a standard in place of hand starters at the Youngstown Sheet & Tube Company.

The main points embodied in the motor control for the new work now being installed are as follows: All mill controllers are to be automatic. They will have two double-pole shunt switches for reverse duty, either three or four series switches for acceleration, one single-pole shunt switch for line circuit breaker with electrical and mechanical interlocks on the reverse switches, overload coils in both sides of the line arranged to open both the line circuit breaker and the reverse switch, and a reversing master controller.

For crane work, each crane switchboard is to be arranged with a knife switch, a double-pole shunt contactor of sufficient capacity for all the motors on the crane, one overload coil in each of the motor circuits and in the common return, arranged so that if any one trips it will open the double-pole contactor, a safety lock and a re-set switch. The controllers for the trolley and bridge motors are all to be automatic and a duplicate of the mill controllers, with the omission of the overload protection and the single-pole shunt switch for circuit breaker protection. The controllers for hoisting duty offer the least possible use for the series switch, as it is necessary to use shunt switches to get the speed points on hoisting and the divided power and dynamic braking circuit for lowering. In this type of controller the series switch is used in the same capacity as the series overload coil on the old type of controller.

For sizes less than 15 h.p., the reversing drum has been adopted in place of reverse switches, and it is quite possible that the ultimate development along this line will see the reversing drum used in place of the two double-pole shunt switches for considerably larger sizes of motors.

A summation of the results that are obtained in steel plant operation by the use of the automatic controller follows:—

The use of automatic controllers cuts down the abuse of the motors and hence lessens the number of burnt-out armatures, broken shafts, &c. Of course, one point must be borne in mind in this respect, and that is that unless the automatic controller is made as simple as possible and the ordinary motor inspector can understand it, there is liable to be a loss of time in the end due to the greater length of time that is taken in locating any trouble, which may more than take up the amount of time saved by the reduction in the number of breakdowns.

The automatic controller saves all the machinery that receives its power from the motor as well as the motor itself.

The automatic controller allows the motor to work at its maximum efficiency at all times, and this in conjunction with the reduction in time lost in breakdowns increases the output of the plant.

World's Largest Warship.—The super-Dreadnought "Texas" was launched a few days ago from the Newport dockyard. The vessel has been constructed for the U.S. Navy, and is the biggest and most powerful battle-ship in the world. Her displacement with the stores aboard amounts to 28,367 tons. Her length is 573ft., and her speed 21 knots. In view of the general adoption of steam turbines in the principal European navies, it will come as a surprise to many to learn that the 27,000 h.p. required to maintain her speed will be developed by twin-screw vertical triple expansion engines. This decision was arrived at by a committee of American naval engineers, who decided that the reciprocating engine was the most economical and reliable for battle-ship practice. The "Texas" will be the first vessel to carry 14in. guns. She will have ten distributed in her five turrets. The total cost of the vessel is estimated at two millions sterling. Her sister ship, the "New York," will be launched at Brooklyn in July.

THE INFLUENCE OF CARBON ON THE CORRODIBILITY OF IRON.*

BY C. CHAPPELL.

DURING the past few years the subject of the corrosion of iron and steel has been receiving a well-merited and rapidly-increasing attention. Despite this fact, however, it is often difficult to obtain reliable information as to the specific influence exerted upon the corrosion of these metals by varying proportions of alloying elements. Especially is this the case with regard to the influence of increasing percentages of carbon on the corrodibility of iron. In view, therefore, of the prime importance of carbon in the metallurgy of steel, investigations have been carried out to ascertain the nature and extent of this influence.

Two main elements of uncertainty enter more or less into practically all the experimental results that are available in connection with this question—the lack of chemical purity in the steels employed, and the negligence of precautions to ensure that the steels shall be in a uniform condition of treatment before testing. Special attention has been paid to these two features throughout the present paper, which will therefore constitute a basis from which the influence of other elements upon the corrodibility of steel may subsequently be individually and accurately determined.

General Scheme of Investigation.—A series of practically pure iron-carbon steels has been prepared. Suitable bars of each steel have been subjected to typical heat treatments, and their relative corrodibilities and other properties have been investigated in each of these various states of heat treatment. By these means, not only has the influence exerted on these properties by variations in carbon percentage been determined, but also the influence of variations in the chemical and physical condition in which the carbon exists in these alloys, within the range of commercial treatments. Microscopic investigations into the *modus operandi* of the corrosion of iron-carbon steels have also been made, and have been productive of much interesting and important evidence, despite the considerable difficulty of examining corroded surfaces at high magnifications.

Production and Composition of the Steels.—The steels were all manufactured by the coke crucible process in the Metallurgical Department of the University of Sheffield. Six ingots were made, ranging from 36lbs. to 40lbs. in weight. The carbon contents ranged from 0·10 per cent. to 0·96 per cent. The materials employed throughout the series were Swedish bar-iron and charcoal. This method has previously proved itself by far the most satisfactory one for the production of iron-carbon steels of a high degree of purity. "Killing" was effected by aluminium in every case, and all the steels gave sound ingots. The chemical analysis of the steels is given in Table I., together with the distinguishing number employed throughout the research for each steel. It will be observed that in no case do the total impurities exceed 0·28 per cent.

TABLE I.—*Analysis of Steels.*

Steel. No.	Carbon.	Silicon.	Manganese	Sulphur.	Phosphorus.	Aluminium.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1	0·10	0·019	0·091	0·030	0·011	0·02
2	0·24	0·037	0·072	0·028	0·015	—
3	0·30	0·030	0·094	0·021	0·012	—
4	0·55	0·053	0·100	0·020	0·017	0·03
5	0·80	0·048	0·168	0·028	0·016	—
6	0·96	0·018	0·133	0·027	0·014	0·02

Treatment of Steels.—Each ingot was rolled down so as to give about 4ft. of ¾in. round bar, and the remainder taken down to ⅝in. diam. The treatments employed are briefly described in Table II., together with the letters used to denote the respective treatments.

TABLE II.—*Treatments and Characteristic Marks.*

Treatment.	Mark.
Rolled	R.
Normalised at 900° C., cooled in air	N.
Annealed at 950° C. for 20 hours, very slowly cooled in furnace	A.
Quenched from 800° C. in water	C.
Quenched from 800° C., tempered at 400° C.	D.
Quenched from 800° C., tempered at 500° C.	E.

* Paper read before the Iron and Steel Institute, May, 1912.

DETAILS OF TREATMENTS.

Rolled.—Test bars were turned from the ⅝in. round bars as received from the mill.

Normalising.—This was carried out in a large gas muffle on the ⅝in. size bars. These were put in at 800° C.; the temperature of the muffle fell to about 600° C., and was then gradually raised to 900° C. The bars were removed after 20 minutes at this temperature, and allowed to cool in air.

Annealing.—This treatment was carried out in a coal-fired annealing furnace according to the details given in Table II. The ¾in. round bars were employed for this treatment, so that the decarburised skin could be completely machined off in the lathe in preparing the test pieces, and its influence thus eliminated from the subsequent tests.

Quenching.—The bars were heated in a Brayshaw salt-bath furnace to 800° C., allowed to remain at that temperature for 15 minutes, and then rapidly quenched out in water at 15° C.

Tempering.—The quenched bars were heated up to the required temperature in a lead bath, maintained at that temperature for 10 minutes, and then cooled in air.

It must be noted that in both the quenched and tempered series the test pieces were machined to slightly over the finished size before treatment. Any influence possibly exerted by the

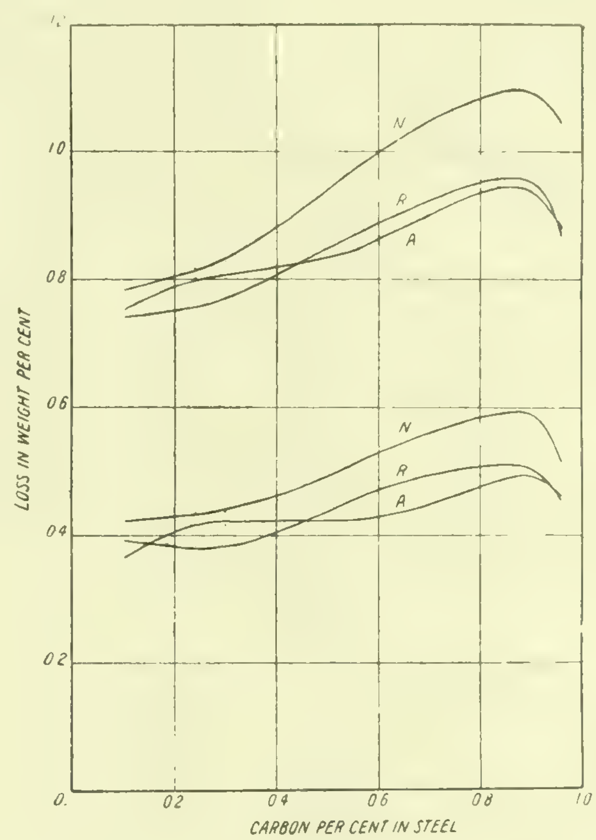


FIG. 1.—RESULTS OF CORROSION TESTS ON CARBON STEELS.

molten salt on the surface of the bar was subsequently obviated by the entire removal of the surface in reducing to the required finished size.

CORROSION TESTS.

Method of Experiment.—Test bars, 4½in. long by ⅝in. diam., were prepared from each steel in all states of treatment. Each bar was drilled at a distance of ¼in. from one end, with a hole ⅛in. diam., for suspension purposes. The suspension was effected by means of thin glass hooks passing through the centre of the corks closing the jars. Separate jars were used for each test piece, and free access by the air to the interior of the jar was carefully ensured in each case.

The test bars themselves were polished in the lathe to a uniformly high degree of polish with fine emery paper. The importance of having the specimens as nearly uniformly polished as possible is considerable, and must be insisted upon in comparative corrosion testing. The author has frequently found, during the microscopic examination of corroded surfaces, that the finest scratches from the polishing block are often productive of more vigorous corrosion than occurs in any other portion of the specimen, even after several months' immersion in sea water. So that uniformity of polish, as the nearest practicable ideal, should receive careful attention in experimental corrosion research.

After polishing the bars wese accurately weighed, immersed in pure ether for at least an hour to remove all grease, dried in a vacuum dessicator, and then suspended in 700 cubic centimetres of filtered sea water, in jars. This sea water was obtained from the Irish Sea, and its analysis is given in Table III. The room in which the tests were carried out was well lighted, but situated so that no direct sunlight entered it. Variations in temperature were largely atmospheric, as the room was not artificially heated.

TABLE III.—*Analysis of Sea Water Employed.*

Specific gravity at 12° C., 1·0240.

1,000 parts by weight of sea water contain :—

	Parts by weight.
Sodium chloride	27·20
Magnesium chloride	2·95
Magnesium sulphate	1·84
Calcium sulphate..................	1·20
Potassium chloride................	0·77
Calcium carbonate	0·11

After 91 days' immersion, the bars were taken out, well washed, cleaned with chamois leather until all adherent deposits were removed, dried thoroughly, and weighed again. The bars were then re-immersed in the same jars and sea water as before, for a further period of 75 days, cleaned thoroughly again, and re-weighed. The results obtained are given in Table IV., and are set out in graphical form in Figs. 1 and 2. It will be convenient to consider these results in three main groups, as indicating the influence: (*a*) of carbon, (*b*) of treatment, and (*c*) of time, respectively, upon the corrodibility of these steels in sea water.

TABLE IV.—*Sea Water Corrosion Results.*

Treatment.	Steel No.	Carbon per Cent.	Weight before Immersion in Grammes.	Weight after 91 Days' Immersion in Grammes.	Loss in Weight after 91 Days' Immersion. Per Cent.	Weight after 166 Days' Immersion in Grammes.	Loss in Weight after 166 Days' Immersion. Per Cent.
Annealed (A).	1	0·10	63·8038	63·5700	0·366	63·3239	0·752
	2	0·24	64·5852	64·3112	0·424	64·0667	0·803
	3	0·30	63·8254	63·5600	0·416	63·3140	0·801
	4	0·55	63·6710	63·4004	0·425	63·1314	0·848
	5	0·81	63·5256	63·2200	0·481	62·9278	0·941
	6	0·96	63·8870	63·5926	0·461	63·3240	0·881
Normalised (N).	1	0·10	63·7760	63·5058	0·424	63·2750	0·786
	2	0·24	63·3868	63·1120	0·433	62·8724	0·812
	3	0·30	64·5350	64·2545	0·435	64·0012	0·827
	4	0·55	63·5522	63·2248	0·515	62·9330	0·974
	5	0·81	64·0190	63·6424	0·588	63·3224	1·088
	6	0·96	64·4842	64·1544	0·512	63·8125	1·042
Rolled (R).	1	0·10	64·5524	64·2950	0·399	64·0728	0·743
	2	0·24	64·3982	64·1500	0·385	63·9100	0·758
	3	0·30	64·5544	64·3122	0·375	64·0570	0·771
	4	0·55	63·6150	63·3234	0·458	63·0600	0·872
	5	0·81	64·0697	63·7442	0·508	63·4576	0·955
	6	0·96	64·2130	63·9200	0·456	63·6457	0·868
Quenched (C).	1	0·10	64·1152	63·8800	0·413	63·6734	0·771
	2	0·24	65·1968	64·8430	0·543	64·5608	0·981
	3	0·30	65·0368	64·6895	0·534	64·3855	1·010
	4	0·55	65·2292	64·8614	0·564	64·5252	1·088
	5	0·81	65·2700	64·8765	0·603	64·5400	1·124
	6	0·96	65·5850	65·1800	0·617	64·8552	1·119
Tempered (D).	1	0·10	64·5094	64·2920	0·337	64·0610	0·699
	2	0·24	64·5400	64·2920	0·384	64·0244	0·803
	3	0·30	65·1546	64·8440	0·477	64·5255	0·971
	4	0·55	64·6986	64·3364	0·560	64·0112	1·067
	5	0·81	65·0828	64·7130	0·568	64·3640	1·111
	6	0·96	64·8880	64·5042	0·591	64·1238	1·184
Tempered (E).	1	0·10	63·9120	63·6589	0·391	63·4299	0·754
	2	0·24	64·8710	64·6128	0·398	64·3796	0·757
	3	0·30	64·7970	64·5073	0·447	64·2745	0·806
	4	0·55	65·0828	64·7286	0·544	64·4950	0·903
	5	0·81	65·8320	65·4578	0·568	65·2200	0·930
	6	0·96	66·0814	65·7049	0·570	65·4497	0·956

(*a*) **Influence of Carbon.**—A comparison of Figs. 1 and 2 shows clearly that the influence exerted by increasing percentages of carbon upon the corrodibility of iron is of two distinct types, dependent upon the treatment employed. In the *normalised, rolled, and annealed* steels, where the cooling through the critical ranges during treatment has been sufficiently slow to produce well defined pearlite, the corrodibilities tend to rise with increase of carbon up to 0·81 per cent. carbon, but, without exception, fall again on reaching 0·96 per cent. carbon. This points very strongly to the conclusion that the corrodibility rises to a maximum at saturation point (0·89 per cent. carbon) and begins to fall on the appearance of free cementite in the steel. Other evidence, given later, also supports this conclusion.

The ratio of the increase of corrodibility to the carbon percentage is more satisfactorily shown in the 166 days' immersion results than in those taken over the shorter period. From the upper set of curves shown in Fig. 1 it is seen that the increase in corrodibility after 166 days' immersion is continuous with the rise of carbon from 0·10 to 0·81 per cent. in the case of all three treatments considered.

In the normalised and rolled steels this increase is less rapid in the low-carbon range, from 0·10 to about 0·30 per cent. carbon, than in the higher range up to the saturation point. This feature is noticeable in the 91 days' as well as in the 166 days' immersion results.

The small influence exerted by carbon in the low percentage range probably accounts for the inconclusiveness of many of the relative corrodibility results obtained during the wrought-iron versus mild-steel contest. The greater quantity of slag and other impurities in the wrought iron may easily set up more than sufficient galvanic action to counteract the decrease in corrodibility due to lower carbon contents.

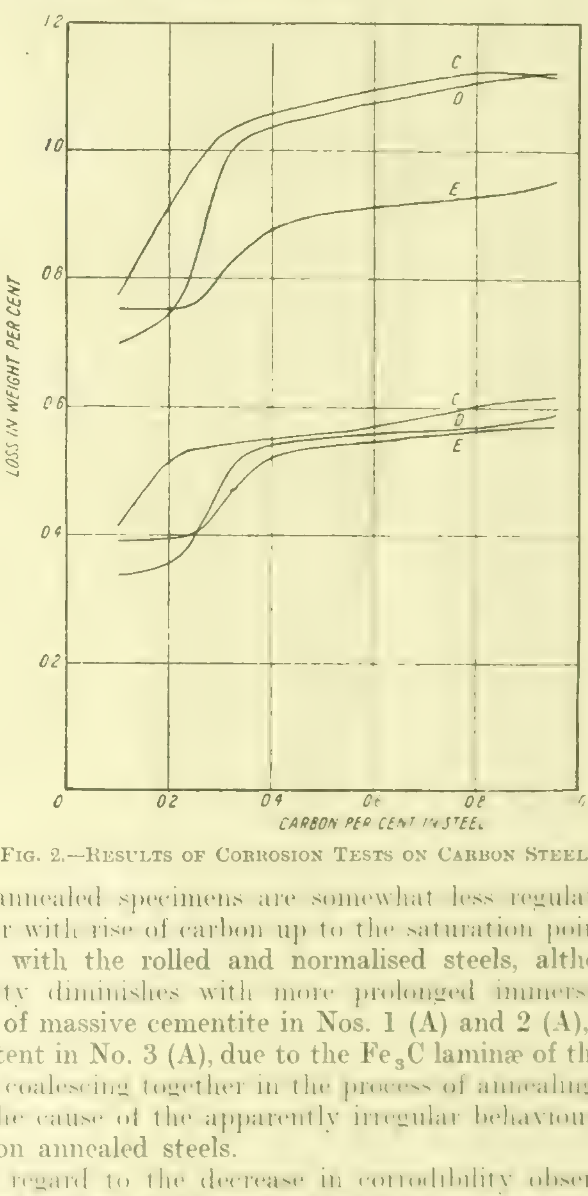


FIG. 2.—RESULTS OF CORROSION TESTS ON CARBON STEELS.

The annealed specimens are somewhat less regular in their behaviour with rise of carbon up to the saturation point than is the case with the rolled and normalised steels, although this irregularity diminishes with more prolonged immersion. The presence of massive cementite in Nos. 1 (A) and 2 (A), and to a slight extent in No. 3 (A), due to the Fe_3C laminæ of the pearlite partially coalescing together in the process of annealing, may be largely the cause of the apparently irregular behaviour of these low-carbon annealed steels.

With regard to the decrease in corrodibility observed with rise of carbon from 0·81 per cent. to 0·96 per cent., interesting confirmation has been obtained from experiments carried out on a series of iron-carbon steels containing 3 per cent. tungsten, having the composition shown in Table V.

TABLE V.—*Analysis of Carbon-Tungsten Steels.*

Mark.	Carbon per cent.	Tungsten per cent.	Silicon per cent.	Manganese per cent.	Sulphur per cent.	Phosphorus per cent.	Aluminium per cent.
924	0·14	3·25	0·044	0·065	0·055	0·010	0·011
922	0·22	3·24	0·050	0·071	0·050	0·010	—
921	0·48	3·11	0·060	0·075	0·050	0·010	—
920	0·57	3·17	0·078	0·080	0·054	0·010	—
965	0·89	3·08	0·039	0·093	0·040	0·012	—
964	1·07	3·09	0·040	0·055	0·042	0·012	0·014

The corrodibility tests were carried out under exactly the same conditions as those previously described, the only deviation being

in the case of steel No. 965, where the test bar was only $3\frac{1}{4}$in. long instead of the standard length ($4\frac{1}{2}$in.). The results, after 91 days' immersion, are given in Table VI.

TABLE VI.—*Sea Water Corrosion Results on Carbon-Tungsten Steels.*

Mark.	Carbon per cent.	Tungsten per cent.	Weight before Immersion in Grammes.	Weight after 91 Days' Immersion in Grammes.	Loss in Weight. Per cent.
924	0·14	3·25	65·3618	65·1216	0·368
922	0·22	3·24	65·3186	65·0726	0·378
921	0·48	3·11	65·6550	65·3900	0·405
920	0·57	3·17	64·3380	64·0746	0·412
965	0·89	3·08	48·0280	47·7750	0·530
964	1·07	3·09	63·7820	63·5070	0·433

These results, which are graphically shown in Fig. 3, entirely corroborate those obtained with the iron-carbon steels. The corrodibility steadily rises to a maximum at 0·89 per cent. carbon, which is practically the saturation point in this series of steels. The appearance of free cementite again produces a marked decrease.

Comparison with the values given by the rolled steels in the iron-carbon series shows that the influence exerted by the 3 per cent. of tungsten present in these steels is very small, and is quite insufficient to warrant any definite conclusions as to the influence of tungsten on the corrodibility of steel.

The *quenched* and *tempered* steels of the iron-carbon series show a continuous rise in corrodibility, with increase of carbon throughout the whole range investigated. No indications of a maximum corrodibility at the saturation point are found, as in the previously described instances.

The proportional increase in corrodibility is very rapid in the range from 0·10 per cent. to approximately 0·40 per cent. carbon, but beyond this point the rate of increase relative to the rise in carbon percentage becomes very small. The increase in this latter range is remarkably constant. The dissimilarity between these two ranges is probably due to incompleteness of the hardenite-ferrite solution in the low-carbon steels under the conditions of quenching which were adopted.

The behaviour of these steels in the higher carbon range shows clearly that variations in carbon exert much less influence when the carbide is evenly distributed throughout the steel—either in solution or in the emulsified form—than when it is present in the more concentrated normal pearlite form.

(*b*) **Influence of Treatment.**—The influence of treatment is almost as important as that of carbon percentage. On the whole, annealing renders the steel most resistant to corrosion in sea water, while quenching causes it to corrode most rapidly. Normalising decidedly increases the corrodibility of the steels as rolled in this series. The extent to which this may prove to be a general rule must necessarily be open to modification, and possibly to exceptions, in view of the variations in these treatments in practice. The influence of tempering appears to be considerably affected by the temperature at which it is carried out. In the case of treatment D (tempered at 400° C.), the corrodibility is but slightly less than that of the quenched steels, and generally higher than any of the pearlitic steels. On increasing the tempering temperature to 500° C., as in treatment E, the corrodibility is reduced in all except the very low carbon steels. This decreased corrodibility, with rise in tempering temperature, is comparatively slight as measured after 91 days' immersion, but after longer immersion becomes very pronounced.

The influence exerted by treatment upon corrodibility may be the result of changes produced in the physical or chemical condition of the carbide, and also in the physical condition of the steel as a whole. The information available regarding the factors involved in the corrosion of steel is not yet sufficiently detailed for absolute certainty, but it is nevertheless probable that the main factors determining the corrodibility of pearlitic steels, and which may be influenced by treatment, are as follows: (*a*) The difference of electrical potential between the pearlite and the ferrite or cementite; (*b*) the difference of electrical potential between the Fe_3C and the ferrite in the pearlite itself; (*c*) the state of division of the Fe_3C in the pearlite; (*d*) the differences of potential existing between various parts of the steel due to variations of internal stress.

Accurate differentiation of the relative importance of these factors in determining the sum total of the influence exerted by a given treatment is obviously difficult, as the same treatment may not necessarily influence all the factors similarly, so far as their influence upon corrodibility is concerned. With a view, however, to obtaining some evidence upon this point if possible, determinations of the electro-potentials of steels Nos. 1 and 5 in all states of treatment have been made, after several weeks' immersion in sea water. The method employed in these determinations has been to combine the steel-sea water element with a calomel electrode of known constant electro potential. The electromotive force of the combination is then measured by comparison with that of a standard cadmium cell. The comparison is carried out by a modification of Poggendorf's compensation method, a capillary electro-meter being employed to determine the point of balance between the two electromotive forces.

The values obtained may be taken as being at any rate roughly indicative of the relative electro potentials of the ferrite

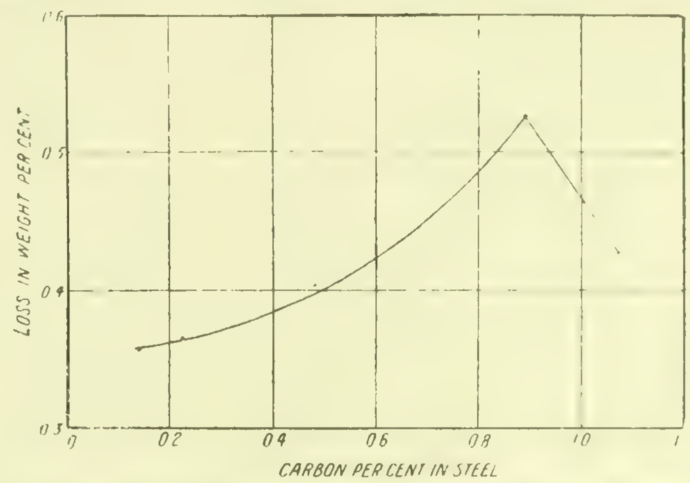


FIG. 3.—RESULTS OF CORROSION TESTS ON CARBON-TUNGSTEN STEELS.

and pearlite constituents respectively in the various states of treatment; and also, but to a less extent, of the difference of potential between the components of the pearlite itself. The results, together with the corresponding differences of potential in each case, are given in Table VII., and are arranged in the ascending order of the differences of potential.

TABLE VII.—*Electro-Potentials in Sea Water, &c.*

Treatment.	Electro-potential in Volts.		Difference of Potenti'l in Volts.	Loss in Weight per cent. after 166 Days' Immersion in Sea Water.	
	Steel No. 5, 0·81 per cent. Carbon.	Steel No. 1, 0·10 per cent. Carbon.		Steel No. 4, 0·55 per cent. Carbon.	Steel No. 5, 0·81 per cent. Carbon.
A	0·2150	0·2169	0·0019	0·847	0·941
R	0·2129	0·2100	+0·0029	0·872	0·955
E	0·2283	0·2145	+0·0138	0·903	0·930
N	0·2234	0·2088	+0·0146	0·974	1·088
D	0·2216	0·2037	+0·0180	1·067	1·111

On comparing these differences of potential between the constituents with the corrodibility values in the corresponding states of treatment given by steel No. 4 (see Table VII.), in which steel both ferrite and pearlite are present in considerable quantities, a distinct correlation is seen to exist in the influence of treatment upon both values. This agreement is only slightly less complete in the case of steel No. 5, failing in but one instance (Table VII.).

It appears, therefore, that in unsaturated steels containing any appreciable amount of pearlite, say from 0·40 per cent. up to 0·89 per cent. carbon, the dominant forces governing their corrodibility in sea water are the two factors (*a*) and (*b*), *i.e.*, the galvanic action between the pearlite and ferrite, and between the components of the pearlite itself.

These two factors are accentuated in tempered steels by the emulsified nature of the Fe_3C, which facilitates galvanic

action in the pearlite; and also by the presence of residual quenching stresses which are likely to be sources of differences of electrical potential, and consequently of galvanic action. The converse of these supplementary factors operates in the annealed steels, where the resolution of the pearlite into the laminated variety reduces the number of galvanic couples within the pearlite to a minimum. The influence of annealing in removing stresses also comes into play in reducing the liability to corrosion, although a comparison with the corrodibility values of the rolled bars shows that this influence has been very small in the case of these steels. The wide variations in steels "as rolled," however, render annealing, nevertheless, a necessary safeguard where resistance to corrosion is required.

Endeavours to ascertain and differentiate between the forces at work in the corrosion of quenched steels have not been productive of sufficiently clear evidence to warrant definite statements. Attention may be drawn, however, to the remarkable similarity in type which exists between the corrodibility curves of the quenched and tempered steels (Fig. 2), despite the fundamental difference produced in the condition of the carbide by the respective treatments. It might be mentioned in this connection that the electro-potential of steel No. 5 after quenching was 0·2040 volts. It will be seen, by comparison with the values given in Table VII. for the same steel in the tempered condition, that a very drastic change in potential is involved in the tempering of quenched steels. This is so considerable as entirely to preclude any possibility of this similarity observed between the corrodibility curves being due to any similarity in the electro-potentials of the main constituents. The evidence consequently tends, by a process of elimination, to attribute the similarity to the feature which is common to both their treatments, that is, the physical influence, more or less modified, of the quenching process. On the other hand, this deduction derives little or no support from the results given by steel No. 1, where the influence of stresses is least complicated by the presence of carbon, and which should consequently be most productive of corroborative evidence on this point.

Moreover, in the range above 0·4 per cent. carbon, in which the solution of the carbide may be presumed to have been fairly even throughout the steel, the corrodibility curves of the quenched and tempered steels are practically a linear function of the carbon contents. The concentration of the solution in carbon would therefore appear to exert some influence, but the small effect produced by variations in this concentration militate against it being considered a very important one. This question, therefore, is one that requires further investigation.

(*c*) **Influence of Time.**—Comparison between the results, after 91 days' and 166 days' immersion respectively, shows that the influence of time on the rate of corrosion varies considerably with different steels over these periods. The most striking example is that of the E steels, where the ratio between the rates of increase of corrosion and of time falls on the average by nearly 10 per cent.

(To be continued.)

The Institution of Water Engineers. — The seventeenth summer general meeting of this Institution will be held at Cheltenham, on Thursday, Friday, and Saturday, June 6th, 7th, and 8th, under the presidency of Mr. J. S. Pickering, M.Inst.C.E. The following papers have been promised for reading and discussion at the meetings: "The New Waterworks for Skegness," by Percy Griffith, M.Inst.C.E.; "The Rating of Water Undertakings," by Donald Dinwiddy, F.S.I.; "The Rating of Water Undertakings," by Arthur Valon, Assoc.M.Inst.C.E. A discussion on the desirability of standardising the "General Conditions of Contracts" will be introduced by Harold W. Woodall, M.Inst.C.E.; "The Hinckley Waterworks," by E. H. Crump, Assoc.M.Inst.C.E.; "The Gloucester Waterworks (Witcombe Reservoirs)," by R. Read, A.M.Inst.C.E., City Engineer; "The Use of Sulphate of Copper in Purifying Water Supplies," by Geo. Embrey, County Analyst of Gloucestershire; "The Self-Pollution of Water by Natural Growths," by Dr. J. H. Garrett, M.O.H., Cheltenham; "The Geology of Cheltenham with Special Reference to the Water Supply," by L. Richardson, F.R.S., Ed. F.L.S., F.G.S. Further particulars may be obtained from the secretary, Mr. Percy Griffith, 54, Parliament Street, Westminster, S.W.

ELECTRIC MOTOR TESTING.

ONE of the benefits attending the introduction of electrical distribution of power in industrial plants is the ease with which measurements of power requirements and use may be made. Another benefit of which advantage is being taken more and more is the analysis which may often be made of machine action by the aid of recording or curve-drawing wattmeters. An outline of some of the methods and utilities of testing motors in service in manufacturing plants is given in an article by Mr. S. P. Goodale in the "Electrical World and Engineer." Such tests, the writer states, are of interest to three classes of people: (1) Motor builders, who must know the requirements to be met in various industries in order intelligently to plan and sell their products; (2) central stations, whose interest is of the same general order, and (3) manufacturers who desire to conduct their plants under the most economical and advantageous conditions. In general, similar methods will meet the needs of these three classes.

Obviously the equipment should comprise as few pieces of apparatus as will serve the purpose thoroughly. The most essential meters for testing motors are voltmeter, ammeter, indicating wattmeter, recording wattmeter, and watt-hour meter. For alternating-current work these may be chosen of such capacity that, with the aid of transformers, one meter of each kind will serve for any range of motor sizes. Care must be taken to choose meters whose own power requirements will not overtax the

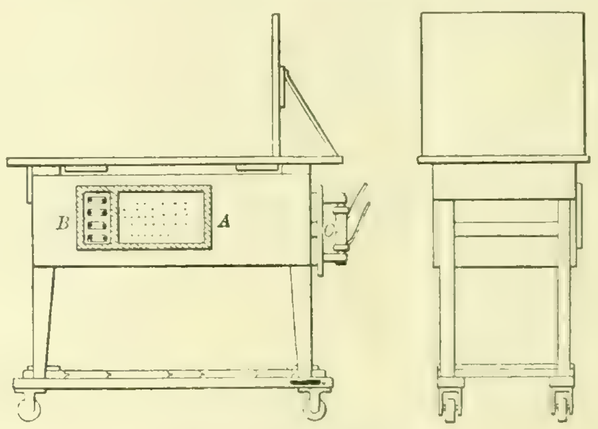


FIG. 1.—TEST TABLE.

transformer's capacity and, conversely, to choose transformers of sufficient size for the meters. A considerable amount of care in choosing meters best adapted for the conditions to be met will be well repaid.

The use of meters in testing is much facilitated by the provision of a permanent stand on which they may be placed. The stand should provide ample room for meters, switches, and connections, be of such size and shape as not to interfere with its location near the motors to be tested, and be easily movable. Switchboard-type meters can best be mounted on an upright panel and portability secured by mounting the panel upon a truck, the top of which will provide room for the transformers. If available, the portable-type meters are more desirable. A box form of structure has the advantage of affording better protection to the meters and connections and being well adapted for shipment, but, on the other hand, it is more complicated and inaccessible. A table is, in general, the most convenient and adaptable form of construction for a testing stand. Fig. 1 shows side and end views of a table which has been used with much success in testing an installation of 3-phase 550-volt motors ranging in size from 3 h.p. to 175 h.p. With very few changes this form may be adapted to almost any conditions met in testing motors in service.

The table top is made 2ft. by 4ft. The legs are set in somewhat to give more clearance when moving the set through narrow aisles. An upright wooden panel is bolted near one end of the top to provide for a recording wattmeter and watt-hour meter, the available meters being of a switchboard type. Flexible meter leads (not shown) project through the table top and are so arranged as to go directly to the proper binding post without any crossing when the meters are in position.

On both sides and at one end boards are nailed to the table legs and extend down about 13in. Rigidity is thus secured as well as room for other attachments which add to convenience and adaptability. A rectangular hole is cut out of the board on one side

to make room for a fibre panel *A*, with binding posts, to which are connected the leads from the meters. From other binding posts on the same panel leads are carried to the terminals of the test set. By connecting the proper binding posts with suitable jumpers any desirable scheme of connections for the meters, with or without the transformers, may be easily worked out and changes made when necessary. It should be noted in passing that a connection panel of this sort may be made so complicated as partly to destroy its value. Its use should be limited to those connections which are likely to need changing, and so employed it contributes markedly to the convenience and ease of manipulation. The meter fuses, *B*, are mounted adjacent to this connection panel.

To facilitate connections to the motor circuit use is made of fuse blocks, *C*, mounted on the end board of the table. The fuse clips of these blocks form the terminals of the test set. Wires attached to the caps of blown fuses, as indicated in Fig. 1, form a connection between test set and motor circuit exactly resembling the familiar plugs and cord used on telephone switchboards. If the motor is protected by a circuit breaker and no fuse block is conveniently located, it will be necessary to use some other form of connection to the motor circuit. For this purpose Dossert connectors are both neat and convenient.

The table is set loosely on a flat truck made for the purpose and prevented from slipping by cleats on the truck. Pieces of felt or other elastic material placed under the table legs absorb vibration and jar and lessen their injurious effect upon the meters. The flat top of the truck forms the logical place for transformers and any other material needed. Fig. 2 is presented to show the arrangement of meters and switches used. *A* indicates the voltmeter; *B*, ammeter; *C*, watt-hour meter; *D*, indicating wattmeter; *E*, recording wattmeter. One 3-pole switch is provided to cut all current off potential leads and a single-pole switch for short-circuiting each meter current coil. Two two-pole, double-throw switches are used to reverse the direction of current in the series coils of the indicating wattmeter and provide for entirely disconnecting those coils when using the wattmeter alone to determine power factor. One single-pole, double-throw switch permits of throwing the voltmeter to either one of two phases. These switches are all small knife type and in addition to their other use permit the removal of meters while motor is in use, this being sometimes desirable. They are mounted in such location as to indicate their use and are wired through the table top. Knife switches are preferred to snap switches, as their position is apparent at a glance. A sketch, *S*, showing the permanent wiring of the table, is placed where it may be readily consulted and a glass cover is used to keep it free from dirt. The sketch will save tracing out wiring or reliance on memory and is, in fact, a necessity when the use is intermittent.

Protection to the table and meters and provision against accidental contact may be provided according to the circumstances of use. In particular the connection panel, fuses, and fuse block terminals should be covered in such a way as to afford complete protection against accidental contact without interfering with easy access. A hinged cover would be suitable. The permanent wiring is protected by the construction used.

It is very convenient and quite possible to be able to move the test set from one part of a factory to another without removing meters. The meters should, however, be rugged in construction and much care be taken lest shock and jar from moving affect the delicate bearings. Most portable indicating meters are provided with a device to lock the moving element in place while the meter is being handled, and this feature should be looked for. The moving elements of recording and watt-hour meters may be secured by blocking with folded strips of paper. Rubber-tyred wheels are effective in lessening vibration, though by no means necessary. The provision made on the table illustrated is in the form of felt placed under the table legs as before mentioned, supplemented in some cases by a mat of cotton placed under the different meters.

TEST No. 52.—*Manufacturing Company, April 14th,* 1911.

Time.	Volt.	Amperes.	Kilowatts.	Electric Horse-power.	Revolutions per Minute.	Temperature.	Frames in Use
6.50	573	120	80	107	....	90	12 3-4
.55	582	102	74	99	796	..	13 5-4
7.	579	95	62	83	..	99	13 5-4
.05	570	100	61	81	796	..	13-4-4
.10	573	96	64	86	...	107	12 4-3
.15	558	104	66	88	793	. .	14-5-3
20	540	110	70	94	.	115	13 5 4
25	579	98	68	91	796	.	13-5-4
.30	576	103	68	91		122	14-6-4
.35	573	92	64	86	807		13-5-4
40	564	100	67	90	...	128	13-5-4
45	561	98	66	88	790		13-5-4
* * * *	* * *	* * *	* *	* * * *	* * * * *	* * *	* * * * * *
10.50	570	77	54	72	. .	151	12-0 4
.55	564	85	58	78	802	..	12-3-4
11.	561	86	56	75	...	152	11-4-4
.05	573	93	62	83	790		11-4-4
.10	576	90	58	78	...	152	12 5-4
15	570	94	64	86	785	..	13-6-4
20	567	96	66	88	..	155	13-6-4
25	567	100	66	88	775	...	13-6 4
30	564	104	65	87	. .	155	13-6 4
.35	564	105	68	91	785	..	13 6 2
40	567	100	62	83	...	159	14-5-2
45	564	96	62	83	808	..	12-4-2
50	564	76	50	67	...	159	11 4-1
55	570	60	42	56	795	.	7-4-0
12.	558	50	38	51	....	157	4-4-0
Max......	585	120	80	107	815	159	14 6-4
Min......	540	50	38	51	761	...	4 4 0
Aver.....	570	90	60	81	797	...	11 5-5-3 3

Motor No. 1 (General Electric Company, No. 64204).
550 volts, 75 amp, 75 hp. three-phase, 40 cycles, Class 6-75-800
Type I, Form L.
Location.—No. 1 Spinning Room
Load.—
15 Whitin Spinning Frames,
256 Spin., No. 24 Warp Yarn
6 Fales & Jenks Spinning Frames,
208 Spin., No. 7 Warp Yarn.
4 Mason Spinning Frames,
176 Spin., No. 24 Warp Yarn.
Weather.—Cloudy and damp. About 50° F
Room Temperature.—Rose uniformly from 69° F to 82° F. Temperature at motor level 2 to 7 degrees higher
Humidity:—78% to 85%.
Spin. Speed (average), 8,000 Whitin & Mason, 5,000 Fales & Jenks.
Spin. per electric horse-power, 56.
Shafting takes electric horse-power (see Remarks).
Load Factor.—79%
Remarks.—
There is a peculiar fluctuation in the power taken by this motor which prevented close reading of meters and made it difficult to get good graphic curve. The fluctuation was most marked with shafting only running.
Speed variation due to waterwheels being overloaded and steam-driven unit used at times to bring speed up.
Total time lost in making repairs to frames equal to 1½ frames stopped for entire period.
No second-hand in room during test.
Supply of roving small and insufficient.
Load-factors for Saturday and Monday mornings following this date were 67% and 72% respectively. Corresponding loads in electric horse-power were 76.2 and 80.7.
Column headed "Frames in Use" shows the number of frames of each make in use at each interval in the order noted under "Load."

Relay-type recording wattmeters deserve special consideration. These meters are usually provided with adjustments to control their sensitiveness and quickness of action, changes being needed to adapt them to the characteristics of different circuits. If a meter of this type is used it should be mounted so that the various points of adjustment are accessible without removing the meter from its place. It is a peculiar fact and one worthy of mention, that a particular meter of this type gave notably better results when subjected to the vibration in the factory rooms than when located on the station switchboard.

In making a test the indicating meters should be observed at regular intervals, five minutes being a common and convenient choice, and the readings noted. At the same time speed of the motor should be taken with a tachometer, if one is available, or with a common revolution counter, and the load conditions should be noted. The temperature of the motor should be taken at regular intervals, which need not correspond with the intervals chosen for the other readings. All readings, except temperature, should be taken at as nearly as possible the same instant after each interval. A fair approximation is made possible by practice.

The duration of the test should be sufficient to admit of striking a fair average from the readings taken and to permit of a good recording curve. In general, a full morning or afternoon run,

giving about five hours, will furnish excellent results, but in certain cases it is preferable to choose the time covering one or more complete cycles of operation. It is of the utmost importance that all data bearing on the test should be taken at the time. Nothing is more exasperating than to find essential information lacking in an otherwise full and complete test report. Knowledge and understanding of the operations and functions of the driven machinery are needed in order that important facts may not be overlooked. The data to be secured include number and kind of driven machines, as well as their important specifications, room temperature and conditions. Anything abnormal, such as scarcity of help, lack of raw material, poor layout or condition of machinery, method of lighting, lack of supervision, &c., has a

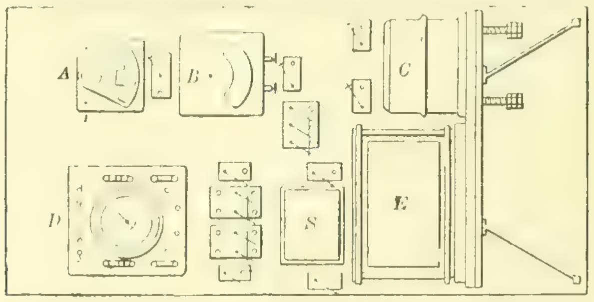


FIG. 2 ARRANGEMENT OF METERS AND SWITCHES.

decided effect upon production and must be noted if full utilisation of tests is desired or looked for. Friction and shafting load are important items.

Method and order are of importance in setting down the readings and data taken and will facilitate analysis and deduction of important points. This refers particularly to the test report which will have to be made from the observed readings and data. The first step in making up the test report will be to determine a form to be used. The readings, corrected to their true value, may then be set down in definite sequence. A form found satisfactory in practice is shown in the accompanying table.

The corrected readings are set down in vertical columns opposite the time at which they were taken, and other values, such as horse-power and power-factor, figured from them. At the bottom of each column are noted the maximum, minimum, and average values found in that column, thus serving to show very quickly the important facts. It may be noted that the quickest method of figuring the average is to assume a figure which a glance down the column will indicate to be approximate and then to add or subtract the difference between this figure and the readings, each in turn, to obtain an amount which, divided by the number of readings, will give the difference between the assumed and actual average value.

The heading of the report gives sufficient information to identify the particular test, and the further data obtained are set down at the right of the readings. Analysis of the data should be carried far enough to deduce the facts of immediate interest and value, the character of these being determined by the purposes of the test, which may relate more particularly to the behaviour of the motor or to the characteristics of the load or other matters of interest. Further analysis may be made later if desirable or if additional information is required.

It will be of interest to glance briefly over this report and note what information it contains. As the heading indicates, it is one of a series made in a particular plant. The motor rating is given in full, and it may be noted that the motor records in this plant cover the entire history of this motor. The excess of current in proportion to power developed shows the motor not to be in first-class condition. This is further confirmed by the existence of a fluctuation in power consumed so rapid and violent that it was only with difficulty that the recording wattmeter could be adjusted to give a readable curve. As the action was even more violent when the motor was running light, it is evident that the fault lay in the motor itself. Temperature readings show that in spite of the defect the motor was still usable and could, in fact, have carried a larger load safely provided that the fault was not so localised as to throw an excessive strain on some particular part of the windings. The average voltage, being slightly high, indicates a supply circuit amply large. Neither the average value nor the extremes vary enough from normal to have an injurious effect upon the motor or its operation.

Speed of the motor varied over somewhat wide limits, and, in explanation, we find a note to the effect that a steam-driven generator was used at times when the water-power was insufficient to carry the connected load to speed, and it may easily be inferred that the steam-driven unit was not used until the waterwheels had actually gone below normal speed. The variation was of consequence rather as affecting the quality and quantity of the product than as being injurious to the motor.

The load carried by the motor is described somewhat briefly. As several makes of spinning frames were included, it would be difficult or impossible to analyse the power requirements of each separately, but an average showing the number of spindles driven per horse-power has been computed. This is the usual basis of comparison between the power requirements of various spinning frames. Power consumed by the shafting is not noted because of the defect mentioned, which made an accurate determination impossible. It would be an important item to know both in order to judge whether the amount of power so used was excessive and also to determine, at least roughly, the amount of power lost per frame because of the method of driving, which value would serve as a basis of comparison with individually driven frames.

It is generally preferable to include losses in motor and shafting when determining the power requirements of a given installation, since thus all power which must be paid for—whether the power be generated or purchased—may be determined. The percentage of electric horse-power input to the motor corresponding to the motor efficiency will determine the power required by the driven machinery alone if that information is required. As may be inferred, electric horse-power input to the motor is the standard unit adopted for power in the series of test records of which this forms one.

The load-factor or percentage of time machinery was in use during the test is important. It is derived with fair accuracy by dividing the number of frames in use at each five-minute interval by the total number of frames. The load-factor proper for spinning frames may be taken from published figures or calculated for a given set of conditions and a comparison with the observed amount shows how fully machinery is being utilised. Special conditions contribute to a low factor in the test shown and we find noted : (1) Several machines under repair, (2) lack of oversight, (3) lack of raw material. Load factor is of value not only as indicating the efficiency at which a department is being operated, but also as indicating whether the load on the motor may not be increased by a more intensive utilisation of the connected machinery. In connection with other tests it indicates the normal percentage of use of intermittently operated machinery, a figure of use when determining motor sizes for extensions and changes.

Important information, not otherwise discoverable, may be noted during a test owing to any abnormal condition being

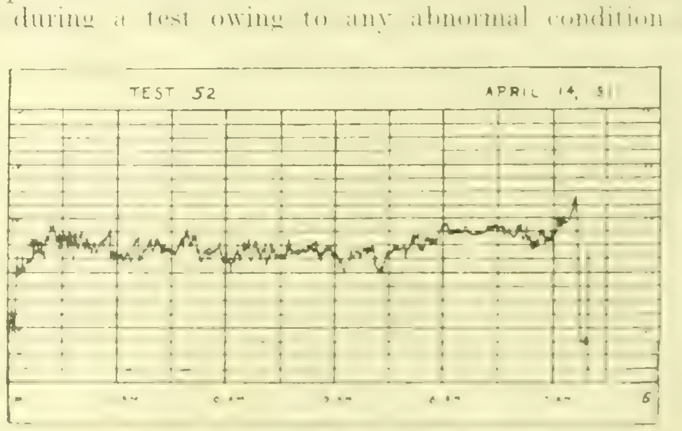


FIG. 3.—RECORDING WATTMETER CHART

immediately indicated by the meters, whereby investigation may be made at the time when the cause is most evident. Defects not suspected may thus be brought to notice. The recording wattmeter chart, shown as Fig. 3, is a most valuable portion of the test record. While it is true that meters may and do have inherent faults and weaknesses, they are, on the other hand, far more accurate and reliable than human observers. Thus they serve to check the results obtained by observation. A further check is afforded by the use of a watt-hour meter, though it was not availed of for this test.

Test records may have a value for future reference exceeding their immediate use. Tests such as described may be considered

as standards of reference to be supplemented by simpler tests from time to time. Their value depends largely upon the ability of the tester and his recognition and record of important facts concerning the motor-driven machinery and general conditions. Familiarity with the uses and peculiarities of meters is always desirable and often essential. Curves drawn by recording meters vary according to the characteristics and adjustment of the meter and may be misleading. Accuracy of the meters may, and should, be assured by frequent checking and calibration. Errors due to improper use must be guarded against by the tester.

Having made tests to serve as standards, other simpler forms of testing may be employed to note variations and, in particular, to note a falling off in manufacturing efficiency due to defects in machinery or labour. A very excellent method of continuous testing is found in the use of a recording meter, which may be connected to various circuits in rotation and serve to show variations, which, if sufficiently marked, may be further investigated. This method may not be fully and economically available in an installation comprising a large number of small motors and may be supplemented by readings taken on the various motors with an indicating wattmeter or ammeter. For rapid work of this kind an ammeter is far more convenient than a wattmeter and serves to show variations quite as accurately. Defects in individually driven machines may be located when an inspection of the machine discloses nothing wrong.

Electrical meters are of value for other forms of testing. The actions and operation of particular machines may be analysed and the structure and design requiring least power determined. The effect of variations may be studied with accurate results—that of dynamometer testing is in practice difficult and costly. Misconceptions exist regarding the actions of machines in common use. A case may be cited in the spinning frame, familiar to all cotton mill men. Roughly quantitative tests show that power supposed to be consumed by the weight and motion of various parts is due to the resistance of the air to the motion of the product—yarn—through it. In an ordinary case air resistance absorbs an average of 10 per cent. and a maximum of 20 per cent. of the total power required, these figures being conservative.

These amounts are hardly negligible and yet they are only coming into general knowledge among spinners through tests made by electricians. It may be noted in passing that exact tests on spinning frames demand a regulation of conditions very difficult to obtain, and that the difficulty of obtaining exact results is added to by the large number of bearing surfaces, the frictional resistance of which decreases for some time after starting. The variations occurring can, however, be followed more closely with the aid of electrical meters than in any other manner.

Another type of meter deserves mention, although it may be considered electrical only in that it employs electricity to overcome a mechanical difficulty. The meter comprises a drum driven by suitable clockwork and carrying a paper chart (ruled to correspond with time) on which one or more pens rest and draw a line or lines which are interrupted or changed in position by the action of electro-magnets in unison with the starting and stopping of a particular machine or machines. The meter will, therefore, indicate during what times the machines connected to it were in use. Obviously, it might have been employed in the test outlined above to have relieved the tester of a part of his observations and have given a more accurate result. Its value is considerable in the case of certain intermittently operated machinery, such, for example, as looms, pickers, or spinning frames in a textile plant. It would be of more utility than a recording wattmeter placed in the foreman's office and connected by him to different machines in turn—a plan which has been suggested as a feasible one.

Although tests may be made to determine the conditions under which a motor is being operated, it should be remembered that the motor is entirely secondary to the driven machinery. It is only the means by which power is applied where needed. While it is important and essential to know if the motor is being operated and is operating properly, the economically important facts deduced from tests concern the driven machinery. When only a limited range of information is called for the tester must judge whether further information, necessarily acquired, shall be reported and to whom. At the present time it is rare that the full inherent value of electric-motor testing is recognised or utilised.

LOCOMOTIVE BOILER CORROSION AND TREATED WATER.*

BY J. R. FRANCIS, CHEMIST, C.C.C. AND ST. L. RY.

DURING the fall of 1908, the writer at that time being in charge of the chemical work for the company, locomotive boiler corrosion of a serious nature developed on the Peoria and Eastern division of the Big Four Road. The division referred to, as relates to engine service, was divided at Indianapolis, "West End" engines working between Indianapolis and Peoria (Ill.), and "East End" engines between Indianapolis and Springfield (Ohio), except during unusually busy periods, when engines were occasionally transferred for several runs from one district to the other; engines from both districts, however, running into Moorefield roundhouse at Indianapolis, and taking water before leaving Indianapolis on their runs from the Moorefield water softener. The latter was a standard Davidson type continuous system machine, using lime and soda ash in the usual manner. The water softener referred to had been in continuous service 10 months prior to the first evidence of corrosion troubles, and had served as the exclusive water supply for the yard engines working in Moorefield yards, the stationary boilers at Moorefield shops and roundhouse, and the road engines, as before stated.

The first evidence of corrosion in boilers of road engines was reported under date of October 8th, 1908, in the case of freight engine 6,169 on the "East End" giving up her train on account of a bursted flue, which, upon examination, together with entire set of flues, revealed a bad case of pitting and corrosion. Following this experience, in rapid succession, and extending over a period of several months, engine failures due to pitted flues were frequent, a total of 3,335 flues being scrapped in 1909, and 1,069 in 1910. At about the time of the first case in question, the general foreman of the Moorefield shops and roundhouse reported that an occasional nipple or elbow in the feed pipes of the stationary boiler plant, between the feed water heater and the boilers, had to be removed on account of being honeycombed by pitting, and that this trouble had developed after the installation of the water softener, the pipes previous to the installation of the latter becoming limed up badly from time to time.

Within a short time after this report, yard engine 6,522, which had been in service at Moorefield yards and using treated water from Moorefield water softener exclusively, was taken to the division shops at Urbana, Ill., where, upon being overhauled, it was found that the entire set of flues were pitted so badly that they had to be scrapped. In the light of the above-mentioned cases, namely, road engines failing on account of pitted flues, nipple and elbows in the feed water line of the stationary boiler plant pitting, and a yard engine turning up with an entire set of flues useless on account of pitting, it is not surprising that suspicion pointed, as the treated (softened) water had been used exclusively or in part, toward the water softener; in fact, it was the only new or unusual thing to be found in connection with the water service.

Upon investigation, by a process of elimination as it were, it was found that the stationary boilers of the Moorefield plant were in excellent condition, with no evidence whatever of any pitting or corrosion; that the yard engine in question had been in service at another point where a hard water had been used before coming to the Moorefield yards, and that the road engines affected were confined to those which were in service exclusively or most of the time on the "East End." Samples of boiler waters from all engines coming into Moorefield roundhouse were then called for, with the object of noting by chemical examination what difference, if any, existed in the condition of concentrated waters of "East End" boilers as compared with "West End" boilers. These samples were drawn at the water gauge in a bucket, allowed to cool, bottled, tagged as to number of engine, East End or West End, dated, and forwarded to the laboratory for examination. At the laboratory the examination was conducted as follows:—

One hundred c.c. of the sample was titrated with phenolphthalein indicator and normal ten hydrochloric acid, the number of c.c. of acid required being noted and the titration completed with a methyl orange indicator; the number of c.c. of additional acid required with this indicator being noted,

* Paper prepared at the request of the committee on water service of the American Railway Engineering Association, and submitted at the annual meeting of the Association, in Chicago, March 19th to 21st, 1912.

and also the total number of c.c. of acid required with both indicators. For the purpose of explanation, we will call this operation the "first step." Another 100 c.c. of the sample was then taken, and 30 c.c. of a 10 per cent. solution of barium chloride added, with phenolpthalein indicator, and the mixture titrated with normal ten hydrochloric acid, the number of c.c. of acid required being noted and set down as the "phenolpthalein titration of the second step."

In arriving at results from the above, the following procedure was observed. If the acid required with the phenolpthalein indicator in the first step exceeded that required by methyl orange, the difference was charged to hydrates and reported in equivalents as sodium hydrate. The amount of acid required with phenolpthalein indicator in the second step was compared with the amount required with phenolpthalein indicator in the first step. If less, the difference was multiplied by two and charged to alkaline carbonates and reported in equivalents as sodium carbonate. The total acid required by sodium hydrate and sodium carbonate was then deducted

Boiler Waters, East End Passenger Engines.

(Corrosion occurring.)

(Note absence of Sodium Hydrate in appreciable quantity, and presence of Sodium Carbonate and Bi-Carbonate.)

Parts per 100,000.

Date.	Engine Number.	Sodium Carbonate.	Sodium Bi-Carbonate.	Sodium Hydrate.	Calcium Carbonate.	Chlorine.
October 30, 1908	7077	2·12	—	0·80	6·00	27·00
October 30, 1908	7113	2·12	0·84	—	8·00	30·80
October 30, 1908	7071	2·12	—	0·40	8·00	43·00
Nov. 2, 1908	7071	4·24	4·20	—	2·00	35·80

Boiler Waters, East End Freight Engines.

(Corrosion occurring.)

(Note absence of Sodium Hydrate and pressure of Sodium Carbonate and Sodium Bi-Carbonate.)

Parts per 100,000.

Date.	Engine Number.	Sodium Carbonate.	Sodium Bi-Carbonate.	Sodium Hydrate.	Calcium Carbonate.	Chlorine.
October 31, 1908	6595	2·12	3·36	—	1·00	24·20
Nov. 2, 1908 ..	6577	2·12	2·52	—	5·00	16·60
Nov. 24, 1908 ..	6571	4·24	1·68	—	5·00	35·20
Nov. 24, 1908 ..	6586	5·30	2·52	—	3·00	28·00
Nov. 24, 1908 ..	6597	4·24	2·52	—	2·00	29·80

from the total acid required by both phenolpthalein and methyl orange indicators (the total alkalinity), and the difference, if any, charged to alkaline earth carbonates and reported in equivalents as calcium carbonate.

In case the acid required with methyl orange in the first step was greater than that required with phenolpthalein, the difference was charged to bicarbonates and reported in equivalents as sodium bicarbonate. The second step was then conducted the same as before, the sum of the sodium bicarbonate and carbonate subtracted from the total alkalinity, and the difference charged to alkaline earth carbonates and, as before, reported as calcium carbonate. The use of hydrochloric acid instead of sulphuric acid in the titration is obvious, on account of the use of barium chloride.

By way of comment on the above procedure, no claim is made for scientific accuracy, because the steps, as outlined, are not absolutely accurate. They are, however, sufficiently so to serve the purpose to which they were put, and reference for explanation in detail will be found in "Sutton's Volumetric Analysis," under "Titration of Alkaline Salts." Besides the above figures on the samples, we also titrated for the chlorine content with standard silver nitrate solution in the usual manner, save that we first carefully neutralised the sample with nitric acid. The accompanying tabulations are transcripts of results of laboratory examinations as per above, of a few boiler water samples.

It will be noted that the average chlorine content of all waters on the East End is about 1·39 parts per 100,000, and that they do not vary a great deal. Comparing this average figure with the chlorine content of East End freight engine No. 6,571 boiler water, reported above as having a chlorine content of 35·2 parts per 100,000, we note a concentration of about 25 times.

Attention is called to this observation for the reason that where the chlorine content of water supplies within a district are approximately the same, by comparing the average figure with that found in concentrated boiler water samples, a figure is obtained which serves as an index to the concentration of the boiler water, and may be used to check up engine crews working under instructions as to blowing down of boilers, and to check up roundhouse practice as to washing boilers, changing water, &c.

Technical Analyses, Water Supplies, East End.

Station No. 1.—Moorefield treated water. Total hardness averaging less than 5 grains per gallon to standard soap solution. Total causticity averaging about 3 grains per gallon. Sodium chloride average, 3·13 grains per gallon.

—	No. 2. Fairbanks, Ind.	No. 3. Maxwell, Ind.	No. 4. New Castle, Ind.	No. 5. Lynn, Ind.	No. 6. Arcanum, Ohio.	No. 7. Troy, Ohio.	No. 8. Durbin, Ohio.
	Water Stations. Grains, U.S. Gallon.						
Total Solids	25·62	21·93	23·94	22·68	38·73	22·77	29·01
Volatile	2·34	1·16	·20	3·52	3·68	2·05	2·15
Fixed Solids	23·28	20·77	23·74	19·16	35·08	20·72	26·86
Incrusting Solids......	22·08	19·39	22·14	18·38	32·93	20·07	25·26
Non-Incrusting Solids..	1·20	1·38	1·60	·78	2·12	·65	1·60
Composition of Incrusting Solids, Hypothetical Combinations :							
Silica	·54	1·08	1·35	·60	·99	·69	·81
Iron Oxide and Alumina	·12	·51	·24	·12	·15	·12	·12
Calcium Carbonate ..	13·50	11·74	13·43	11·03	19·00	10·80	14·93
Calcium Sulphate ..	2·37	—	—	—	—	—	—
Magnesium Carbonate	—	6·06	7·12	3·36	2·95	4·26	4·63
Magnesium Sulphate	5·55	—	—	3·27	9·47	3·91	4·77
Magnesium Chloride	—	—	—	—	·37	·29	—
Composition of Non-Incrusting Solids, Hypothetical Combinations							
Sodium Chloride	1·20	·98	·99	·78	2·12	·65	1·60
Sodium Sulphate ..	—	·40	·61	—	—	—	—
Total Sulphuric Anhydride	5·15	·29	·34	2·25	6·31	2·61	3·19

Station No. 9. Springfield, Ohio, treated water, averaging same as Sample No. 1. Machine Standard American Continuous System. Sodium Chloride average, 1·00 grain per gallon.

Concerning the general character of the water supplies of the East End, reported in the analyses above, as relates to the corrosion experienced, it will be noted that none of them is "acid water." On the contrary, they are so-called alkaline waters, and two are treated waters, showing, as a result of treatment, a slight causticity. Ordinarily one would not expect to find corrosion following the use of such waters, and with corrosion occurring, as it did, with their use, it is quite a temptation to theorise as to the exact cause of the corrosion. By way of comment it may be stated that upon chemical examination of corroded or pitted spots of sections of affected flues, taken while yet moist and before samples had had time to become oxidised, the content of such pitted vesicles contained, according to qualitative analysis, ferrous ion and sulphuric anhydride, while on surfaces of other portions of the sections, alkaline earth carbonates were in evidence, most of the pitted and corroded spots on the cleaner flues being universally on the under or lower side.

In searching for a cause for the corrosion, no attention was paid to the composition of the flues in use, further than to establish the fact that the flues in service on this division were no different from flues furnished other divisions of the company where no trouble was being experienced in the use of mixed, treated and untreated, waters.

Attention should be called to the fact, however, that many of the flues affected (not all of them) had been in use some

time prior to the installation of water softeners at each end of the district, and as a consequence were heavily covered with hard scale, the worst corrosion, when appearing in the form of blisters, in contradistinction to pitted points, occurring in its most active form immediately under the edge of adherent scale. An analysis of a sample of scale, showing :—

	Per cent.
Silica	1·48
Ferric oxide	17·47
Calcium carbonate	9·32
Calcium sulphate	65·92
Magnesium oxide	5·62
Ferrous ion	Trace
	99·81

Considering the ferrous ion and sulphuric anhydride found by qualitative analysis of contents of pitted vesicles, as mentioned, one might theorise that the sulphates of the alkaline earths had been broken down under the influence of carbon of organic matter, high heat, pressure, &c., but in the examination of the water supplies no organic matter in appreciable quantity was found. Passing by the exact cause of the corrosion, since, under the conditions under which it took place, any explanation would of necessity be hypothetical in its details, the remedy for counteracting and stopping the trouble was based on the information obtained in the chemical examination of the boiler waters of West End engines as compared to those of the East End. The West End boilers giving

Boiler Waters, East End Passenger Engines.
(No corrosion occurring at this time.)

Date.	Engine Number.	Sodium Carbonate.	Sodium Bi-Carbonate.	Sodium Hydrate.	Calcium Carbonate.	Chlorine.
August 12, 1909	7071	3·8	—	4·40	1·00	16·0
Sept. 3, 1909 ..	7081	2·12	—	2·80	—	13·0

Boiler Waters, East End Freight Engines.
During treatment of waters at Arcanum (Ohio), and Troy (Ohio), as mentioned.
Parts per 100,000. Total of 59 samples.

Date.	Engine Number.	Sodium Carbonate.	Sodium Bi-Carbonate.	Sodium Hydrate.	Calcium Carbonate.	Chlorine.
July, 1909......	Total	40 Samples From 0·85 to 7·42		5 Samples None 35 Samples 0·16 to 8·40		40 Samples 3·00 to 25·40
		Av of 5·43		Av. 2·81		Av 14·24
		19 Samples From 2·12 to 9·54	19 Samples From 0·84 to 6·72			19 Samples From 12·00 to 17·20
		Av. of 5·43	Av. of 2·92			Av. of 14·92

no trouble and being quite caustic in comparison, it was concluded that if East End boilers had caustic in some form added by the injection of the same into the raw water supplies, thereby keeping the East End boilers slightly caustic due to "hydrates," that the trouble, pending the installation of additional standard water softeners, would cease.

This recommendation accordingly went out from the laboratory in December, 1908, and again in January, 1909, but on account of diversity of opinion as to the cause of the corrosion, some of the official staff believing that the Moorefield treated water was causing the trouble, the use of the caustic was not begun until March 5th, 1909. On this date the use of caustic soda at the Arcanum (Ohio) water station was commenced, 9 grains per gallon, in the form of solution, being injected into the delivery line from the large pump discharging into the wayside tank. The apparatus used consisted of a boiler feed pump having a plunger $1\frac{1}{4}$in. diam. which was attached to the large pump in such manner that it had a stroke of 3in. with each stroke of the large pump. This small pump was connected to an iron tank having a capacity of about 200 gals., in which the caustic soda solution was diluted to the desired strength, and discharged into the discharge line of the large pump. It is advantageous to have the line from the small pump enter the discharge line of the large pump as near the tank as possible, on account of the gradual deposit in the pipe occasioned by the interaction of the caustic soda with chemical salts in solution in the raw water.

Boiler Waters, West End Passenger Engines.
(No corrosion occurring.)
Parts per 100,000.

Date.	Engine Number.	Sodium Carbonate.	Sodium Bi-Carbonate.	Sodium Hydrate.	Calcium Carbonate.	Chlorine.
October 28, 1908	7072	19·08	—	14·00	2·00	16·40
October 28, 1908	6159	21·20	—	18·80	3·00	24·00
October 29, 1908	7080	19·08	—	14·60	0·00	18·20
October 30, 1908	7115	15·60	—	7·60	6·00	16·40

Boiler Waters, West End Freight Engines.
(No corrosion occurring.)
Parts per 100,000.

Date.	Engine Number.	Sodium Carbonate.	Sodium Bi-Carbonate.	Sodium Hydrate.	Calcium Carbonate.	Chlorine.
October 28, 1908	6591	3·18	—	1·20	9·00	30·20
October 29, 1908	6584	4·24	—	1·60	5·00	19·80
Nov. 24, 1908 ..	6589	5·30	–	4·00	2·00	26·00

On May 1st, 1909, a similar outfit was put in operation at the Troy (Ohio) water station, and four grains per gallon of caustic soda were used there. Following these installations at the stations named, a passenger engine which had been overhauled at the shops and given an entire new set of flues, was caused to double the district until 28,000 miles had been made, when several flues were removed for examination. These were found to be without any evidence of pitting or corrosion.

During the treatment of these waters, as mentioned above, namely, nine grains per gallon of caustic soda at Arcanum and four grains per gallon of the same at Troy, the boiler water samples titrated as is indicated in the accompanying tabulation for East End passenger engines.

It is proper to explain that the passenger engines on the East End, on their runs east, took water at the Moorefield water softener, New Castle (Ind.), Arcanum (Ohio); and, going west, at the Springfield (Ohio) water softener, Troy (Ohio), and Lynn (Ind.). This being true, they received a larger amount of caustic soda in proportion to the total amount of water used than did freight engines, which used water from all water stations.

It will be noted that out of 59 samples, 35, or about 59 per cent., of them showed presence of sodium carbonate and sodium hydrate. Five of them, or approximately 8 per cent., showed sodium carbonate, but no sodium hydrate. And that 19 samples, or about 33 per cent., showed sodium carbonate and sodium bicarbonate.

It was believed at this time, by reason of the fewer engine failures on account of flues, that under this treatment the corrosion was under control. This assumption, however, was likely not true, as it afterwards was demonstrated that the corrosion did not entirely stop until a causticity due to "hydrates" was maintained practically all of the time.

The treatment of the waters at Arcanum and Troy, in the proportions already stated, was continued until November 1st, 1909, when it was reduced one-half, on account of complaint on the part of enginemen that the treatment of the water was causing foaming. It developed later, however, that the greater part of these complaints was occasioned by an effort on the part of the enginemen to protect one of their number who had carelessly allowed the water to run low in a boiler and burned a crown sheet. This reduction in treatment lowered the percentage of boiler water samples, showing the presence of

sodium hydrate so much that the majority of the samples indicated the presence of sodium bicarbonate instead.

Within four months after the reduction in the treatment several engine failures on account of pitted flues again occurred, and on this account the treatment of the waters at Arcanum and Troy was increased on June 10th, 1910, to the figures as at first used, following which a systematic patrol of the district by the road foreman of engines quieted the complaints on the part of enginemen concerning foaming, it being very clearly demonstrated that these complaints had been greatly exaggerated. Sampling and examination in the laboratory of boiler waters was continued as before, the object being to raise the causticity due to sodium hydrate until all boiler samples showed the presence of at least a slight amount.

This feature was not finally accomplished until a third caustic soda treating station was established at the Maxwell (Ind.) water station, August 12th, 1910, where two grains per gallon were injected into raw water supply. With this additional installation in operation no more trouble was experienced as to samples of boiler waters failing to show the presence of sodium hydrate in appreciable quantities. This point for the third installation was selected by reason only of its distance from the other installations. The daily sampling of locomotive boiler waters and chemical examination, as described, was continued for seven months, during which time more than 90 per cent. of all samples showed the presence of two to 15 parts per 100,000 of sodium hydrate, along with about an equal amount of sodium carbonate.

Under this treatment the corrosion entirely ceased and no more trouble on this account was experienced, neither was there any more complaint of moment on the part of engine crews of foaming boilers, the enginemen apparently having learned better how to handle the boilers under the treatment. It is also worthy of note that under this treatment the boilers became and remained clean and practically free from scale.

To recapitulate, it is desired to call attention to the fact that between November 1st, 1909, and June 10th, 1910, when the treatment was reduced, with corrosion reoccurring as already stated, that the freight engine boiler waters did not show the presence of sodium hydrates in appreciable amounts with any regularity. They did, however, show the presence of small quantities of sodium carbonate and bicarbonate. It is desired to emphasize this point because of the fact that only after a sufficient quantity of caustic soda had been added to show an appreciable amount in the concentrated boiler waters, did we succeed in stopping the corrosion.

It is also worthy of note that, in the use of the caustic soda, we at no time used an amount so large as the equivalent of the half-bound carbonic acid of the alkaline earth bicarbonates in the waters naturally. Therefore it must have followed that the caustic soda so used, when injected into the raw waters, became sodium carbonate, and that it was finally hydrolised within the boiler and partially reconverted into "hydrate."

The question naturally arises at this point why sodium carbonate (soda ash) would not have done just as well as sodium hydrate, since it is obvious that the latter when added to the raw water first became sodium carbonate and afterwards was in part reconverted by hydrolysis into "hydrate." In our opinion this probably would have been the case, since it is clear that sodium carbonate and sodium bicarbonate are partially hydrolised within a boiler. This point is again clearly brought out by reference above to the titration of West End boiler water samples from passenger engines. These samples, showing from seven to 18 parts per 100,000 of sodium hydrate, along with a slightly larger amount of sodium carbonate, and being accounted for only by the fact that, in addition to the treated water taken at the Moorefield shops, two raw waters on the West End carry sodium bicarbonate naturally, one of them about four parts per 100,000 and the other eight parts per 100,000, the presence of the sodium hydrate occurring on account of the partial hydrolysis of the same within the boiler during concentration.

In our opinion, the features worthy of note concerning the above experience consist in part of the troubles which may follow the installation of standard water softening or treating apparatus where all of the waters within a district are not treated; also, in the importance of chemical laboratory examination and control of boiler waters, where corrosion, as described, is being experienced, the features of such control aiming to maintain within the boilers a causticity due to the presence of "hydrates" in an appreciable amount, and that whether sodium hydrate or soda ash be used, that it be used in sufficient quantity and so distributed that boiler water samples upon chemical examination show an appreciable amount of causticity due to "hydrates." This plan, in our opinion, ensures a sufficient treatment to counteract the "permanent hardness" of all waters used, therefore controlling ordinary corrosion troubles, and, doing so without using an undue excess of reagent, thereby guards against any unnecessary aggravation of foaming troubles, due specifically to excessive treatment.

INDUSTRIAL AND TRADE NOTES.

French Railways.—The total length of line in operation in France at the close of 1911 was 37,016 miles, of which 708 miles were brought into working last year.

United States Rail Production in 1911.—According to statistics prepared by the American Iron and Steel Association, the total rail production in the United States during 1911 was 2,822,790 tons, as compared with 3,636,031 tons in 1910, a decrease of 813,241 tons, or over 22 per cent. Of the 1911 production, 1,138,633 tons were made by the Bessemer process, and 1,676,923 tons by the open hearth process.

Welsh Tinplate Trade.—At the annual joint conference held on the 22nd inst. at Swansea of the masters and men engaged in the South Wales tinplate trade, which employs 28,000 people, several minor claims were arranged, but in view of the stoppage through the coal strike, the general claim for 10 per cent. increase was not pressed, on the understanding that the men could raise the matter any time during the year on giving notice.

A Large Crane.—A large travelling crane has just been completed by Messrs. Cowan, Sheldon, & Co., Carlisle, for a foreign dock yard. A feature of the crane is that it lifts its maximum load at the large radius of 125ft. and travels with it suspended at that radius. The height from the ground level to the top of the jib is 170ft. The primary use of the crane is for placing armour and fittings on battle ships.

Automatic Telephony.—The automatic telephone system at Epsom came into operation a few days ago. This is the first public experiment with the automatic telephone in the British Isles. The Strowger Automatic System is the one adopted, and is of American origin. Under it the meter does not record a charge against the person telephoning until the required subscriber has answered. The new system will shortly be installed also at Caterham and for the Government departments.

Apprentice Engineers' Institute.—The Clyde Model Engineering and Electrical Institute was formed on May 13th with the object of assisting apprentice engineers to develop their ideas as mechanics by providing them with a suitable workshop equipped with modern machinery. The rent of premises and the initial cost of the plant is estimated about £140. This sum, it is expected, will be realised by donations from local engineers and ship builders added to the members' subscriptions. The scheme, it is anticipated, will be in operation about the beginning of August.

Humphrey Pump at Wapping.—For the purpose of experiment and demonstration the Hydraulic Engineering Company, of Palace Chambers, Westminster, have installed at the pumping station of the London Hydraulic Power Company, Wapping, a Humphrey pump of the 4 cycle type, which is being run with town gas. The pump has a 21in. barrel and a play pipe 15in. diam. The lift is 25ft., and the discharge 1,950 galls. per minute. The rate of working is about 13 cycles per minute. The builders will be glad to show the pump in operation to those interested.

Mining and Smelting Plant in New Zealand.—It appears that steps are being taken to develop the Onakaka iron field at Golden Bay, Nelson, New Zealand, which is estimated to contain considerably over 22,500,000 tons of iron ore of first class quality. It is intended to erect blastfurnaces, at a cost of from £75,000 to £80,000, for the manufacture of pig iron. The property is situated on the coast at a point where, it is stated, the largest vessels can lie close in, and the elevation of the nature will allow ordinary quarrying, and transport by gravitation to furnaces and wharves. Coal and lime are, it is stated, also found in close proximity.

Railway Electrification in Australia.—The Agent-General for Victoria is asking for tenders for certain plant in connection with the electrification of the Melbourne Suburban Railways. This plant includes turbo-alternators and transformers, sub-station equipment, electrical equipment of coaches, boilers and boiler house equipment, and condensing plant. The consulting engineers are Messrs. Merz & McLellan, 28, Victoria Street, West

minster, S.W. Tenders are to be delivered not later than June 4th, 1912 to the Agent General for Victoria, Melbourne Place, Strand, W.C., from whom specifications and forms of tender may be obtained.

Oil-driven Cargo Vessel.—There was launched a few days ago by Messrs. Raylton, Dixon, & Co., Middlesbrough, the "Eveston," the first ocean-going cargo vessel built in this country with a single-screw Diesel engine. The vessel has a gross tonnage of 3,150 tons, with a deadweight capacity of about 3,100 tons. Her propelling machinery is designed to give her a speed of about 10 knots, and consists of a Carels-Westgarth 2-stroke marine Diesel engine of 1,000 h.p., built by Messrs. Richardsons, Westgarth, & Co., and having four cylinders 20in. diam. with a stroke of 36in. Steam from two large donkey boilers is used for the steering gear and cargo-handling machinery. The same builders have just completed a sister ship driven by ordinary reciprocating steam engines, and a comparison of the working results obtained from the two vessels on service should yield valuable information. The fuel consumption of the oil propelled vessel is calculated at four tons a day, and that of the steam driven one at 15 tons a day. Therefore for a voyage of 30 days the latter must carry 450 tons of coal, while the former needs only 120 tons of oil, and thus can take 330 tons more cargo. The weight of her machinery is also 68 tons less.

The Miners' Federation and the Working of the Minimum Wage Act.—As was generally anticipated, the decisions of some of the Wages Boards appointed under the Minimum Wage Act are not meeting with the approval of the miners, and at a meeting of the Federation, held in London on the 22nd inst. to consider the matter, the following resolution, as drawn up and recommended by the Executive Committee, was submitted and carried: "This conference, having received the report of the work done by the various district boards where decisions have been given under the Minimum Wage Act, regrets, notwithstanding the many declarations of the Prime Minister and his colleagues that the least minimum rate of wages to be paid for adult underground workers should be a reasonable living wage, we have a number of awards which fix the minimum wage for underground adult workers at less than a reasonable living wage, and also that in some cases chairmen have refused to take into consideration the average wage earned by piece workers when defining the action of Section 2, par. 2, of the Minimum Wage Act. This conference hereby records its strongest protest against these awards, and calls upon the Government to take such immediate action as will remedy the defects complained of. The conference instructs the Executive Committee to ask for an interview with the Government, and that a further conference be held without delay to receive the report of the deputation." It was then left to the Executive Committee to fix the date of the next meeting.

Reduction in Postal, Telegraph, and Cable Rates.—The Postmaster-General, in his estimates submitted to the House of Commons a few days ago, presented some interesting information respecting the work of his department. He stated that the Government contemplated making a tube railway of their own running east and west to carry mails and parcels. Within the next few weeks he hoped to reduce the postage rates for parcels sent abroad. The telegraph business had received a great deal of attention, and many reforms and improvements had been effected. He proposed to introduce shortly two reforms one consisting of night telegrams at very cheap rates dispatched during the night when the wires were not busy. It would come into force on June 1st. The other reform was an extension of the time for the issue of reply telegraph forms from 2 to 12 months. Mr. Samuel also referred to the reduction which had been made in the cable rates and to the proposed wireless telegraph system linking up the whole of the Colonies. He was also contemplating the establishment of a triple rate system between this country and the Continent, as at present British business men were at some disadvantage compared with their competitors on the Continent, where the system was in operation. He hoped, also, to reduce the charge for telephone communication to Paris, and, in the course of time, that good communication would be secured between London and Berlin. The trunk telephone system had, he said, made enormous progress during the past few years, and he proposed to spend nearly £1,000,000 during the current year on further work, including an underground programme. On the whole telephone system he proposed to spend £2,600,000, and felt sure that the revenue and the trade would respond to this increased expenditure.

Railway Accidents and Casualties.—The Board of Trade has just issued a blue-book containing a summary of accidents and casualties on the railways in the United Kingdom during the three months ended December 31st, 1911. The number of persons killed and injured in the course of public traffic was 285 and 2,261 respectively, as compared with 284 and 2,279 in the corresponding period of 1910. Including accidents in which no personal injury was sustained there were reported five collisions between passenger trains or parts of passenger trains, 16 collisions between passenger trains and goods or mineral trains, light engines, &c.; 17 collisions between goods trains, parts of goods trains, light engines, &c.; two collisions between trains and vehicles standing foul of the line, nine collisions between trains and buffer stops or vehicles standing against buffer stops, of which three were caused by trains running into stations or sidings at too high a speed, and six were due to other causes; three cases of trains coming in contact with projections from other trains on parallel lines, 12 cases of passenger trains or parts of passenger trains leaving the rails, 58 cases of goods trains or parts of goods trains or light engines leaving the rails, 86 cases of trains running through gates at level crossings or other obstructions, and 20 cases of fires in trains or vehicles.

Shipyard Wages.—A conference between representatives of the Shipbuilding Employers' Federation and the Shipyard Trade Unions met in Edinburgh on the 22nd inst. to consider various matters of importance to the men engaged in the industry. The outstanding result of the day's negotiations was that the shipyard trades will, subject to a recommendation being accepted, receive another advance of wages three months hence. This of itself is evidence of the continued prosperity of the shipbuilding trade, remembering that two advances were granted last year one in the spring and the other in the autumn. The official report to the Press, given by the joint secretaries of the Federation, was as follows: "In the terms of our agreement, the general position was discussed with respect to the wages question. There was an agreement arrived at to mutually recommend our respective constituents that an advance of 5 per cent. on piece-work and one shilling per week, or a farthing per hour, where payment is made by the hour, come into force three months from this day. An application for a special advance of 1 per cent. on behalf of riveters was declined. An application for a reduction of working hours to 48 per week was discussed, and the employers intimated that they could not entertain it. The application of Clyde sawmillers was further considered, and a former offer by the employers was renewed, but the workmen's representatives said they were unable to recommend its acceptance. So far as this latter question is concerned, the machinery under the National Agreement is exhausted."

THE PROPULSION OF SHIPS.

At a recent meeting at the Institute of Naval Architects, Mr. A. E. L. Chorlton, of Messrs. Mather & Platt, Ltd., dealt with some of the questions that had been raised as to the utilisation of gas power for the propulsion of ships. One of the main difficulties, he said, consisted in finding an engineer who could design the whole plant and who had had the proper experience both with producers and engines. His own practical experience had been gained in connection with a set of 600 h.p., which was designed and built complete in every respect. The engine was a 3-crank 2-cycle engine with a cellular producer. The engine exhaust was used to raise steam in a donkey boiler for the auxiliaries. This steam was used with a small dynamo in order to drive the auxiliary plant electrically, so that the whole auxiliary power was obtained from the heat of the exhaust from the engine. Each part of the complete plant was designed by the same people, consequently each part bore the correct relation to the others. The trials indicated a number of difficulties, but they were all successfully overcome. Mr. Chorlton then proceeded to detail the minor difficulties to which he alluded—the reversibility and the ignition, and he explained the means by which they were overcome. To-day ignition presented no difficulty and gas engines would reverse as well as any other engine. He emphasized the special features of the 2-cycle engine, and explained the great advantages of the new type over the 4-cycle engine which was at one time invariably used. To be able to reverse a marine engine rapidly, and to run slow, was, of course, essential. A gas engine, therefore, would have to fire at the first and every stroke at all speeds to fulfil these conditions. In that respect the 4-cycle engine was at a disadvantage, for the variation in the resistances of the gas and air passages at different speeds made it difficult to draw in accurate mixtures at all speeds, particularly slow ones, that would fire satisfactorily and with certainty. With 2-cycle engines the mixtures were invariable at any speed. His firm had installed 2-cycle engines for driving mills in which the engine was started against the load without a clutch. That was more difficult than in ship propulsion, because there was a dead weight to oppose and the first stroke had to begin to drive the mill. He expressed the opinion that too much attention was just now being given to the Diesel engine to the neglect of the gas engine. In view of the fact that our natural fuel was coal and not oil, it appeared foolish to neglect the engine which used such coal and to specialise in those that used oil, especially when the cost of coal was but 10s. per ton against 60s. or more for the oil; or, taking their thermal values, 3 to 1 in favour of coal.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1910.

Carburetting apparatus. Thornton. 20656.
Heating apparatus of the closed circuit type. James Carrington. 25415.
Carburetters for internal combustion engines. Hamilton. 25680.

1911.

Propulsion of sea going vessels. Fox & Zohrab. 5246.
Turbines. Corthésy. 10715.
Valves. Money. 10815.
Hydraulic or other high pressure piston valves. Shields. 10838.
Furnaces. Battle & Trolley. 10951.
Valve chest for steam, water, and air pressures. Curry. 10960.
Fuel feeding devices for furnaces. Hofmann. 10990.
Either side brakes for railway wagons. Turner. 11050.
Carburetting apparatus for internal combustion engines. Lindblom. 11167.
Dynamometers. Heenan & Froude, Ltd., and Harrison. 11267.
Fire bridges for boiler furnaces. Butterworth & Canlin. 11277.
Ball and roller bearings. Sankey. 11553.
Belt fasteners. Kerby. 11613.
Steam heating apparatus. Barty. 11618.
Internal-combustion engines. Saunderson & Kelly. 11629.
Apparatus for shaking ingot moulds. Mensing, Bruckmann, et Cie. 11838.
Safety speed-control apparatus for motors used for driving reciprocating devices. Eckmann & Wagner. 12436.
Valve motions for rock drills. Lake. 12440 and 12474.
Tooth gearing. Westinghouse. 12571.
Valves. Farrer. 13059.
Process and apparatus for treating melted metals, alloys, and steels. Baraduc-Muller. 13188.
Driving mechanism for motor road vehicles. Rowland, and Warne, Wright & Rowland, Ltd. 14313.
Tool-holders for rock-drilling machines. Ferguson & Rule. 15153.
Means for actuating the record drums of steam engine indicators. Graham. 15401.
Valve operating mechanism. British Thomson Houston Company. 15770.
Clutch, more particularly adapted for the hauling drums of coal cutting machines. Sutcliffe. 16981.
Pneumatically actuated percussive boring machines. Altenhoff. 17128.
Lifting jacks. Wilkins & Richards. 19153.
Carburetters for internal combustion engines. Soc. F. & G. Longuemare frères. 19247.
Apparatus for use in butt welding the ends of rails. Th. Goldschmidt. 19473.
Furnace and flues of internally fired boilers. Bean's Bunsen Smokeless Furnace Company, and Bean. 19790.
Anti breakage box and gear for loading coal. Sir W. G. Armstrong, Whitworth, & Co., and Wright. 20388.
Method and machines for making metal wheels. Knight. 20729.
Piston rings. Faudi & Smith. 21518.
Damper arrangements for Lancashire, Cornish, and dry back generators. Sugden. 21922.
Propelling mechanism for flying machines. Short, Short, and Short. 22675.
Wind motors and propellers. Mendez & Ypina. 23102.
Lubricator, with feeding valve actuated by the vibrations of the machine. Glass. 23107.
Carburetters. Smith & Smith. 23201.
Railway signalling apparatus. Hurst. 23345.
Fly wheels for explosion engines. Constantini. 23848.
Joints for railway rails. Weiezner & Laczay. 24633.
Coke ovens. Still. 24806.
Flying machines. Harrison. 25253.
Cranking device for explosion engines. Liddle. 25299.
Means for starting and pre-heating internal combustion engines using liquid fuel and high compression. Rabsilber. 25604.
Force feed lubricators. Green. 25610.
Automatic grinding machine for twist drills. Mayer. 26452.
Pneumatic supporting and feeding apparatus for rock drills. Rayner & Rayner. 26603.
Lubricators. Birkigt. 27042.
Two stroke cycle internal combustion engines. Kemp. 27137.
Flying machines. Von Willisch. 27405.
Atomisers or spraying devices. Babcock & Wilcox, Ltd. 27675.
Pistons. Patrick. 27776.
Machine for testing the hardness of metals. Guillery. 28045.
Furnaces. Oktassa. 29355.

1912.

Conveyers of the jigging type. Hinselmann. 362.
Horizontal coke ovens. Carl Still. 1458.
Valves for steam heating apparatus. Sawyer. 1977.
Rotary pumps. Foxlee. 2089.
Pipe cutters. Howe. 2556.
Means for discharging coal trucks. Sir W. G. Armstrong, Whitworth, & Co., Ridley, and Wright. 3053.
Furnace fronts. James Howden & Co., and Hume. 3293.
Exhaust silencers for internal combustion engines. Clarke. 3446.
Turbo driven rotary pump. Vereinigte Dampfturbinen Ges. 4076.
Dampers for the flues of steam boilers. Gordon. 4499.
Unidirectional flow steam engines. Maschinenbau Anstalt Humboldt. 4596.
Rotary internal combustion engines. Bourlon. 4764.
Rotary pumps. Abels & Luhulsen. 4788.
Water tube steam boilers. Todd. 5061.
Flying machines. Kitchen. 5282.
Machines for slotting and similarly treating metals. Wm. Muir and Co., and Melloy. 5379.

ELECTRICAL, 1911.

Hydraulically balanced electric lifts. Boddam. 8356.
High-tension electrical coils and the process of forming same. Milton. 10827.
Magneto ignition system for internal combustion engines. Milton. 10828.
Electrical apparatus for transmitting and receiving signals. Dawson & Buckham. 11019.
Machine for making electrically welded chains. Ryan. 11791.
Electrical switch devices, applicable to the wireless control of mines. Stille. 13648.
Electric heating and cooking devices. Ferranti, Ltd., and Field. 15889.
Ignition devices for internal-combustion engines. Benz & Co. Rheinische Gasmotoren Fabrik Akt. Ges. 16604.
Electrical influence machines. Clark. 17452.
Electric lamp holders. Lucas & Jenkins. 19182.
Electrical connecting apparatus operated from a distance. Betulander. 19553.
Electric measuring instruments. Brown. 20452.
Incandescent electric lamp and holder. Harvey. 23979.
Electric switch. Heilbrun. 24003.
Vapour devices for rectifying electric currents. Conrad. 27086.

1912.

Automatic safety switch for electric currents. Gruber & Fruhwirth. 579.
Electric furnaces for endothermic gas reactions. Grohmann. 919.
Alkaline electric accumulators. Dickson. 957.
Electric switch mechanism. Record. 1817.
Electric heaters for liquids. Bland & Simester. 1983.
Electrical switches. Crawford. 2896.
Regulation of direct and alternating current dynamos. Siemens Schuckertwerke Ges. 3924.
Direct current electricity meters. Korting and Mathieson Akt. Ges. 4535.
Stuffing boxes employed for packing and sealing the ends of electric cables in joint boxes. Stratton & Claremont. 4670.
Winding of the rotors of dynamos. Siemens Schuckertwerke Ges. 7571.

METAL QUOTATIONS.

TUESDAY, MAY 28TH.

Aluminium ingot	67/-	per cwt.
„ wire, according to sizes, &c. ......from	102/-	„
„ sheets „ „ ...... „	120/-	„
Antimony ...... £27 - - to	£28/-/-	per ton
Brass, rolled	8½d.	per lb.
„ tubes (brazed)	10⅝d.	„
„ „ (solid drawn)	9d.	„
„ „ wire	8½d.	„
Copper, Standard	£74 -/-	per ton.
Iron, Cleveland	53/10½	„
„ Scotch	59/10½	„
Lead, English	£17/-/-	„
„ Foreign (soft)	£16/8/9	„
Mica (in original cases), small	6d. to 2/-	per lb.
„ „ „ medium	2/6 to 4/-	„
„ „ „ large	4/6 to 8/6	„
Quicksilver	£8/5/-	per bottle
Silver	28 1/16d.	per oz.
Spelter	£25/15/-	per ton.
Tin, block	£200/10/-	„
Tin plates	14/9	„
Zinc sheets (Silesian)	£29/-/-	„
„ Stettin; Vieille Montagne	£29/7/6	„

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Mill Driving.

MILL driving in Lancashire, and to a less extent in Yorkshire and some other districts, is a matter of great interest outside as well as within engineering circles. Five years ago Lancashire was plunged into a series of discussions as to the relative merits of various methods of driving textile mills. The fiercest recriminations raged between the advocates of the existing reciprocating engine and rope drive and the supporters of electric driving, although the gas faction and the Diesel men somewhat vainly endeavoured to obtain a hearing for their claims. Two technical societies essayed to solve the problem and both burned their fingers. The first was the Bradford Engineering Society, which appointed a committee to investigate and report. The report was generally in favour of the existing method of driving from a reciprocating engine by ropes on to the various line shafts of the mill, but the report lost something in value because the electrical members of the committee refused to sign it and, instead, rather questioned the good faith of those who did. Whatever the merits or demerits of this dispute it was certainly most unfortunate from the point of view of those who wished sincerely to learn the true facts and to have an unbiased expert report upon them. The second attempt was made by the Institution of Electrical Engineers, which induced the Textile Institute to form a joint committee of investigation. That committee has recently been disbanded because it was found that millowners and millwrights objected to the constitution of the committee. No doubt the objection was in large part due to a natural disinclination to give away manufacturing and technical information. Still, there can be no doubt that the constitution of the committee was improper. It is not a right thing that a body of men who are seeking to carry a certain position should call a judicial enquiry and through their technical institution constitute themselves half of the jury and judicial bench. Such methods are repugnant to honest men.

The abandonment of the Textile Institute and Electrical Engineers committee fortunately does not mean the complete

cessation of all investigation and discussion of the problems of mill driving. At its autumn meeting the Textile Institute has arranged for papers on steam, electrical, gas, and oil methods of driving. Some criticism was called forth by the name of the author of the paper on steam installations, but it appears that this paper is not a defence of the existing system and that apparently no such paper has as yet been arranged. It is to be hoped that a competent defender will be found, as a trial with life itself at stake in which the accused was not defended would hardly seem desirable. The blame for the unfortunate bickerings which have marked these mill driving discussions of late does not rest wholly with the advocates of electrical and other new methods of driving. It is a perfectly natural and legitimate thing that these people should work for the success of their own methods, and they have made sufficient progress in the practical application of these methods, especially electric driving, to justify a careful review of the position. Such review may take the form of a discussion between rival advocates or it may take the form of an enquiry by a capable and unbiased committee. Of discussion there has already been a respectable amount and it has advanced the subject considerably during the last five years. Enquiries so far have failed, either one side or the other averring that the particular enquiry was prejudiced, and we seem to be thrown back once again on verbal discussions. We do not propose to review judicially the relative advantages of the various methods of driving now being advocated, but it may be helpful to briefly indicate the salient features of the present position.

The accepted method of driving a cotton spinning mill is by ropes from the fly pulley of a reciprocating engine to second motion pulleys on the line shafts of the mill. In the case of a weaving shed there is usually only one main second motion pulley and its line shaft drives a series of cross shafts by bevel gears. The advocates of gas and oil for the most part propose to replace the steam engine by an internal combustion engine, but not materially to alter the rope drive and the mill gearing. In some cases it is proposed to employ the engines simply to generate electricity and then to drive the mill on one or other of the electrical systems. One electrical system proposed merely requires the present steam engine to be replaced by a large electric motor, but this system has not received much support. Two electrical systems have received a good deal of support. One, usually called the group system, involves driving the several line shafts of the mill by separate motors, but not modifying seriously the mill gearing apart from the rope race. The other system comes as near to a separate motor for each individual machine as is practical. In connection with the electrical systems there is some discussion as to the type of generating plant and whether or not the advantages lie with a supply of current from outside. The problem of the source of supply is largely a matter of cost and of course no rigid rule can be laid down, but in general a mill can generate more cheaply than it can buy. Here, however, difficulties in raising capital may suggest an outside supply even at some little sacrifice in the cost for energy.

The defendant in the case is of course the reciprocating steam engine combined with the rope drive. Four lines of attack may be followed, viz., cost, quality of output, quantity of mill output, and convenience. On the question of cost there seems little doubt that the reciprocating engine can at least hold its own with the turbo-electric system, and before the recent advances in turbine economy were made there was certainly a marked advantage in favour of the existing arrangement. So far as cost is concerned the fiercest struggle will probably be with the gas engine. Cotton mill conditions in Lancashire are not favourable to the gas engine, but even so it can make a good showing on this point. The oil engine is generally in a less favourable position. As a matter of convenience the existing system is probably best off and the electrical system with outside supply in the next best position. Internal-combustion engines were formerly backward in this respect, but have progressed rapidly during the last year or two.

The real struggle, however, lies between the steam rope drive and the electrical drive and the issue turns mainly upon the question of output. The advocates of electricity claim that, especially if current is obtained from a turbine-driven generator, they obtain a steadier drive and that as a result a higher spinning or weaving speed can be adopted with resultant increased output, and that the quality of the product is better. The defendants of the accepted system deny the justice of these claims, and both sides can produce some evidence in support of their respective contentions. Nothing like sufficient evidence is available to justify a dogmatic summing up. It is a matter of common knowledge that good spinning requires steady driving, and in a less degree the same is true of weaving. There is, however, a limit to the practical advantage of steadier driving, and the question remains unsettled as to whether or not that limit has yet been reached in the best rope drives. Further, it remains to be proved that the electrical system does in fact give an appreciably steadier drive than its rival, assuming good examples of each. The problem is really very complex and cannot be settled by a few isolated tests, however accurate and unbiased. It is a big subject, and its importance justifies a careful and extensive research covering the whole of the mechanical aspects of the driving of the various cotton machines, from the prime mover in the engine house to the producing mechanism of the machine. Not until this aspect of the problem is understood can we hope to make substantial progress with any form of drive or to make a final choice between rival systems.

DIESEL LOCOMOTIVE.

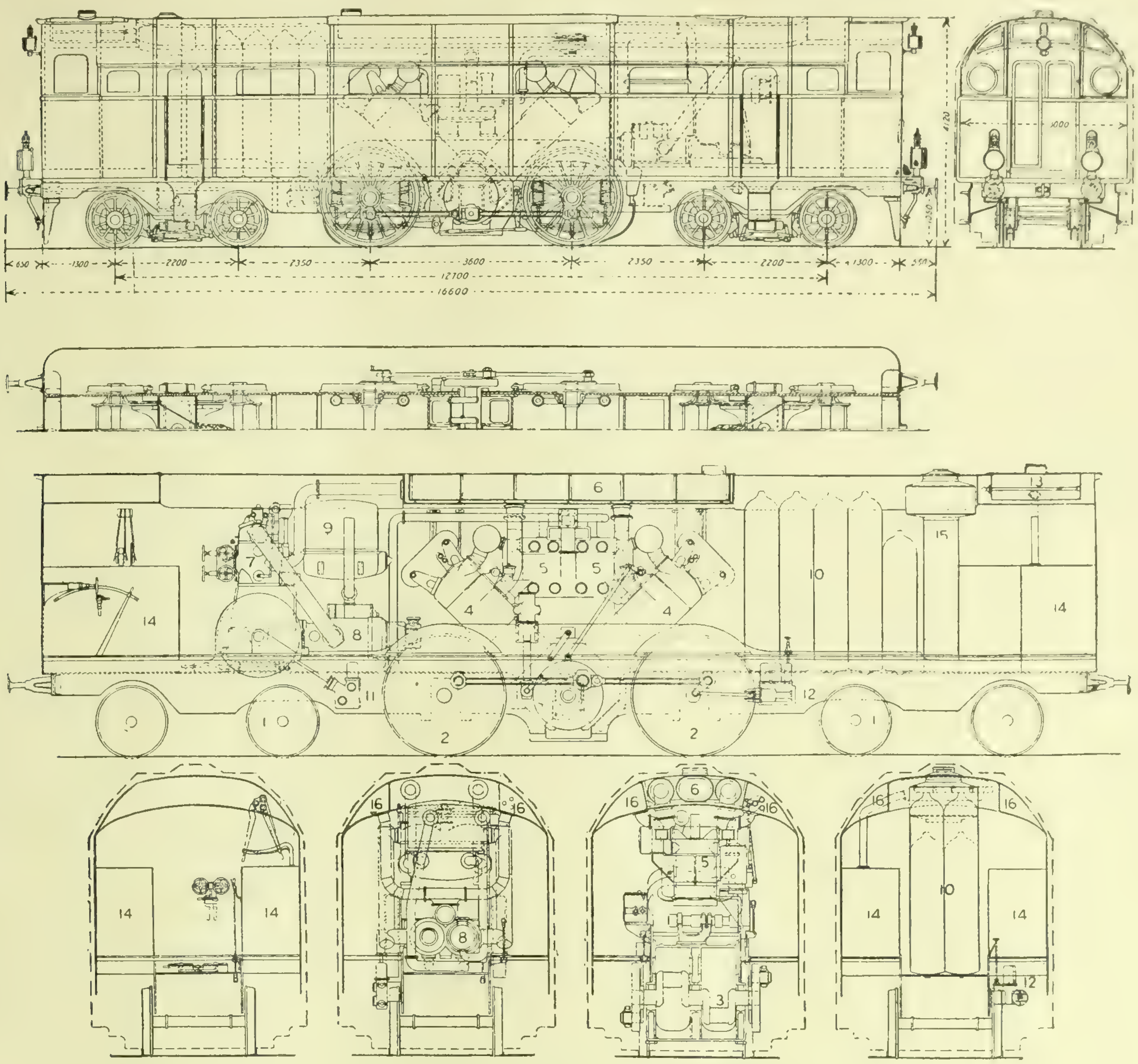
IN the course of a lecture delivered before the American Society of Mechanical Engineers Dr. Rudolph Diesel furnished some particulars of the locomotive propelled by Diesel oil engines which Messrs. Sulzer Bros., of Winterthur, have recently completed. Of the Diesel locomotive nothing, he said, had been published yet. From the early days of his invention he was of the opinion that the special features of the Diesel engine would be of even greater importance for transport purposes than for stationary work. The first automobile engine for trucks was made in the year 1899, and Dr. Diesel looked forward to the development of this branch within a few years. He had, he said, worked for the past five years, together with Sulzer Bros., at Winterthur, and Adolph Klose, of Berlin, on the construction of a Diesel locomotive, and the first express-train locomotive of 1,000 h.p. to 1,200 h.p. was finished a few weeks ago, and is now on the testing bed in the Winterthur shops. Five years was, he observed, a very long time, but the locomotive was the most difficult problem of construction that could be taken up in the way of modern engine building, not only on account of the difficulties in starting and manœuvring with this special kind of motor, but also on account of the excessive limitations as to space and weight. Compared with this, the development of the reversing marine motor had been relatively simple.

The accompanying illustrations, for which we are indebted to "Engineering News," show the design of this locomotive, the car of which was made in the locomotive works of A. Borsig, at Berlin. It is 16·6 metres long over the buffers and has two 4-wheel trucks, and two pairs of driving wheels. The latter are not directly coupled to the Diesel engine, but indirectly by means of the jackshaft 3, which is the crank shaft of the Diesel engine 1. The Diesel engine is an ordinary 2-stroke cycle engine with four cylinders coupled in pairs at an angle of 90° and driving the jackshaft, the cranks of which

are at an angle of 180°. This arrangement gives complete balancing of the moving masses, the first and most important condition when placing such engines on a movable platform.

Between the working cylinders are placed two scavenging air pumps 5 driven by levers from the connecting rod. Beyond the engine in the roof of the car is placed the muffler 6. On the right of the main engine stands an auxiliary engine 7. This latter consists of two vertical 2-stroke cycle Diesel cylinders coupled to horizontal air pumps 8 driven by these cylinders. The cooler for the air compressed by these pumps is shown at 9. These air pumps serve, according to a special and patented process, to increase the power of the main engine when starting, manœuvring, and going up grade in such a way that auxiliary compressed air and auxiliary oil fuel are conducted into the main cylinders, by which means the indicator diagram is enlarged, which makes the engines as elastic as a steam engine. In the ordinary running of the locomotive, the main cylinders work like ordinary Diesel engines without the help of the auxiliary.

To the right of the main engine is placed a battery of air reservoirs 10, which help the action of the auxiliary engine and which can be refilled by the auxiliary engine at times when the latter is not in use to help the main engine. Two pumps 11 and 12 provide for the water circulation in the cylinder jackets; 13 indicates an apparatus for the cooling of the jacket water by evaporation, and 14 the tanks for fresh water and for fuel; 15 is a small donkey boiler for the heating of the train. The passages 16 under the roof lead the fresh air to the suction pipes of the different motor and pump cylinders. The whole plant is contained in a closed engine room. The driver can operate the machine equally well from either end of the locomotive, as the engine is arranged for running in both directions. He has a direct view of the track. Doors and platforms lead from the engine to the train. The total weight of the locomotive ready for service is 85 tons.



VIEWS OF LOCOMOTIVE PROPELLED BY DIESEL ENGINE.

Errata.—In the paper on "Processes in the Production of Gears," reproduced in our last issue, the weight of the drop test for gear teeth is given on p. 677, line 6 from bottom, first column, as 2lbs. This should read 10lbs., which has been adopted as a standard.

The British Acetylene and Welding Association.—The annual meeting of this association was held in London on May 21st. Mr. Kenneth S. Murray, of the British Oxygen Company, Ltd., was appointed president of the association, and occupied the chair. The association is, we understand, making arrangements to establish classes in the various technical colleges and important engineering centres as a means of instruction regarding oxyacetylene welding. In addition to this it is the intention of the association to keep closely in touch with the developments in acetylene welding and in metal-cutting which are constantly taking place. It is also the intention of the association to hold periodical meetings in order to read and discuss any papers of interest that may bear on these subjects.

THE TROLLEY VEHICLE SYSTEM OF RAILLESS TRACTION.*

BY HENRY C. ADAMS, A.M.INST.C.E., M.I.M.E., A.M.I.E.E.

The trolley vehicle system of railless traction is a comparatively recent development so far as this country is concerned, and the literature on the subject is by no means voluminous, so that some brief description of it in its various forms should prove interesting. Briefly the system may be described as consisting of mechanically-propelled vehicles adapted for use upon roads and moved by electrical power transmitted thereto from some external source. The power is obtained from bare overhead conductors erected and fixed in a manner somewhat similar to that now so familiar in connection with the side-swivelling trolley electric tramway systems, except that as there are no steel rails to take the return current, a second overhead wire is necessary for the purpose. The vehicles are fitted with trolley poles, or other connections, for completing the circuit between the overhead wires through the motors on the car. The system of double overhead wires, one positive and the other negative, was introduced in America some 25 years ago, and was known as Short's system. It was adapted for use by ordinary electric tramcars, the current being collected by a 4-wheeled trolley running on the wires and conveyed to and from the cars by a flexible cable.

Fig. 1. Fig. 2.

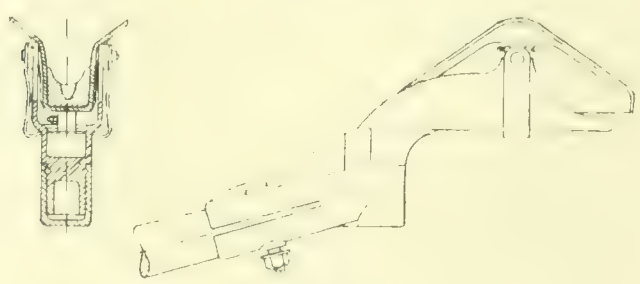


Fig. 3.

Figs. 1 and 2. Details of Single "Schiemann" Trolley Head.
Fig. 3. "Schiemann" Double Contact Trolley Head.

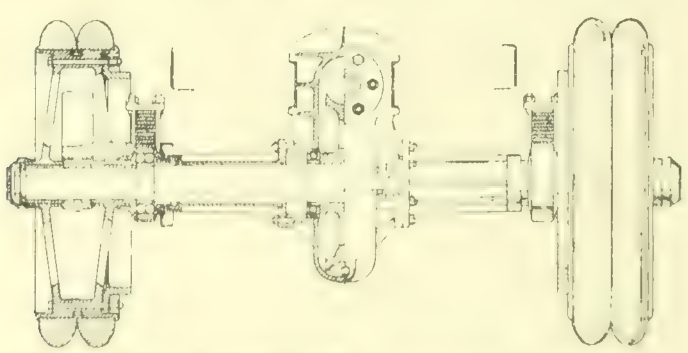


Fig. 4.—Driving Wheel of "Schiemann" Vehicle.

The four principal methods of applying the trolley omnibus system abroad are the "Max Schiemann," "Mercedes-Stoll," "Lloyd Kohler," and the "Filovia," which will be described later. There are in addition several British companies at work who have devised many improvements on the original methods and have adapted the system to British ideas. Installations have been working abroad for some years in Vienna, Dresden, Bremen, Drammen, Spezia, California, and about 30 other places, there being 30 miles in Italy alone. It was first definitely suggested in this country in November, 1902, when the Stroud District and Cheltenham Tramways Bill was deposited in Parliament. In 1903 a comprehensive scheme was designed for linking up Tunbridge Wells with Tonbridge and other surrounding places. The Dundee Corporation obtained powers for the installation of this system in their Order of 1907 and the approval of the Board of Trade to the plans has been obtained. The next towns to take the matter up were Leeds, Bradford, and Sheffield. In September, 1909, trial trips with an experimental car were run at Hendon. Bills were deposited in Parliament in November, 1909, on behalf of the Leeds and Bradford Corporations respectively, and they eventually received the Royal Assent in July, 1910. In November, 1910, there were 15 Bills deposited in Parliament, and of these, powers were obtained at Aberdare, Brighton, Chiswick, Halifax, Northampton, and Rotherham. Eleven Bills were deposited in November, 1911, seeking powers to install this system of traction.

The subject is being discussed with a view to its installation in many towns all over the country, while to come nearer home the London County Council and the Metropolitan Electric Tramways Company have decided to investigate its possibilities. The Leeds and Bradford schemes were completed and opened to traffic on June 20th, 1911, while the lines at Dundee and Rotherham have recently been completed. Although the Bradford system was installed as recently as last June proposals for extensions are already on foot, owing to the report of the general manager detailing the success of the short length at present in operation. Negotiations are also in progress for the installation of the system at the end of other of the tramway routes on the outskirts of Leeds.

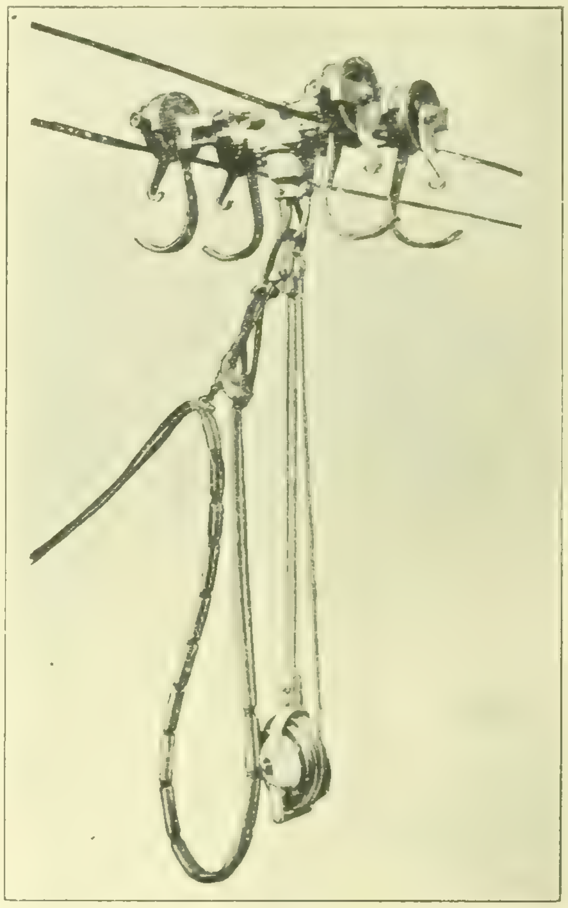


Fig. 5.—Mercedes-Stoll Current Collector.

This brief reference to the progress of the system up to date is sufficient to show that it has long passed the experimental stage and that those engineers who have kept in touch with it in its various phases have now sufficient data to enable them to give reliable advice and to carry into effect schemes which would prove financially satisfactory and generally advantageous to the community. There are many localities where additional means of transport are urgently required, but the probable traffic is not sufficient to warrant the outlay necessary to construct an electric tramway. Now that people have become accustomed to the appearance of the overhead work most of the objection to tramways centres around the track, and its exclusion in the trolley omnibus system considerably facilitates negotiations for the adoption of the latter. The noise of the trams is also an objection to their use under certain circumstances. A trackless system can be installed without

* Abstract of paper read before the Society of Engineers, March 18, 1912.

there being any necessity for expenditure in road widenings, so frequently required in tramway schemes. In fact this method of traction can be, and is, employed in roads which are too narrow even for a single line of tramway with passing-place loops.

Until recently the only alternative to a tramway was the self-propelled motor omnibus, and although at the present time in London the most recent additions to the service leave little to be desired in reliability, comfort, speed, and economy, there

FIG. 6. "MERCEDES-STOLL" CARS ON TERMINAL CURVE.

is no doubt that the same result has not been obtained with the smaller fleets tried from time to time in provincial towns. It does not follow, however, that success is impossible, and better results may be obtained with a general adoption of the latest improved type of omnibus. The engine and fuel which all self-propelled vehicles have to carry add considerably to their weight, and consequently to the dead load to be carried, which involves an increased consumption of power. The extra load also increases the wear of the tyres, an important item of expense. It is cheaper to generate power in bulk for a whole fleet of vehicles than to do so separately for each individual vehicle, but in the former case it is necessary to add the cost of transmitting the power along the routes. There is the other aspect of the case, namely that if the generating plant at the central station breaks down the whole system is stopped, whereas if the motor of a self-contained vehicle breaks down, only that vehicle is put out of service; the former, however, is a much more remote contingency than the latter. The motor omnibus and the trolley omnibus can be steered with equal facility in crowded narrow streets.

In addition to those places where there are now no regular means of transport, the railless system of traction is specially fitted to form extensions beyond the termini of existing tramway systems. In these cases the trolley omnibuses would not only feed the tramways but would create a traffic of their own, so that ultimately, when the time was ripe, tramway tracks could be laid down if desired, and provided the contingency has been anticipated in the design, the overhead work could be re-arranged at very little cost to meet the requirements. It is important where the railless routes are an extension of the tramway system that the trolley on the omnibus should be of such a pattern that, provision being made for the return current, it can be used to obtain power from the overhead tramway wires, because in the majority of instances it will be found that such routes are at some distance away from the tramway depôt to which the omnibus will have to return each night.

The "Max Schiemann" system is the oldest, being brought out in 1900 and now in use at some 14 places abroad, including Drammen, Monheim, Wurzen, Mulhausen, and California. The positive and negative overhead wires are placed parallel about 6in. apart and 17ft. above the surface of the ground. The current is conveyed between the omnibuses and the wires in alternative ways. In one method two trolley booms are fixed on top of the cars, one behind the other; the collectors being under running and making a sliding contact, and formed as shown in detail in Figs. 1 and 2. In the other method one trolley boom only is employed, fitted with a special lubricated double sliding contact collector as shown in Fig. 3.

The cars are driven by a single motor from 15 h.p. to 25 h.p. running at 1,200 revs. per minute and placed under the driver's seat, whence power is transmitted to the rear axle, through spur gearing, by a shaft longitudinal with the vehicle. The axle revolves and drives the wheels through interlocking movable fingers; the wheels are fitted with ball bearings. The controller is actuated by a hand lever and gives three running speeds, the resistances being carried in a frame under the body of the vehicle. The tyres are of solid rubber, single on the front wheels and twin on the rear. Fig. 4 shows a part elevation and part section of the rear wheels and driving gear.

The cars on the California route maintain a speed, under favourable conditions, of 25 miles per hour, while up the maximum gradient of 1 in $8\frac{1}{3}$ a speed of 8 miles per hour is maintained. At Munich the cars are allowed to travel as fast as 20 to 30 miles per hour, and this speed is obtained by simply raising the line voltage from 500 to between 600 and 700 volts. The traction coefficient of one of the early 24 passenger cars was found to be 55lbs. to 66lbs. per ton on a level road.

The "Mercedes Stoll" system is in use on nine routes in Austria, Hungary, and Bohemia, four of the routes being in the neighbourhood of Vienna. The first line was opened in July, 1907. It is now being installed also at Fribourg (Switzerland), Paris, New York, and Berlin, as well as in Australia and South Africa. The English company exploiting this system is the Trackless Trolley Limited. In this system the positive and negative overhead wires are placed side by side at a distance of 12in. apart and about 21ft. above the surface of the ground. The current collector consists of a small 4 wheeled trolley as shown in Fig. 5. The wheels are

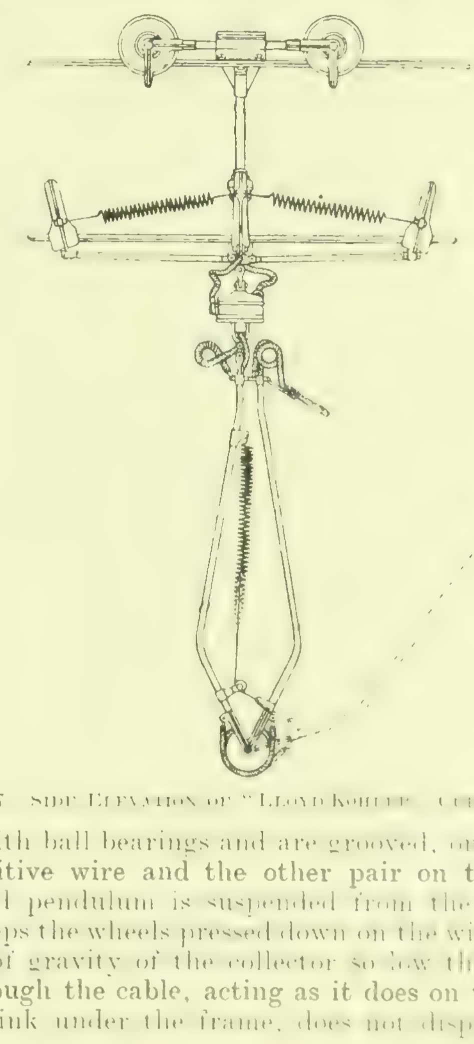


FIG. 7. SIDE ELEVATION OF "LLOYD KOHLER" CURRENT COLLECTOR.

fitted with ball bearings and are grooved, one pair running on the positive wire and the other pair on the negative. A weighted pendulum is suspended from the frame which not only keeps the wheels pressed down on the wires but throws the centre of gravity of the collector so low that the pull of the car through the cable, acting as it does on the short leverage of the link under the frame, does not displace the collector

Even if by some means the collector left the wires it would be prevented from falling into the road by the safety hooks fitted to each wheel. The collector only weighs 25lbs. and is easily placed on the wires by one man. It should be added that the company have designed an ordinary double under-running pole attachment to the car for use in localities where there are objections to the over-running trolley; this, however, adds about 4cwt. to the dead weight of the vehicle. The cable is a twin one and is looped where it joints the frame so as to allow for extension to absorb any sudden jerk from the car. This extension is effected by means of a spring fitted into the weight of the pendulum and connected to the cable by a flexible wire. About 10 yards of the cable at the car end is coiled on a drum having a spiral spring which automatically winds the cable up or lets it out as required so that the vehicle possesses a very wide range of movement. A ball-and-socket joint is fitted between the cable and the collecting trolley which enables the car to describe circles underneath the trolley so that when a single set of wires is used the direction of travel can be reversed without it being necessary to interfere with the trolley or the connecting cable.

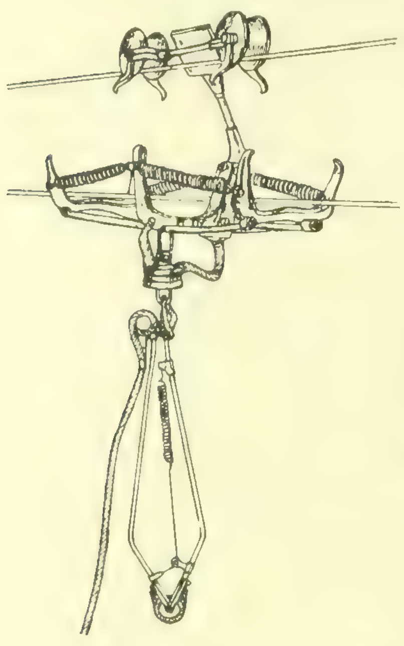


FIG. 8.—"LLOYD-KÖHLER" CURRENT COLLECTOR.

In order to permit the cars to pass each other when only one set of overhead wires is employed a connecting link is fitted in each cable so that after the slack is wound in the car can be disengaged from the overhead collector. When desirous of passing, the two vehicles are drawn up opposing each other with the front axles approximately in line; each driver draws down the sliding rod, separates his cable and hands the loose end of the hanging cable across to his colleague who connects it up with his car. It is said that this exchange can be effected in 8 seconds. After having performed the operation each vehicle can proceed in its original direction. The connecting link on the cable can be seen in Fig. 6 to the left of the trees just above the sliding rod of the right-hand omnibus. This connector is so formed that it would separate automatically if by any means the cable fouled any passing obstruction or the car was driven to too great a distance from the overhead wires. This last illustration also shows a terminal curve which enables the direction of the vehicles to be reversed at the end of a route in a wide sweep without backing them. In the centre of the rear wheels of the left-hand omnibus the motors which form the most distinguishing feature of the design of these vehicles can be seen. The standard power of these is 20 h.p. each, they run at 200 revs. per minute and are specially designed to resist the road shocks. A car speed of 14 miles per hour is attained. The field magnets of the motors are fixed on the axle and form the nave of the wheel, the rest of the wheel being mounted on ball bearings. There is thus no loss of power in transmission. The cover hermetically closes the motor and protects it from dust, as well as fixing it securely on the axle. The motors fixed on the 18-passenger cars running on the Gmund line in Northern Austria, which was opened in July, 1907, have now run over 100,000 miles without any attention, saving that necessitated by external physical damage, and, according to the report of the superintendent, are still working in a faultless manner.

Cars designed for use with trailers are fitted with two extra motors on the front wheels. There is no transmission gear, and the weight of the motor being direct on to the wheel the springs may be made fairly light and flexible as they only have to support the bare chassis and body, together with the passengers. The controller is of the tramway pattern of the usual drum type; it is reversible, and for reversing purposes a separate reversing barrel is employed inside the controller itself and operated by a separate key, but so interlocked with the main barrel that it cannot be reversed unless the main barrel is in the open position. The drum of the controller is insulated throughout with mica, and is provided with six speeds forward and three rheostatic braking points. The contacts on the drum are renewable and of hard-drawn copper; the fingers are of the usual type supported from brass carriers which are in turn supported by an iron bar and insulated therefrom with mica. A powerful blow-out coil is provided to act for all contacts; there is also an arrangement for cutting out either motor as occasion may require, and this is so arranged that it is impossible for the driver to short-circuit the line with the controller in parallel position after one motor is cut out. The resistances are of the usual standard type and of two-minute rating. The brakes act on the rear driving wheels. The tyres are of solid rubber with single treads on the front wheels and twin treads on the rear wheels. The weight, loaded, of a car holding 26 passengers is 4 tons 10 cwts. The line voltage varies from 450 to 600 on the different routes in operation.

The "Lloyd-Köhler" system is in operation at Bremen, Germany, upon two routes, one between Arsterdam and Arsten, and the other, which is run in the summer only, from the centre of the town to a public park on the outskirts. Each route is approximately 2 miles long. It has also been installed on a route $8\frac{1}{2}$ miles long at Ludwigsburg, and also at Breslau. Further schemes are now under consideration. The overhead wires, in this system, are placed one above the other at a distance apart of 11in. The upper one is negative and would therefore act as a guard wire to prevent any falling telegraph or telephone wires coming in contact with the lower or positive wire. The current collector is shown in Figs. 7 and 8. Its weight is carried by the upper wire, on which the 2-wheeled trolley forming the upper part of the collector runs. A short metal horn is formed on both sides of each wheel to prevent the carriage slipping off the wire. The lower part of the apparatus, which is the actual collector, consists of a stirrup and two aluminium sliding bows permitting the whole thing to swing laterally over a considerable arc, as can be seen from Fig. 9, which shows the extreme positions the trolley wheels and bows may take up. There is no danger of it falling to the ground as the clearance between the stirrup and the lower wire is so small that the collector cannot rise sufficiently for the

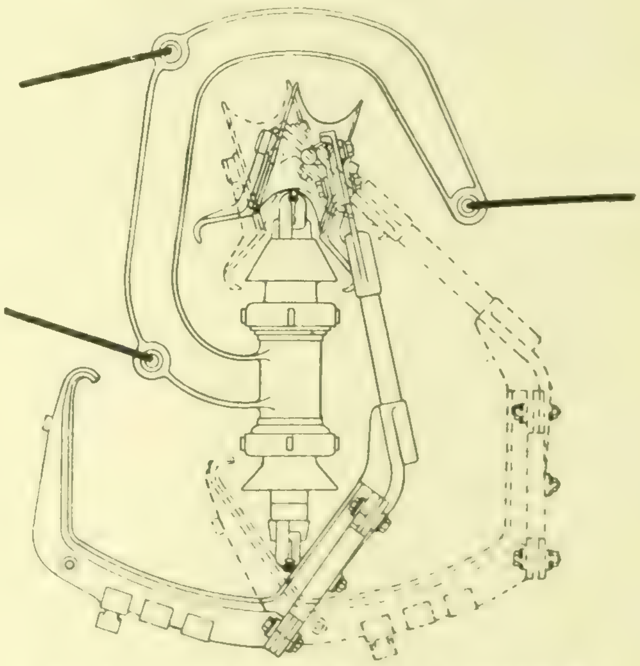


FIG. 9—DIAGRAM SHOWING RANGE OF MOVEMENT OF "LLOYD KÖHLER" COLLECTOR.

wheels to leave the upper wire. The bows are hinged at their connection with the central stirrup and are thus free to move vertically. They are drawn up by means of two springs to each bow, to make contact with the wire. The cable is a twin one and passes through a hinged metal loop arrangement attached to the collector to relieve the latter from any sudden jerk from the car when starting or stopping. The two arms are drawn up towards each other by a light spring. At the car end the table is wound on a drum as already explained in the Mercedes Stoll system, to give a wide range of movement and allow the car to pass freely in and out through other traffic.

The passing of two vehicles travelling in opposite directions is effected by exchanging collectors in the same manner as in

the Mercedes-Stoll system, except that the cable post is so arranged that by pulling down a handle placed immediately above the driver's seat the upper part of the post with the collector is brought within easy reach, thus facilitating the exchange, which occupies from 15 to 20 seconds from the time

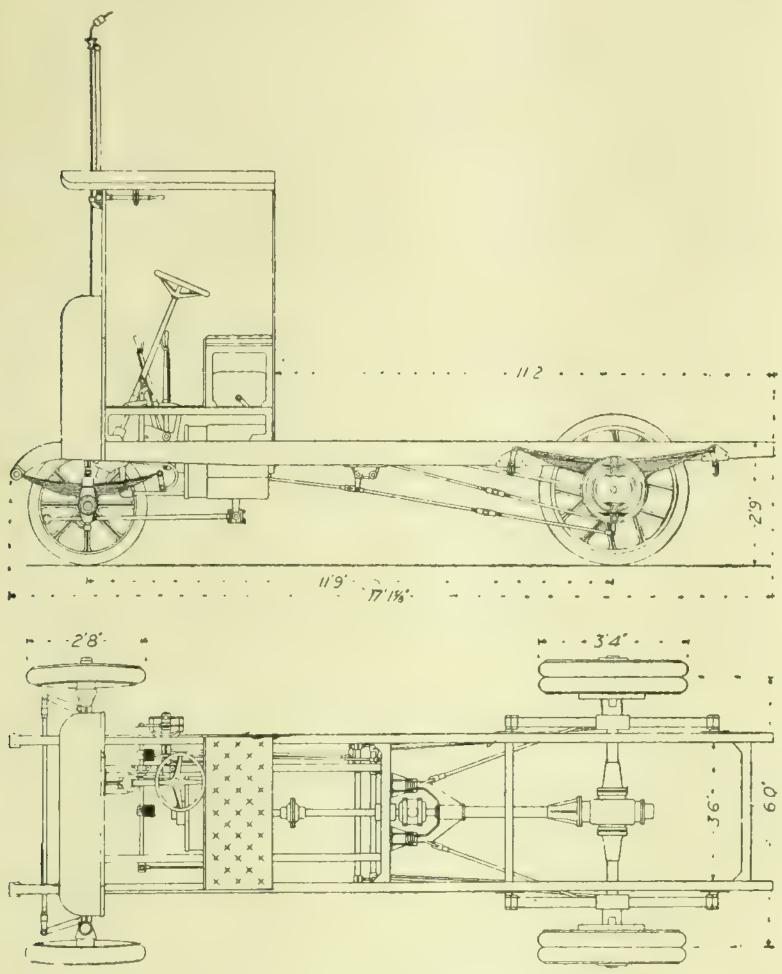
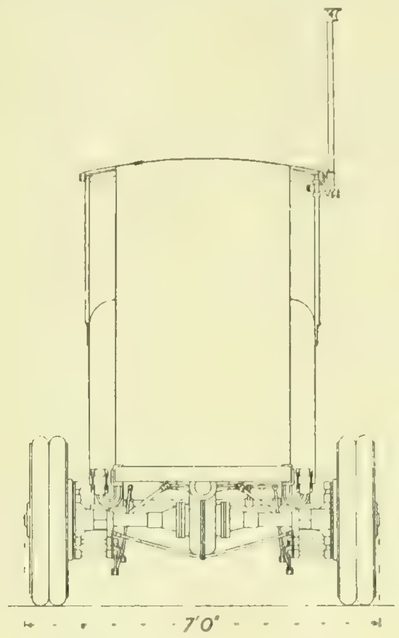


FIG. 10.—DETAILS OF BRUSH CHASSIS.

the cars stop to the time at which they are in readiness to proceed. Where the traffic is sufficient to justify two sets of overhead wires the cars can, of course, run past each other in opposite directions without stopping, but if at any time one of the cars broke down an overtaking 'bus would not be delayed but could pick up the collector previously used by the first car and proceed at once. There is no obstruction to the use of the positive wire by an electric tramcar with ordinary underrunning trolley boom, travelling in the same direction; and in special cases where the route of a tramway crosses the trolley omnibus route the overhead work can be designed without difficulty to admit of through-running in the cross directions.

The details of a chassis specially designed by the Brush Electrical Engineering Company for use with this system and having a carrying capacity of about 3 tons in addition to the body are shown in Fig. 10. The wheels are of cast steel and run on ball bearings mounted on the axle casing; they are fitted with solid rubber tyres, 4in. single on the front wheels and 4in. twin on the rear. The tyres are guaranteed to run 12,000 miles. Power is transmitted to the rear axle through a propeller shaft running inside a tube, which is anchored to the frame, thus taking the torque from the rear axle. A universal joint is provided at the front end of the shaft to compensate the rise and fall of the rear axle. At the back end of the shaft a hardened steel worm is fitted, running on ball bearings and gearing with a phosphor-bronze worm wheel mounted on the differential box. The propeller shaft is connected to the motor shaft by means of an intermediate shaft and couplings.

The motor is of the drum armature 4-pole type, series wound, and capable of giving, at 400 volts direct current, an output of 25 b.h.p. at the road wheels for one hour continuously, with a temperature rise of not more than 135° Fah. The bearings of the motor are of ball-bearing type and adapted for grease lubrication. A thrust bearing is provided to take the weight of the armature when the vehicle is on a gradient. The main control—from starting to full speed—is operated by the foot pedal on the left-hand side; the reverse and electric brake are operated by hand lever. These are interlocked in such a way that the current must be cut off by the pedal before the reverse and brake control handle can be used. This allows the driver to have both hands on the steering wheel while controlling the speed of the vehicle.



The controller is of the drum type made up of two parts, one for starting and regulating the speeds and the other for reversing and applying the rheostatic brake in either direction. It is placed under the driver's seat and has running notches for one-third, two-thirds, and full speed, in addition to the speed control which the three notches of the starting resistances give. Two mechanical brakes are fitted, one operated by the foot pedal on the right-hand side, and the other by a hand lever. They both act on separate brake drums attached to the hubs of the rear wheels. The weight, unloaded, of a vehicle seating 24 pasengers, complete, is 3 tons 12 cwts. Fig. 11 shows the latest type of vehicle and also the overhead construction at a turnout.

The vehicles at Bremen are of the single-deck type and have a seating capacity of 16 with ample standing capacity; they are each fitted with one motor of 18 b.h.p. normal, and 35 b.h.p. maximum, running at 650 revs. per minute on 550 volts. The power consumption is 600 watt-hours per car mile. The maximum authorised speed on the first two routes mentioned is 12½ and 15½ miles per hour respectively, but the mean speed from end to end only averages 9½ and 10 miles per hour.

The "Filovia" system is in use in Italy to a large extent, there being as already stated over 50 miles installed, all of

FIG. 11.—"LLOYD KÖHLER" VEHICLE AND OVERHEAD CONSTRUCTION.

which have been constructed by the Societá Trazione Elettrica. This growth of the system, which was first installed in 1902, is doubtless largely due to the Government, which grants a subsidy up to £60 per annum for each mile of line equipped with railless traction in districts not already provided with

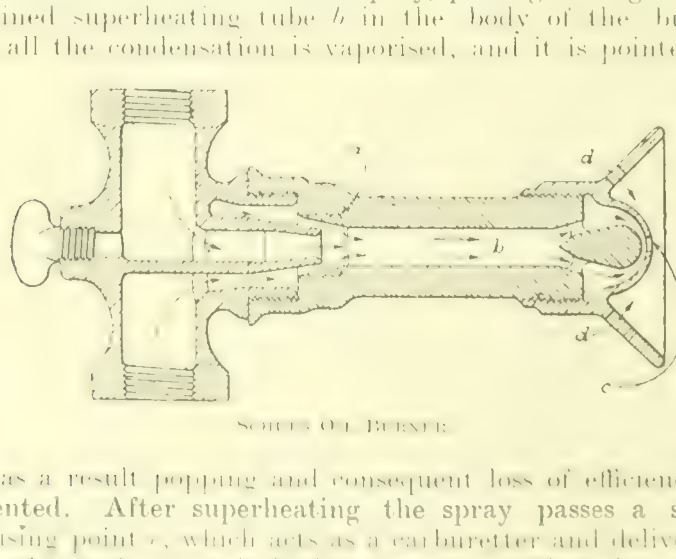
tramway or railway services. Further than this, in the case of the Intelvi Valley line from Lake Como to St. Fedele the Government pay a subsidy of £320 per annum for the carriage of the mails. In this system the double overhead wires are placed side by side at a distance of 13½in. apart and 17ft. or 18ft. above the ground, but the current is collected by a special 4 wheeled truck making contact with the under side of the wires and carried at the end of a single boom of the rigid type fixed on top of the vehicles, and which contains the twin cables. The upward pressure of the collector on the wires is about 12lbs., while a ball-and-socket joint between the boom and the collector affords the necessary flexibility for sideway movement of the cars, which can run at a distance of 10ft. from the wires. A speed of 20 miles per hour or more can be obtained with safety.

The cars are of the single-deck type, generally seating 20 to 24 passengers and weighing 2 tons 13 cwts. when empty and 4 tons loaded. They are fitted with two motors, one to each wheel; to meet the conditions obtaining in this country, they are of 15 h.p. each and drive through a flexible coupling, spur reduction gear, and a roller chain. The gear ratio from the motors to the road driving wheels is 12·75 to 1. The speed attained is 18 miles per hour on the level and about half of this on a gradient of 1 in 20. The current varies in different schemes from 500 to 650 volts. On the Ivrea Cuorgne line, 15½ miles long, the generating station is located half-way along the route and the whole length is fed with current at 650 volts through the trolley wire. The controller is placed in a horizontal position under the driver's platform; it is actuated by pedal levers and fitted with magnetic blow-out and gives five speeds forward and reverse. The cars are fitted with an electric brake and two mechanical brakes, one acting by expansion on drums on the inside of the wheels and controlled by a hand lever, and the other acting on the motor countershaft and controlled by a foot pedal. On the Lake Como line, which has an average gradient of 1 in 16½ over the length of 5½ miles, with a maximum of 1 in 7·7, and where the whole of the downward journey is done without using any current, the brakes are cooled by water carried in a tank on the roof of the vehicles. The wheels are of steel, running in ball bearings and fitted with single solid rubber tyres. In some cases the lines are fed by an overhead cable carried on the same poles as support the trolley wires.

(To be continued.)

THE SCHURS OIL BURNER.

THE oil burner shown in the accompanying sectional view has been designed specially for use in connection with furnaces for heating, welding, annealing, case hardening, and similar operations. One of the special features of this burner is the use of two distinct atomising points. The first *a* breaks the oil and steam or air into a fine spray, passing through a self-contained superheating tube *b* in the body of the burner. Here all the condensation is vaporised, and it is pointed out



SCHURS OIL BURNER.

that as a result popping and consequent loss of efficiency are prevented. After superheating the spray passes a second atomising point *c*, which acts as a carburetter and delivers an oil gas flame of extremely high temperature. The volume of air taken in through the holes *d* in the hood tends to secure perfect combustion, since the flame passing the inner end of the holes causes a suction that mixes the air with the flame and thus prevents smoke while at the same time the heat and the economy of fuel consumption are increased. The manufacturers of the burner are the Schurs Oil Burner Company, 1,007, North Main Street, Los Angeles, California.

ELECTRIC MOTORS FOR AUXILIARY DRIVES IN STEEL MILLS.

IN a paper on this subject recently read by Mr. B. Wiley at a meeting of the American Institute of Electrical Engineers, the author said that the application of motors for driving the auxiliary apparatus in steel mills had been a gradual process during the past 20 years. These motors were required to operate in hot and dirty places and in the majority of cases with a gear drive. The mills were usually operated for 24 hours per day, six days a week, and the work was of an extremely severe nature, requiring frequent starting and stopping, rapid acceleration, and sudden stops. These several applications required motors ranging from 5 h.p. to 150 h.p., with speeds of from approximately 800 to 150 revs. per minute. Motors designed for industrial purposes were available only in a few types, and these were not very suitable for the severe requirements. The solution of the problem was to modify the series-wound direct-current motors used for street railway work for the sizes about 25 h.p. and the lighter types were used for these smaller sizes. Changes were made in the frames, the windings were made suitable for 250-volt circuits and the full load speeds were modified. While these motors gave good service, the cost of maintenance was high, and for the most severe reversing service the reliability was often questionable.

About 1905 a careful review of the situation was made in consultation with a majority of electrical engineers of the industry to ascertain the features which should be included in a mill type direct-current motor, and thus, by combining the skill and experience of the manufacturer and the mill engineer, a satisfactory design of motor had been developed. In this motor duplication of parts had been followed to a large extent to simplify the construction and maintenance of the motor. Cast steel should be used for the frame and this part arranged for easy inspection of parts. The armature should be so designed that the shaft could be removed without disturbing the windings or the commutator, and its flywheel effect should be low to minimise the power required for acceleration and reversing. The commutator should be of liberal design to overcome grounding, which was one of the most serious troubles in the older types. Commutation and the capacity of the motor from the standpoint of heating were the two principal factors to be taken into consideration in determining the proper size. The advance in the art of electrical engineering in the steel industry ensured a more accurate selection of motor size for various applications, and the recently developed types of controllers provided special protection against unnecessarily severe conditions being imposed on the motors.

The steel industries had followed the lead of industrial plants and used alternating current on account of the economy of transmission and the wide range of practical sizes of generator units as compared with direct current. On account of the slow motor speed sometimes required, 25 cycles had been adopted as a standard. This power had been utilised as directly as possible, and for this reason alternating current motors were preferable for the auxiliary drives except where very rapid acceleration and frequent reversals were required. Here the direct-current series-wound motor was best suited, but these situations were few. The sizes of motor were the same as for direct current, 5 h.p. to 150 h.p., and the speeds ranged from 750 to 375 revs. per minute. The general features of this motor should be the same as the direct current one and the performance should be such that high starting torque was obtained with comparatively low starting current. A careful study of the requirements and the motor characteristics was necessary to obtain the best starting conditions with the alternating current motor and was a much more important feature than for the direct current motor. Generally the torque of the alternating current motor was proportional to the current with properly regulated resistance steps. The starting torque of the direct current series motor was in a somewhat greater proportion, twice the full load current giving two and one half times the full load torque, and it was not necessary to govern the cutting out of the resistance so accurately to ensure a continued high torque, although these conditions could be provided for in the case of the alternating-current motor by employing magnetic controllers. The inherent features of the alternating current motors were that they protected the driven machines from abnormal shock as well as protected the motors themselves from mechanical

abuse. The series-wound motor had high speed at light load, which was a desirable feature for the hoist of a crane motor. The speed of the alternating-current motor varied but little with change of load, and as a result a somewhat larger motor was required to give a speed which would be equivalent to the average light load and the full load speed obtained with the direct-current motor.

Motors designed with liberal starting torque would give satisfactory acceleration, and the proper application of the alternating-current mill motor to give satisfactory service was not only a question of motor characteristics, but more particularly included a thorough understanding of the conditions to be met.

BOOK REVIEWS.

Steam Boiler Construction. Rules of the National Boiler and General Insurance Company, Ltd., with Notes on Material, Construction, and Design of Steam Boilers and Similar Vessels, by Edward G. Hiller, B.Sc., M.Inst.C.E., M.I.Mech.E., Chief Engineer. Manchester: National Boiler and General Insurance Company, Ltd. 165 pp., 8¼in. by 5½in., price 1s.; full cloth 1s. 6d. net.

This is a new edition revised to date of a most useful set of practical rules and hints on boiler construction issued by the Chief Engineer of the National Boiler Insurance Company, Ltd., Manchester, which we had the pleasure of praising on its first appearance. In the edition now issued advantage has been taken to considerably extend the scope of the book, and it constitutes about the cheapest shillingsworth of notes on boiler construction that we have seen. There is hardly a line in it that an intelligent engine or boiler attendant cannot understand or which he would not find it to his advantage to be familiar with, and we have every pleasure in commending it not only to them but to every steam user as well.

* * *

Heat Engines, by Herbert A. Garratt, Assoc.M.Inst.C.E., M.I.N.A., Principal of the London County Council School of Engineering and Navigation. London: Edward Arnold, 232 pp., 7½in. by 5¼in., price 6s. net.

This is an attempt to summarise in elementary form the leading principles of the various types of prime movers which derive their source of energy from heat. It deals briefly with reciprocating steam engines as well as with turbines and the various forms of internal-combustion engines whether operated by gas, oil, or petrol. As a preliminary to the part devoted to reciprocating and rotary steam motors, one or two chapters are devoted to the combustion of fuel and the construction and working of boilers, while there is also a useful chapter at the end discussing the principles of heat engine testing and another deals briefly with refrigerating apparatus, which may be regarded as a sort of heat engine reciprocal. The work is clearly written and is designed to meet more especially the needs of teachers and classes working to the syllabus of the Board of Education examinations. The limits of space and number of subjects dealt with prevent exhaustive treatment of any section, but so far as it goes it is good, and the work is one which may be commended to the attention both of teachers and students.

* * *

Gas and Oil Engines, a concise account of the most important types, by Alfred Kirschke. London: Scott Greenwood and Son, 160 pp., 55 illustrations, 7¼in. by 4¾in., 3s. net.

In view of the copious literature already existing on gas and oil engines in this country, this little book, excellent though it is in its way, seems hardly called for. The text is almost entirely descriptive and some of the illustrations which represent large engines and plants are so diminutive as to be scarcely intelligible, while the 20 or 30 pages of logarithms and similar tables at the end, in view of the extent to which such information is provided in every pocket book, scarcely seems called for. Apart from these blemishes, however, the description is written from an independent standpoint, and for those who desire a brief glance of gas and oil engine practice as seen through German eyes the book may possess a certain value.

Annual Tables of Constants and Numerical Data, Chemical, Physical, and Technological (Vol. 1, 1910). London: J. and A. Churchill, 11in. by 8½in., 727 pp., price 24s. net.

To the ordinary layman the contents of this volume would probably not prove attractive, but to the patient scientific worker engaged on research in the laboratory the mass of constants and numerical data here collated, and relating to almost every element or compound that enters into chemical or physical investigation, must prove invaluable. The work is the outcome of a National Committee, and when we say the British collaborators include Sir Wm. Ramsay, Prof. Dixon, Prof. Frankland, James Swinburne, Sir Edward Thorpe, and other eminent scientists the standard of excellence will be manifest.

BOOKS RECEIVED.

University of Illinois Engineering Experiment Station, Bulletins Nos. 54, 55, and 56. Published by the University, Illinois, U.S.A., price 20 cents each. No. 54, on Mechanical Stresses in Transmission Lines, by A. Guell. No. 55, on Starting Currents of Transformers with special reference to Transformers with Silicon Steel Cores, by Trygye D. Yensen. No. 56, Tests of Concrete Reinforcements for Structural Steel Columns, by Arthur N. Talbot and Arthur R. Lord.

Iowa State College Engineering Experiment Station, Bulletin No. 25 on Electric Power on the Farm, by Adolph Shane.

Technologic Papers of the Bureau of Standards, No. 3. Tests of the Absorbtive and Permeable Properties of Portland Cement, &c., by Rudolph J. Wig and P. H. Bates. Published by the Department of Commerce and Labour Government Printing Office, Washington, U.S.A.

Engineering Index Manual for 1911, a summary of technical literature published by the Engineering Magazine, Long Acre, London, W.C.

Pattern Making, a practical treatise by Joseph G. Horner, A.M.I.M.E. 4th edition with numerous illustrations. London: Crosby Lockwood & Son, price 7s. 6d. net.

Testing, Fault Localisation, and General Hints For Wiremen, by J. Wright. London: Constable & Co., price 1s. net.

PROCESS FOR COLOURING ALUMINIUM.

THE colouring of metallic aluminium has always been an unsatisfactory process, and heretofore it may be said that no good process for accomplishing it has been known. According to "The Brass World," a process for colouring aluminium has recently been patented by Salamon Axelrod, of Oberschoneweide, Germany. This process is very simple and consists of treating the aluminium surface with a solution of a cobalt salt and then heating. The heat changes the colour of the surface and gradations ranging all the way from a steel grey to a brown and finally black are obtained, depending upon the temperature to which the article is heated. The cobalt salt used is preferably cobalt nitrate (cobaltous nitrate) and should be either neutral or alkaline. The aluminium article to be treated is dipped into this solution or, if desired, the solution may be applied with a brush. The cobalt nitrate is dissolved in water to make the solution for applying, but the proportions to be used are not given. After the cobalt nitrate solution is applied to the aluminium, heating is carried out. This may be done either by a muffle, by a blowpipe, or other convenient methods. The exact temperature to be used is not stated, but is rather low, for aluminium melts at practically a very low red heat. If the heat applied to the aluminium thus coated with the cobalt nitrate is low, then a steel grey colour is obtained. A higher heat produces a brown colour, and one still higher produces a dead black. The black thus produced on the aluminium by the proper heat is stated by the inventor to be very durable and will not rub off by friction like other superficial colours obtained by other methods. The black is also stated to be permanent. The inventor claims that zinc, tin, and other metals may be coloured by the cobalt nitrate or other cobalt salts in the same manner.

MACHINE MOULDING.*

BY WILFRED LEWIS.

(*Concluded from page 682.*)

AT the present time nearly all jarring machine builders contemplate the use of compressed air, whereas originally, and until about the beginning of the present century, they were operated mainly by hand or by cams on a power shaft. The development of the jarring machine is an interesting study, but no attempt will be made to follow it through all its ramifications; a few examples only representing the last

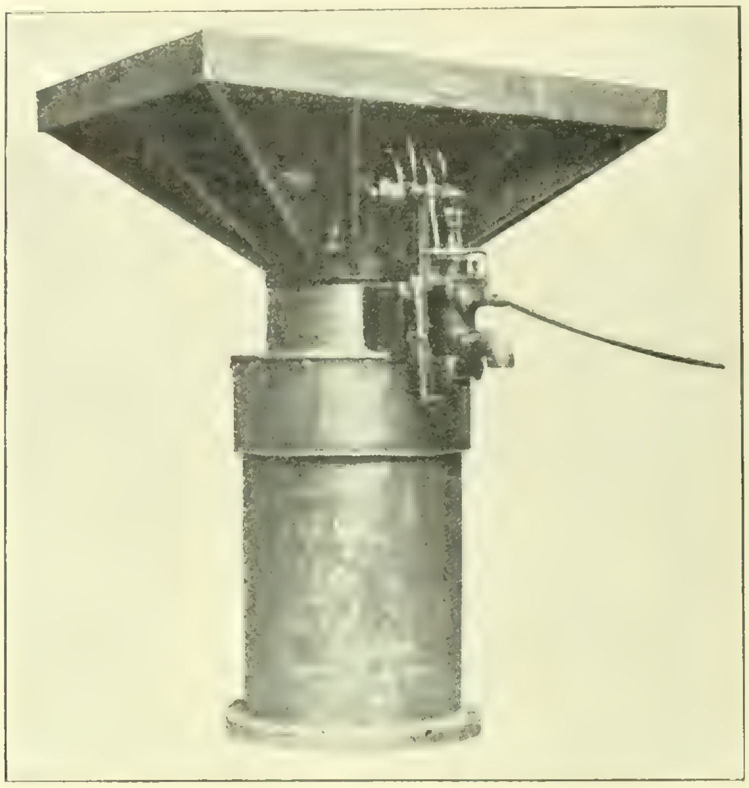


FIG. 6.—SHOCKLESS JARRING MACHINE.

ten years will be considered. In the machine first built the jarring table was struck underneath by a heavy plunger actuated by compressed air. The blow raised the table a short distance from its support, upon which it fell back, striking a second blow. Some of these machines are still in use, but it cannot be said that they are very efficient or successful, and they were superseded five or six years ago by the Tabor jarring machine now in common use.

This is a plain machine with the jarring cylinder formed in the table mounted upon an upstanding plunger. By this construction the table is given enormous strength and stiffness, and the central blow of impact is distributed equally in all directions. The plunger is part of a heavy piece of cast iron forming the anvil, which in turn rests upon a large mass of concrete. Originally the main valve was operated directly by tappets attached to the table adjustable for any desired length of stroke, and later it was modified to operate through the medium of a pilot valve. To avoid unnecessary intensity in the blow struck by the table upon its anvil a few layers of leather or other non-resilient material are introduced as a cushion. These reduce the wear and tear and noise, without having any material effect upon the action of the machine on sand. The plunger base rests upon concrete to form an anvil.

As to the mass of concrete, it may be said from the operating standpoint the more the better, but this must be limited, of course, with regard to the cost and the natural bed beneath. In a general way, about two cubic feet of concrete for every square inch of area in the jarring cylinder is recommended, but if there is a rock bottom beneath the use of very little concrete is advisable, or just enough to level up under the cast iron plunger base. Some builders recommend more concrete than this, some less, and in addition to the concrete a heavy wooden cribwork is frequently put in beneath to prevent the transmission of the shock of impact into the ground. This is in accordance with the usual practice under steam-hammer anvils, and it may have some beneficial effect, but it does not eliminate the whole trouble, and the wooden crib is scarcely worth its additional cost. It is not generally safe to set up finished moulds with hanging sand in the neighbourhood of a jarring machine of this type, and in some foundries the jarring machine has been put out of service for days or weeks pending the completion of large floor work. In fact, the damaging effect of large jarring machines is too well known to need confirmation, and to reduce this to a minimum the drop of the table has been decreased while the foundation has been increased.

But there is a limit to the relief afforded by reducing the drop, because upon this the ramming effect primarily depends. The shorter the stroke the less the ultimate density attained and the less the efficiency of the machine. This can be demonstrated in a practical way by ramming up a deep mould on short strokes until the sand ceases to pack any further. Increasing the length of stroke very considerably alters the effect of the next blow. The sand will pack further immediately, and the conclusion in favour of the long stroke as more efficient in packing sand is inevitable.

With the object of eliminating ground shock, and yet retaining the use of any stroke desired, the Shockless jarring machine, Fig. 6, has been designed. It requires no foundation other than a base to sustain the static load upon it, and it is more efficient in operation than a plain machine mounted on a wooden crib whose anvil weighs twice as much.

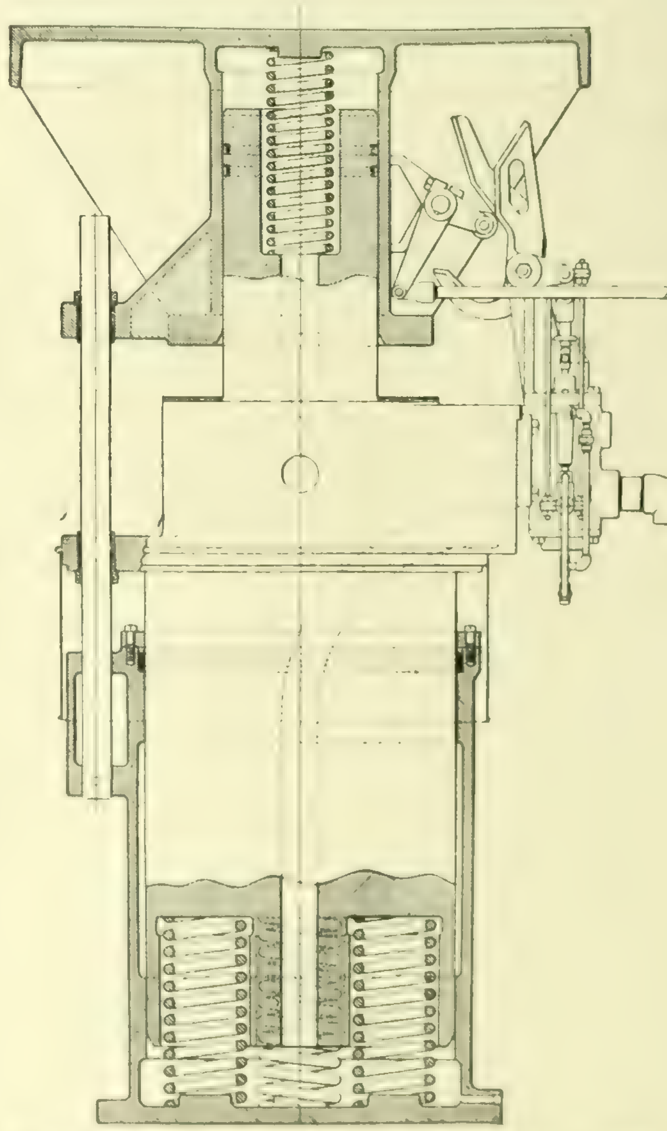


FIG. 7.—SHOCKLESS JARRING MACHINE—SECTIONAL ELEVATION.

The principle upon which it operates will be understood from the sectional elevation shown in Fig. 7. The plunger base forming the anvil is mounted for convenience in an anvil cylinder and rests upon a number of long compression springs. When air is admitted to the jarring cylinder the entire weight of the anvil, table, and load is carried upon these springs, and they are therefore compressed and in readiness to expand when the air is exhausted and the table falls. At the beginning of this movement the loaded table is impelled downward by the same force that moves the anvil upward, and although some of the force of the springs is exhausted as the anvil rises the loaded table and the anvil acquire substantially equal momenta which neutralise each

* Abstract of paper presented at a meeting of the Mechanical and Electrical Section of the Franklin Institute.

other when impact takes place. To compensate in a measure for the loss of spring pressure as the anvil rises, the exhaust from the jarring cylinder may be carried into the anvil cylinder before being discharged. This is accomplished by a combination valve, consisting of a large main valve of the steam-hammer type in connection with a small pop valve such as is used on small power squeezers and split-pattern machines. These valves are attached to the anvil or plunger base, and the pop valve is opened and closed by tappets on the jarring table. When the table drops the pop valve opens, admitting pressure beneath the main valve, which rises and puts the jarring cylinder in communication

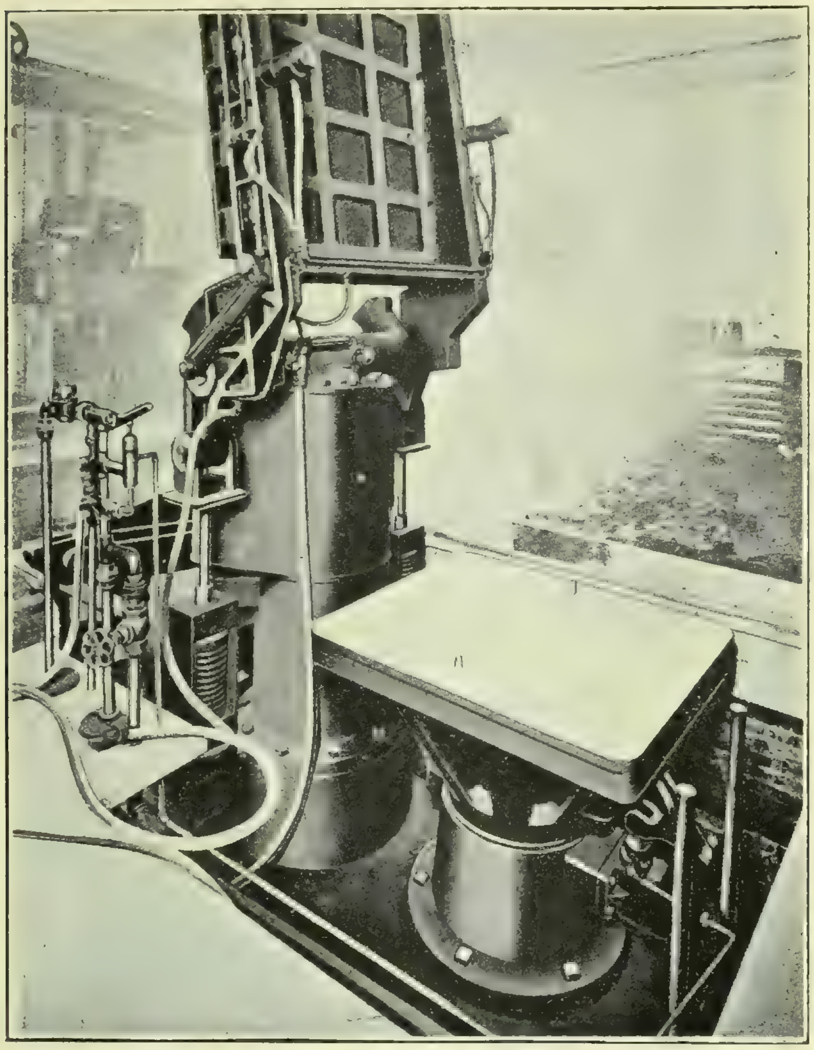


FIG. 8.—POWER ROLL-OVER MACHINE IN COMBINATION WITH JARRING MACHINE

with the air supply, at the same time opening the anvil cylinder to exhaust. When the limit of stroke is reached the pilot valve opens to exhaust and the main valve drops to the position shown. The air from the jarring cylinder rushes into the anvil cylinder, expanding to much lower pressure, which is nevertheless very effective in the large anvil cylinder and causes the loaded table and anvil to collide with greater force and effect upon the sand. The supply of air to these valves is controlled by an air cock at the operating stand, and the table runs automatically as long as the air is turned on. At the same time the stroke of the table is controlled by another lever adjustable, if desired, while the machine is running. The purpose of the pilot valve is to provide a controlling means, easily manipulated, that will give the delayed action required by the main valve. This always presents full openings during the table movement up or down, and the ample lap on the ports gives time for expansion in the jarring cylinder under light or medium loads after the air supply has been cut off. Of course, under full load, or thereabouts, there can be no appreciable expansion in the jarring cylinder.

Fig. 6 is taken from a photograph of a 13in. shockless machine with 4ft. by 6ft. table. A machine of this type will ram any mould, large or small, in a minute or less time, and the saving to be effected by its use on large work is practically the whole of the ramming time by hand. It will not ram small work, such as that on which time study was first given, as quickly as a squeezer or split-pattern machine, and such a jarring machine for half moulds weighing less than 1,000 pounds is not often recommended, but for large deep work particularly it is by far the best machine for packing sand. It is not, however, every pattern that can be rammed in this way, and care must always be taken to avoid projections on the pattern which interfere with the proper flow of sand. This sometimes necessitates the use of a core not required for hand ramming, but the patterns when mounted for jarring require fewer repairs, and the cost of adaptation to the jarring process is soon recovered.

In regard to efficiency, nothing, of course, can be better than an anvil bedded on rock, and therefore of practically infinite weight, but even a rock bottom does not prevent the transmission of ground waves, and when a wooden crib is used to cushion the blow the anvil yields to the impact and softens the effect. The advantage of the uprising anvil will therefore be demonstrated and its action illustrated by reference to two cars on a horizontal track. Let these cars be of equal mass or weight and let them be separated a given distance. Now block the wheels of one car and draw the other to it by a uniform force. Assuming the impact to be inelastic the two cars will move on together at half the velocity acquired by the moving car at the time of impact. The shock of collision is the same on both cars, one gains what the other loses, one-half of the velocity of impact, and the square of that change in velocity represents the ramming effect. If the stationary car had been of infinite mass the moving car would have lost all of its velocity and suffered four times the ramming effect.

Or, we may say, to invert the comparison, when one car strikes another of the same weight the ramming effect is one-quarter of what it would be if the car ran into a stone wall, or encountered a mass so much superior as to have substantially the effect of infinite mass in checking its velocity.

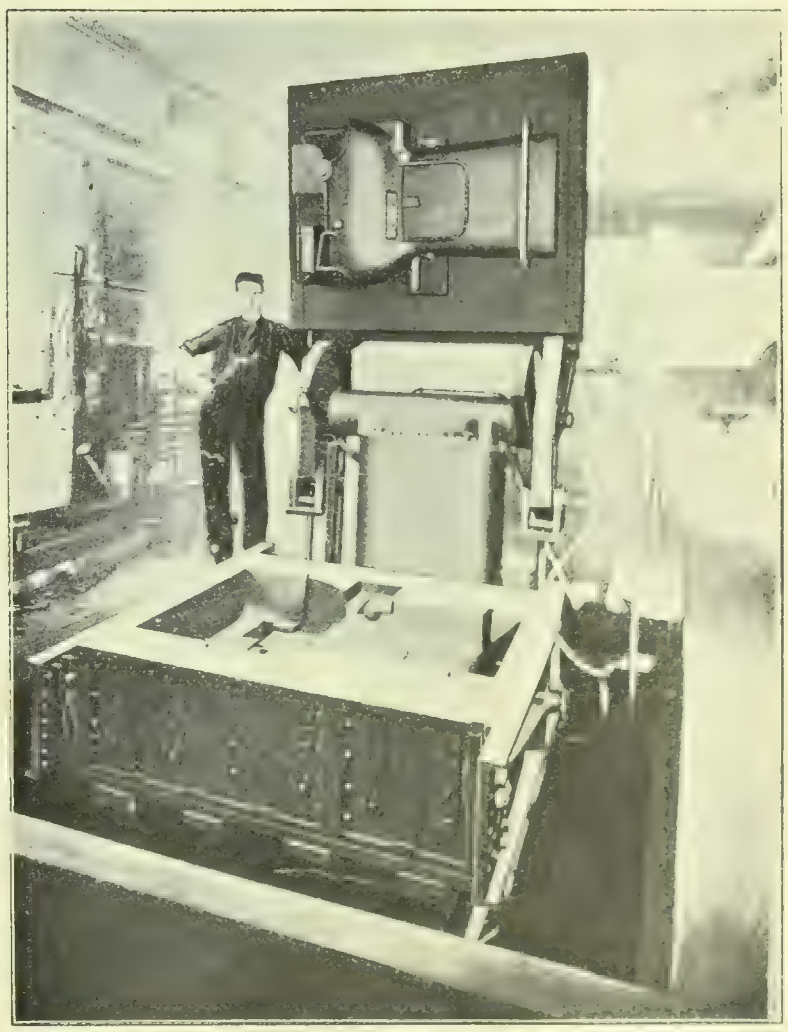


FIG. 9.—GRINDER FRAME MOULD, MADE ON MACHINE SHOWN IN FIG. 8.

Now, if both cars are free to move and are drawn together by the same force as in the first instance, the same amount of kinetic energy will be developed, but it will be divided between the two cars and totally absorbed by inelastic impact, each car sustaining one-half the shock instead of one-quarter. Therefore, when both cars move together the shock of impact is twice as great as when one car waits to receive a blow from the other one. Furthermore, the highest efficiency, or the greatest shock, is realised between

any given pair of cars for any given amount of work done when both cars are actuated by the same force and acquire equal momenta in equal times. This is true for cars of unequal weight as well as for the cars of equal weight just considered, and it can be shown when one car is made heavier than the other to act as an anvil that when both cars are free to move the shock on the lighter car is greater than it would be against a car of double the weight standing to receive the blow. It is not claimed that the shockless jarring machine is always twice as efficient as a plain machine having the same weight of anvil mounted on a wooden crib, although it is sometimes more than twice as efficient. It is simply maintained that the shockless jarring machine is more efficient than a plain machine having an anvil twice as heavy mounted on a wooden crib. But the efficiency of a jarring machine does not depend altogether upon the weight of its anvil, solidity of construction contributes something and the length of stroke still more. Instances could be cited where production has been increased five times by the installation of a jarring machine, and still greater gains have been made from machines which combine the jarring and pattern drawing features just described.

Fig. 8 shows such a power roll-over machine in combination with a jarring machine. Fig. 9 shows a grinder frame mould made on the same machine. This half mould was made by two men in ten minutes, and a complete mould, including core setting, could probably be made in half an hour. Originally two men made two moulds a day by hand. With the aid of a jarring machine they made five a day, and it appears from the time taken on a combination machine that twenty a day might be expected.

Although the foregoing is not a complete summary of the art of machine moulding and many types of machines have necessarily been omitted, the point to which particular attention may be called is the harvest awaiting the introduction of scientific management in the foundry and its bearing upon the proper selection and use of moulding machines.

STANDARD METHODS RECOMMENDED FOR TESTING DRY CELLS.*

THE methods of testing must in the first place be of benefit to those interested in dry cells, and the users may be divided into three classes: the average ultimate consumer, the large user, and the manufacturer. No standard methods of testing can be devised which will be suitable at once for all of these classes, and the most serious obstacles are encountered in formulating methods suitable to the first class. This is unfortunate, since by far the larger proportion of the dry cell output is so distributed that the user is interested in one, two, six, or perhaps twelve cells as supplying his yearly requirements. This very large number of users should have a test, the cost and labour of conducting which should not be out of proportion to the low values of the articles tested. There appears to be no adequate means of meeting this urgent demand for simplicity of equipment and method.

The large users of dry cells, such as telephone exchanges, engine manufacturers, installers of alarm and signal devices, railroads, &c., who purchase cells in large quantities, are especially interested in testing methods. Various methods of testing have been evolved by these users as a basis for purchase specifications and as a means of judging the relative merits of the various makes of cells on the market. To them the matter of elaborateness of tests is of less importance than to the small user. Of even greater importance is the testing of dry cells by the manufacturer, who must necessarily adopt methods which will give him the necessary information concerning his product, no matter how elaborate.

The methods of testing which the committee is recommending are those which are particularly suited to the second class—the large users. These tests, if extensively adopted, will be of indirect benefit to the small consumer, and will be of mutual advantage to the large users and manufacturers. It has been suggested to this committee that the methods for testing should include, aside from electrical measurement, methods of physical and chemical analysis, such that judgment may be made thereby of the merits of a cell, and that what constitutes a satisfactory product should be described in these terms, so that they might form a basis of specification. There is a striking similarity between the various cells on the market as far as materials used and general structure are concerned. Exceedingly slight variations, however, which introduce large variations in the quality of the product, are not capable of detection by physical and chemical examination, and what is of even greater importance in determining the quality are the methods of assembling, such as methods of mixing, grading as to size of the particles which constitute the cell mixture, and methods of tamping, factors which cannot be easily determined by physical or chemical inspection of the resultant product.

The art of dry-cell manufacture cannot be considered as having been worked out to a finality; improvements are being made and will continue to be made. One maker may discover a simple method of neutralising the effects of an impurity on his product which may have a detrimental influence in another product, and a judgment based upon the detection of such impurity would thereby work an injustice. The tests, therefore, should be such as determine the ability of the cell to produce results, and these can be determined only by tests involving electrical measurement. The dry cell, in all of its multitudinous uses, is merely a source of electrical energy, and its ability to deliver this energy, in the quantity and at the times desired, constitutes the principal measure of value.

Dry-cell tests may be conveniently divided into three main groups: (1) Tests to determine whether or not a cell is in good condition before being placed in service. (2) Tests to determine the actual or comparative service capacity of cells. (3) Tests to determine the rate of deterioration of cells on open circuit. This classification is followed in this report.

TESTS TO DETERMINE THE CONDITION OF A CELL BEFORE USE.

Electromotive Force.—The electromotive force of a cell may be read by connecting a voltmeter directly across the terminals. In new cells of various types the electromotive force may vary from 1·5 to 1·6 volts. If a cell of the type now in general use gives an electromotive force less than 1·45 volts it is an almost certain indication either of serious deterioration due to age, or of the external short-circuiting of the cell, or of some defect such as an internal short-circuit, which will soon render the cell unfit for service. It is seldom necessary to measure the open-circuit voltage of cells, since they are seldom deficient in this respect. It is a test which may be considered as secondary in nature, and should be applied when it is suspected that the cells are below standard, for example, when cells are received with wet packets, when the terminals are corroded, when the electrolyte leaks from under the seal, or when the cells are abnormally low in short-circuit current.

An accurate or carefully calibrated voltmeter should be used, the resistance of which is sufficiently high to render the current flow through it inappreciable. A two-scale Weston instrument of 300 ohms resistance with 3-volt maximum deflection and 1,500 ohms with 15 volts maximum deflection has been found very satisfactory for both cells and batteries. Cheap pocket instruments are often so inaccurate as to make their indications of open-circuit voltage worse than useless. The effect of temperature on electromotive force is very slight.

Short-circuit Current.—The short-circuit current of a cell may be obtained by connecting an ammeter directly across the terminals of the cell. The short-circuit current of a cell is of value only when coupled with a familiarity with the brand of cell in question. If the reading is normal for that brand of cell, it is reasonably certain that the particular cell is in good condition, and that it will probably give as good service as others of the same make. This applies only to cells of the same brand and make. That the short-circuit current of a cell of a new and unfamiliar brand is as high as that of another brand is no indication whatever of the equality of the service capacities of the two cells. The short-circuit current bears no relationship to service, and when measured without reference to temperature or other conditions may be entirely meaningless and misleading.

The ammeter for reading short-circuit current should be deadbeat, and with its leads should have a resistance of 0·01 ohm to within 0·002 ohm. Two 30in. lengths of No. 12 lamp cord make very convenient leads. The maximum swing of the needle should be taken as the short-circuit current of the cell. The ammeter should be connected across the brass

* Abstract of a report by the committee on dry cell tests of the American Electrochemical Society.

terminals of the electrodes. Low readings are likely to be obtained if the ammeter is applied to the carbon electrode directly. In order to avoid high contact resistance, the terminals of the cells and of the ammeter leads should be brightened. It has been found very convenient to fit the ammeter leads with small terminals of lead. The contact on the cell terminals is greatly improved, and with such leads it is unnecessary to brighten the contacts. For accurate measurement of the short-circuit current of a new cell, instruments of the pocket type should be avoided. The effect of temperature on the short-circuit current is quite pronounced. The amperage of cells is raised about one ampere for each 10° C. rise in temperature. This value varies considerably with different cells, and is somewhat greater at the lower temperature and less at the higher. At very low temperatures the effect is very pronounced, and it is often noted that cells received in extremely cold weather read but one or two amperes. On bringing them to room temperature, however, the short-circuit current becomes normal and the cell is not impaired by the freezing.

Internal Resistance.—This value is usually determined by applying the formula

$$R = (V - V')/C$$

where V is the open-circuit voltage of the cell, V' the closed circuit voltage, and C the current to which the cell is subjected in order to make the determination. The value obtained varies with the current flowing, the age of the cell, and the temperature. For these reasons we advise against the use of this test. It indicates nothing in regard to the service capacity, nor does it give an exact value of the actual internal resistance of the cell.

SERVICE CAPACITY TESTS.

In general there are but two reasons for desiring a service test upon dry cells: (1) to ascertain what life may be obtained from a brand of cells in a certain service; (2) to ascertain which one of several brands will give the longest life in that particular service. With the former object in view the knowledge is best obtained by actual use of the cells in connection with the appliance. In some cases this is the only feasible way in which the definite information sought can be obtained. The great majority of tests are carried on, however, with the second object in view. Where the amount of testing is large, it is impossible, even were it expedient, to use the actual appliances for testing cells, and it becomes necessary to devise special testing methods and apparatus such that results obtained therefrom shall be comparable to the results obtained from the cells when placed in actual service.

It has been suggested that cells of various makes be tested by connecting them in series and discharging them simultaneously through any suitable resistance, thereby assuring that the cells are discharged at the same rate and under identical conditions. There are several objections to this method and we therefore advise against the testing of cells in this manner.

In interpreting the results obtained from a test of various grades of cells, we wish to caution against drawing definite conclusions from the outcome of a single test or of a small number of tests. When the matter of choosing a brand is of much importance, it is necessary to run a series of tests over a period of six months or a year. In this way a very good idea may be obtained of the average service results which may be expected.

SERVICE TESTS RECOMMENDED.

Telephone Service.—Discharge three cells, connected in series, through 20 ohms resistance for a period of two minutes each hour, during 24 hours per day and seven days per week, until the closed-circuit voltage of the battery at the end of a period of contact falls to 2·8 volts. The following readings are taken: (1) Initial open-circuit voltage of the battery. (2) Initial closed-circuit voltage of the battery. (3) Closed-circuit voltage at the end of the first discharge period. (4) Closed-circuit voltage at the end of a discharge period after three days, and weekly thereafter. Report the results as the number of days during which the closed-circuit voltage remains above the limiting value of 2·8 volts.

Ignition Service.—Discharge six cells connected in series through 16 ohms resistance for two periods of one hour each per day, seven days per week. The periods should be 11 hours apart, but in cases where the circuits are not automatically controlled, the first and the last hour in the working day may be chosen for the discharge periods and the discharge omitted on Sunday, without materially affecting the results.

The following readings are taken: (1) The initial open-circuit voltage and short-circuit current of the battery. (2) The initial closed-circuit or working voltage, and the initial impulse of current which the battery is capable of forcing through a 0·5 ohm coil connected in series with an ammeter, and in parallel with the 16 ohm coil. (3) Closed-circuit voltage and impulse current through the 0·5-ohm coil at the end of the first period of closure, at the end of the sixth period, at the end of the 12th period, and after every 12th period thereafter.

The test is considered completed when the impulse current at the end of a period falls below four amperes. Report the results as the number of hours of actual discharge to the limiting value of impulse current. Particular care should be taken to keep the temperature of ignition test batteries as nearly constant as possible, as the service obtainable is greatly influenced by this factor.

Flashlight Batteries.—Discharge the battery to be tested through a resistance of 4 ohms for every cell in series (8 ohms for a 2-cell battery and 12 ohms for a 3 cell battery), for a period of five minutes once each day until the closed circuit voltage at the end of a discharge period falls to 0·75 volt per cell (1·5 volts for a 2-cell and 2·25 volts for a 3 cell battery). The following readings are taken: (1) Initial open-circuit voltage and short-circuit current. (2) Initial closed circuit, or working voltage. (3) Closed-circuit voltage at the end of the first, third, and seventh periods of closure, and after each seventh period thereafter.

Report the results as the number of minutes during which the battery was discharged through the resistance to the given end point. In case the circuits are not operated mechanically, the results are not materially changed if the batteries are discharged only on working days. Four ohms per cell is chosen for the resistance in circuit, since the tungsten bulbs generally used with a 3-cell battery have a resistance of approximately 12 ohms.

Miscellaneous Service.—In addition to the telephone and ignition services, which are by far the most important services in which dry cells are used, there are numerous other services, among which may be mentioned the operation of automobile horns, sewing-machine motors, small fans, toys, massage vibrators, cigar lighters, bells, buzzers, &c. In the aggregate these miscellaneous services consume enormous numbers of cells, but they are so numerous, and there are such variable conditions prevailing in each kind of service, that it would be useless to attempt to develop standard tests covering them. It is not difficult for anyone particularly interested in any special service to arrange a suitable test for himself. Care should be taken to make the conditions of test, viz., number of cells, resistance in circuit, period of drain, &c., approximate those of the service in question.

RATE OF DETERIORATION ON OPEN CIRCUIT.

The voltage and short-circuit current of the cells for test are read initially in order to ensure that the cells are in good condition. The cells are then stored in a dry place of normal room temperature. The following readings are taken: (1) Initial voltage and short-circuit current. (2) Short-circuit current at the end of four weeks, eight weeks, and each eight weeks thereafter. (3) Voltage at the end of six months.

The cells are kept on the shelf until the short-circuit current has fallen below 10 amperes. This point is arbitrarily chosen, as it represents a point below which it would be difficult to market the cell. For practical purposes, the results are expressed as the number of months during which the short-circuit current remains above this cut-off point. Much more meaning, however, is attached to the rate at which the current falls, generally reported as the drop in amperage for a given period expressed as a percentage of the initial amperage. This is especially true when investigation of the quality of cells is the object. For practical purposes, however, the first rating given, *i.e.*, months to 10 amperes, is perhaps preferable.

The results from this test are largely indicative of increase in internal resistance, and bear no definite relation to the service which the cells may give. However, this information,

coupled with familiarity with a brand of cells, becomes a very good indication of its quality. It also serves to indicate any serious defects of manufacture.

The ammeter for reading short circuit current should be deadbeat, and with its leads should have a resistance of 0·01 ohm. Particular attention should be given to the temperature at which cells are stored, as the rate of deterioration is influenced to a marked degree by the temperature of the cells.

The ideal method for an open circuit deterioration test would be the determination of the decrease of service capacity due to storage over definite periods. This practice, however, would entail much labour and expense where the amount of testing to be done is large.

THE ADAPTABILITY OF TESTS TO THE NEEDS OF CONSUMERS.

The question may arise in the mind of the consumer as to what extent the cells he purchases should be tested. It obviously would not be practical for the small consumer to conduct tests on the same scale as those carried on by a consumer using many barrels of cells per year. It is impossible to formulate any set rules for sampling and testing for any consumer or group of consumers, as the amount of testing done must be regulated by the relation of the cost of testing to the value of the cells purchased. However, we present here suggestions as to the adaptability of these methods to several roughly classified groups of consumers.

The Small User.—In this class may be included the great percentage of consumers. We advise that every cell purchased be read for short-circuit current. Although this reading gives no direct indication of the service capacity of the cell, yet, if the reading is normal for that brand, it may be reasonably certain that the cell is in good condition. It would be impractical for the small user to provide himself with an expensive ammeter, as, for his purpose, a good make of pocket instrument will give readings sufficiently accurate.

The Small Dealer.—This class comprises those dealers who may dispose of from a few hundred to a thousand or more cells per year. The dealer is particularly interested in keeping the quality of his stock up to the standard. As cells are received a representative sample, say, 10 per cent. chosen at random throughout the lot, should be read with a reliable ammeter. If the readings are normal it would scarcely profit to make any further tests. For his protection all cells should be read with the ammeter before being delivered to customers.

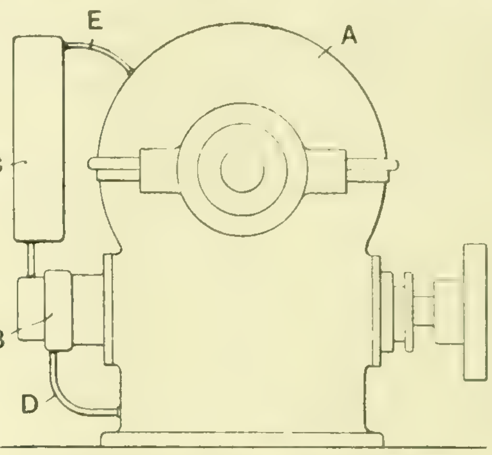
Telephone Companies.—The small telephone company consuming less than 10 barrels of cells per year could install a standard telephone test of small capacity by fitting suitable electrical contacts on a clock and connecting these with a telegraph relay in such a way as to cause the latter to open and close the dry-cell circuits. We would advise that such a test be maintained by each company and that periodical tests (at least four per year) be made on the shipments of cells received and also on small lots of other brands purchased from time to time for the purpose of test. The small company should also test a representative sample (say 10 per cent.) of all consignments received with a good ammeter.

The large telephone company using many barrels of cells per year can well afford to install an apparatus for carrying on the test suggested in this report. We would advise that a battery of three cells from each consignment received be placed upon the telephone test. In addition the short-circuit current and open circuit voltage should be read upon a representative sample of all cells received.

Gas Engine Manufacturer.—To the gas engine manufacturer it is important that the batteries furnished with his engine be the best cells obtainable from an ignition standpoint. As the apparatus necessary for carrying on the ignition test is quite inexpensive and as the test requires very little attention, the manufacturer of such engines purchasing a considerable number of cells should conduct the ignition test not only as a check upon the cells he is receiving, but as a basis for judging the merits of the different grades of ignition cells on the market. An ignition test upon six cells from every fifth barrel received with a maximum of two tests for a single consignment of cells, would probably be sufficient. Before being sent out with an engine the short circuit current on all cells should be read and those reading abnormally low (5 amperes below the average for the brand and grade) should be rejected.

COOLING OF WORM GEARS.

AN arrangement for maintaining a low temperature in connection with worm gears by means of efficient cooling by forced circulation of the lubricating oil or of water or air through the oil, thus avoiding the use of abnormally large gears or casings, has recently been patented by B. J. Shillito and R. Wallwork, Union Bridge Ironworks, Roger Street, Manchester. This is shown diagrammatically in the accompanying illustration, and comprises a pump or fan in com-



ARRANGEMENT FOR COOLING WORM GEARS.

bination with a radiator for the purpose of circulating the oil in the gear, or of circulating water or air through the oil, and thereby lowering the temperature of the oil and also the gear. Referring to the illustration, A is the worm gear casing containing the oil, B is a rotary pump or fan on the end of the shaft of the worm, and C is a radiator. The oil is drawn from the casing A by the pump B through the pipe D and forced through the radiator C and pipe E back into the casing A. In the case of water or air, the same is circulated by the pump or fan through the radiator and through piping arranged in the oil.

OIL ENGINES FOR MARINE WORK.

AT a recent meeting of the Institution of Automobile Engineers a paper on "The Importance of Design in Motor Engines for Marine Work" was read by Mr. R. G. L. Markham. The author divided motors for marine purposes into three general types: (1) The high-speed light petrol engine, with a sub-division in which refined paraffin was used as the fuel; (2) the heavier, slower-running type, using heavier petroleum fuel and generally known as the semi-Diesel type; and (3) the Diesel type proper, suitable for high powers and large vessels, where weight was not of importance. For the light type of engine the conditions to be observed were first that there should be as complete prevision and provision against breakdown as was humanly possible; and, secondly, extreme accessibility so that a breakdown might be remedied as quickly as possible. All accessories, such as carburetter, pumps, and ignition gear, should be so mounted that they were readily accessible, and no one part interfered with access to another. The piston should be accessible from the crank case without the need for taking off a cylinder. In the second class of engine simplicity and substantial construction became of far greater importance than in the first or light class, since the men who had to look after them were of the type who did not treat them with the care the designing staff might think desirable. In regard to the Diesel type—that was, machinery for ocean-going ships—there appeared to be no reason for departing from the general features of design found in the present-day steam engine. These had been evolved from years of experience, and the prejudices of the marine engineer were in favour of their continuance, while good reasons could be quoted against many of the innovations proposed by firms who were in the first place purely gas-engine builders, and who had had no previous experience of marine motor building. A Diesel engine should be of the ordinary steam engine type, so far as possible, with piston rod and crossheads, and the piston should be capable of being taken out in such a way as not to necessitate the breaking of a large number of joints.

THE INFLUENCE OF CARBON ON THE CORRODIBILITY OF IRON.*

BY C. CHAPPELL.

(*Concluded from page 688.*)

IN order to obtain some data as to the influence of time in a specific case under the conditions of test employed, a series of six bars of steel, No. 1 (R), were immersed at the same time under standard conditions, and removed at intervals of 21 days after each other. The results are given in Table VIII., and plotted in Fig. 4.

TABLE VIII.—*Influence of Time on the Rate of Corrosion.*

Mark.	Carbon per cent.	Length of Immersion in Days.	Weight before Immersion in Grammes.	Weight after Immersion in Grammes.	Loss in Weight per cent.	Corrodibility Ratio.	Alternating Stress Test. Reversals.
1·0	0·10	0	—	—			236
1·1	0·10	21	65·5066	65·4455	0·093	100	208
1·2	0·10	42	66·0786	65·9617	0·177	190	234
1·3	0·10	63	66·9738	66·7950	0·267	287	234
1·4	0·10	84	66·5420	66·3000	0·364	392	224
1·5	0·10	105	66·4796	66·1767	0·456	490	232
1·6	0·10	126	65·4132	65·0519	0·553	594	228
1·7	0·10	166	—	—	—	—	238

In this low-carbon steel the corrodibility is practically directly proportional to the length of immersion throughout the period covered by the test.

In view of Longmuir's interesting experiments on the mechanical deterioration of steels resulting from corrosion, the bars employed in this "influence of time" series were tested after immersion on Dr. Arnold's alternating stress testing machine. The usual standard conditions of test were employed. Similar tests were also carried out on the same steel before corrosion and after 166 days' immersion. The results, which are included in Table VIII., show that no appreciable change has been produced in the mechanical properties of the steel with five months' immersion in sea water.

Notes on the Nature of the Deposits on the Bars.—The deposits in general consisted, in the first place, of a complete outer layer of a light brown colour, which was flocculent in nature. This was easily removed on washing, and constitutes the usual "rust." Underlying this was invariably found a layer of darker brown colour, which was less flocculent and more adherent, but could usually be removed with comparative ease. Beneath this, on the surface of the bar itself, was found a thin layer of a very dark bluish-black colour. This was usually found in two forms. Sometimes it was very loosely adherent, and washed off fairly easily with rubbing, together with the dark brown layer mentioned above. The quenched and tempered steels were usually evenly and completely covered by a layer of this form, but the steels in the other states of treatment were only partially covered by this deposit. The other form, which was found in the majority of the steels, and usually in addition to the previous one, was mainly concentrated at the lower end of the bar, where it was very firmly adherent, and involved considerable difficulty in its removal. This bluish-black deposit tends to increase with a rise in the carbon percentage, so that it is probably largely composed of the carbide residue resulting from the disintegration of the surface of the bar, mixed with the ferrous hydroxide which forms the first stage in the passage of the iron into the ultimate Fe_2O_3 or ferric state of oxidation.

Notes on the Surfaces of the Corroded Bars.—The normalised, rolled, and annealed bars invariably showed a crystalline appearance on examination after the removal of the deposits. These markings were especially pronounced in the annealed steels, and tended to become finer with rise of carbon.

This type of surface was also found in the quenched and tempered steels in the case of steel No. 1, and to a slight extent in steels Nos. 2 and 3; but in the higher carbon steels the surface shows an even, amorphous appearance, with few or no signs of crystallinity occurring. This supports the explanation previously advanced accounting for the irregularity of the corrodibility results given by the low-carbon quenched and tempered steels, on the score of the incompleteness of the hardenite ferrite solution in these steels under the conditions of quenching.

Microscopic Analysis.—The microscopic features correspond quite normally to the structures demanded in pure iron-carbon steels by the respective carbon contents of the series. These have been previously described by Arnold and others, so that detailed description may therefore be dispensed with. The main feature is the strong tendency to lamination in the pearlite, which is not only found in the annealed steels, but to a considerable extent in the rolled steels also. The pearlite in the normalised steels is mainly of the diffused variety. In the unquenched specimens of the 0·96 per cent. carbon steel, the free cementite is found as specks evenly distributed over the field.

Microscopic Examination after Corrosion.—This section of the work has been confined to the normalised, rolled, and annealed steels. The ordinary microsections used for the microscopic analysis were employed, and were taken from the treated bars before turning down to finished size. The edges of each microsection were coated with paraffin wax to prevent any mill scale exerting galvanic action on the surface which was being examined.

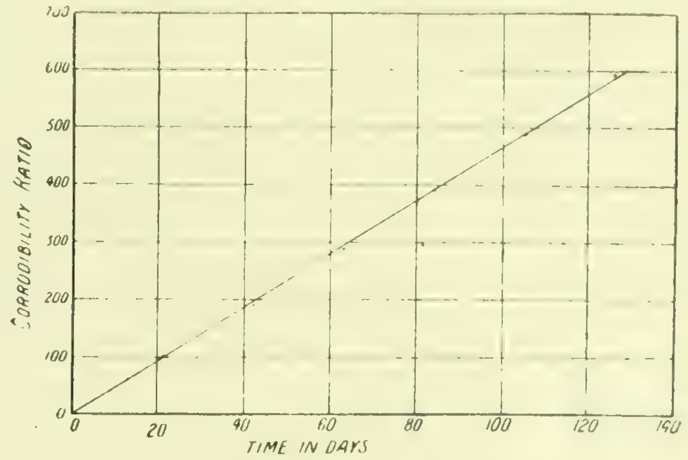


FIG. 4.—INFLUENCE OF TIME ON RATE OF CORROSION.

The sections were polished exactly as for the usual microscopic examination, and then subjected to progressively longer immersions in sea water. They were then examined under the microscope, after the removal of the oxides by vigorous rubbing on selvyt cloth.

(*a*) **Steels Nos. 1, 2, and 3: Mild Steels.**—These steels are taken together because structural steels are usually found within this carbon range, and it is in connection with this class of steels that the question of corrosion becomes most important. The first feature in the process of corrosion is the appearance of numerous dark spots due to the action of the manganese sulphide. After about two hours' immersion the corrosion of the pearlite areas becomes faintly visible. This pearlite action rapidly increases in vigour, and begins to extend its influence to the immediately adjacent ferrite. The attack next develops at the boundaries of the ferrite crystals, and after 48 hours' immersion this feature becomes very marked. So far as can be seen, this action along the ferrite boundaries is different from the production of boundary lines by ordinary etching effects, and suggests distinct penetration along these ferrite junctions. This may account to some extent, at any rate, for the well-known deteriorating influence exerted by prolonged corrosion upon the mechanical properties of mild steel. With further progress of time, selective corrosion of various ferrite crystals sets in, some crystals corroding with comparative rapidity, whilst others remain quite untouched. This selective action is quite irrespective of the influence of the pearlite areas, and can be seen commencing even after 18 hours' immersion. Pitting also becomes pronounced in the ferrite after four or five days, especially in the regions surrounding the pearlite areas. This action together with the corrosion of the pearlite and adjoining areas, and the selective attack in the ferrite portions, continues, until, after 21 days' immersion, two distinct types of field begin to develop. The main portion consists of a dark corroded background, containing the pearlite areas and some of the ferrite. Under the microscope this background is confused

* Paper read before the Iron and Steel Institute, May, 1912.

and generally indistinct in its features, with the exception of a crystalline structure which is sometimes evident under the low-power magnification. The remainder of the field, varying from about 30 per cent. of the whole in the case of the 0·10 per cent. carbon steel, to approximately 10 per cent. in that of the 0·30 per cent. carbon steel, consists of fairly bright and comparatively unattacked ferrite areas. The pits previously mentioned are much more distinct and numerous, and show distinct signs of geometrical form. Three, four, and five sided figures, suggestive of the various sections of the cube, are seen distributed over these ferrite areas, and can also be observed, although with greater difficulty, in the ferrite portions of the corroded background.

The sections were then examined, after 20 weeks' immersion, so as to obtain information regarding the structure, after a period of time comparable in length to those employed in the corrodibility determinations. The main background, consisting of the most deeply corroded portions, cannot be resolved under the microscope, except in some areas where the pits in the ferrite show up more clearly by reason of their sharp geometrical form. The bright ferrite areas remain, but in smaller proportion than before, varying from 20 per cent. to 5 per cent. of the whole, with rise of carbon from 0·1 per cent. to 0·3 per cent. respectively. The proportion of these bright ferrite areas is larger in the annealed than in the normalised steels. Careful examination further revealed the fact that the surface of these bright ferrite areas was at exactly the same level as the original surface of the specimen, as represented by a few areas which had been preserved from attack by a covering of wax accidentally received whilst coating the sides. This identity of level was conclusively proved by the two areas both being in prefect focus at 400 diameters magnification, with the same adjustment of the objective lens. Thus, in very mild steels, an appreciable proportion of the ferrite may remain completely uncorroded even after very prolonged immersion in sea water.

Intermediate in depth between the bright ferrite and the deeply corroded background are also found occasional areas of partially corroded ferrite, in which the process of attack has not proceeded so vigorously as in those areas found in the background. The pits in the ferrite constitute a most striking feature, on account of the extremely sharp development of their geometrical form as a result of the prolonged immersion.

On detailed examination being made of the shape of these pits, it was found that those in the bright ferrite areas were almost exclusively rectangular, and principally square. Indeed, the total number of non-rectangular pits was not usually more than 10 or 15 in the whole of the bright ferrite areas, whereas a similar number of rectangular pits could often be found in a single one of these areas. These non-rectangular pits were not usually complete.

The pits in the partially attacked ferrite, which has been previously described, were found to contain a very much larger proportion of non-rectangular sections than was found in the unattacked ferrite areas; whilst the pits in the deeply corroded ferrite in the background showed a considerable preponderance of the non-rectangular sections, so far as they could be clearly seen under the microscope.

The pits in any particular ferrite crystal were invariably identical in shape, and in the directions of their main axes. They are evidently controlled, therefore, by the internal structure of the crystal itself, so that differences in the shape of the pits in respective crystals may be taken as indicative of differences in the relationship existing between the surface exposed to attack and the axes of those ferrite crystals.

In view of the previously described variation in the general shape of the pits with increase in corrodibility, it follows that the relationship between the crystallographic axes of a ferrite crystal, and the particular surface of it which is exposed to attack, is *cæteris paribus*, an important factor in determining its rate of corrosion. This is quite in accordance with previous knowledge regarding the variation of the solution pressure of crystal faces, with their relation to the crystallographic axes, but its practical importance as a factor in the corrosion of iron and mild steels has not previously been recognised.

This factor has an important bearing on the corrosion of steel castings, where the crystals on the exterior tend to grow perpendicular to the surface during solidification. The relation of the exposed surface to the axes of the respective crystals is practically the same in every case, so that differences of potential due to this factor will be at a minimum, and the resistance of the surface to corrosion will be proportionately greater in consequence. Other reasons have been advanced in the past to account for the generally observed resistance of castings to corrosion, and are probably to some extent correct, but this additional phase of the question is one which must also be kept in mind.

Concerning the much debated question of the corrosion of pure iron, it may also be remarked that it is difficult to see how even the purest iron, in the ordinary form, could be prevented from passing into solution when immersed in a conducting liquid. Differences of potential between the ferrite grains themselves are inevitable, in view of the unavoidable variations in the orientation of the crystals, so that all the elements of galvanic action would consequently exist. The author would venture to suggest this new factor as an addition to Dr. Friend's already lengthy list of the "various factors influencing the rate of corrosion of relatively pure iron."

(*b*) **Steels 4, 5, and 6.** The large proportion of pearlite in these steels causes corrosion to take place rapidly. After one or two weeks' immersion, it is practically impossible to distinguish any clear features in the larger portion of the section by means of the microscope. After 20 weeks' immersion the general field is confused and indistinct, showing the round pits, due to manganese sulphide. Steel No. 4 shows ferrite areas containing geometrically-shaped pits, but only in the case of the annealed steel are any of these ferrite areas bright and outstanding. In the annealed specimens of steels Nos. 5 and 6, mainly in the latter, a similar effect is also observed in the pearlite, where occasional areas are found distinctly raised above the general background.

The *effect of decarbonisation* was markedly shown in the microscopic investigations. The decarbonised edge of anneal steels was invariably much less corroded than the remainder of the specimen, and usually remained comparatively bright. A specimen of a low-carbon steel containing roaks also showed the same effect after corrosion in sea water, the fringe of the roak being but little attacked. The decarbonised surface of annealed steels would appear, therefore, to be of considerable value in protecting the steel from corrosion.

The *action of oxides* in the corrosion of steel affords peculiar microscopic features. Several microsections, with some mill-scale still on the edges, were immersed without any wax coating on the sides. The resulting effect upon the surface adjoining the mill scale was the production of a large number of roughly circular pits, which extended some distance away from the mill scale itself. The presence of the bluish-black deposit, which has been previously described, produces identically the same effect.

Solubility.—The solubilities of all the steels have been determined in several acids, and also their electro-potentials, after 48 hours' immersion. Further investigation into the factors involved in the solution of steel in acids is intended before any detailed communication on the influence of carbon and treatment on solubility is made. It may be stated, however, that the absence of correlation between the corrodibilities of the steels and their solubilities in 1 per cent. sulphuric acid solution is very marked. The so-called acceleration tests, in which the relative solubilities of steels in 1 per cent. sulphuric acid solution are taken as indicative of their relative corrodibilities in neutral solutions, are entirely misleading and unreliable.

SUMMARY.

1. **Influence of Carbon on Corrodibility.**—(*a*) In rolled, normalised, and annealed steels the corrodibility rises with carbon contents to a maximum at saturation point (0·89 per cent. carbon) and falls with further increase of carbon beyond this point. (*b*) In quenched and tempered steels a continuous rise in corrodibility occurs with increase of carbon within the range investigated (up to 0·96 per cent. carbon), no maximum corrodibility at saturation point being found in these steels.

2. **Influence of Treatment on Corrodibility.**—Quenching increases the corrodibility to a maximum; annealing tends to reduce it to a minimum; whilst normalising gives intermediate values. The influence of tempering varies with the tempering temperature.

3. **Factors Determining Corrodibility.** — The electromotive forces between the pearlite and ferrite, and between the components of the pearlite itself, are the principal factors determining the corrodibility of unsaturated pearlitic steels above 0·4 per cent. carbon. In mild structural steels, this galvanic action, due to differences of potential between the constituents, is accompanied by galvanic action between the ferrite crystals themselves. These differences of electro-potential between the ferrite crystals are the result of differences in their orientation. The state of division of the pearlite, and the presence of internal stresses in the steel, may also exert a considerable modifying influence on the foregoing factors.

4. The influence of time on the rate of corrosion varies with different steels. In a low-carbon steel it is shown to be practically directly proportional to the length of immersion.

5. The influence of corrosion on the resistance offered by a low-carbon steel to alternating stress is not appreciable within a period of five months' immersion.

6. Three per cent. of tungsten produces practically no change in the corrodibility of carbon steels.

7. Decarbonisation increases the resistance to corrosion.

8. The two oxides, FeO and Fe_3O_4 (mill scale), both exert a microscopical pitting effect on steel when in contact with it in sea water.

In conclusion, the author would state that the work recorded in this paper has been carried out under the auspices of the Research Committee appointed by the British Association to investigate the influence of elements on the corrodibility of iron. The author wishes to express his indebtedness to the other members of the committee—Prof. J. O. Arnold (chairman), Prof. W. P. Wynne, Prof. A. McWilliam, and Mr. F. Hodson, for facilities and assistance afforded in the carrying out of the work, and to Dr. W. E. S. Turner (secretary), whose kindly counsel and help in many difficulties call for an especial tribute of gratitude. The author's best thanks are also due to Mr. J. H. Harrison for the great care shown in the preparation and treatment of the test-pieces.

AN ELECTRICALLY-DRIVEN REVERSING ROLLING MILL.*

BY WILFRED SYKES.

About the middle of 1905 it was decided by the Illinois Steel Company to make enquiries regarding the possibility of installing an electrically-driven reversing universal plate mill, and the engineers of that company made some preliminary experiments with a view to determining the power requirements and the probability of the success of such an installation. After sufficient data had been obtained, so that a power curve could be given to the manufacturers of electrical machinery, propositions were invited, and in the spring of 1906 a contract was let for the complete installation. The machines and apparatus were designed in June, 1906, and the complete equipment was delivered by the end of the year, and started in operation at the beginning of 1907.

In the meantime the first European installation at Hildegradehuetts was started in operation, and before the plant of the Illinois Steel Company was used commercially, a second European plant was started. It is interesting to note, however, that the installation of the Illinois Steel Company was the second plant of this type to be ready for service. This plant has been in operation for approximately five years, and it is believed that a description of some of the details of the installation and the results obtained may be of interest. The Illinois Steel Company was one of the earliest of the American steel works to utilise the blast-furnace gases in gas engines for supplying power for operating its mills, and the principal reason that led to the installation of this pioneer mill was the realisation of the necessity for greater economy in the generation and distribution of power in such works.

The characteristics of the universal plate mill are such that it is necessary to have the greatest flexibility possible in the driving machine, and it was realised that by installing an electric motor, controlled by regulating the field of a special generator supplying it with power, an ideal system would be obtained enabling all classes of work to be handled in the most desirable manner, the earlier passes being handled at low speeds and the finishing passes at high speeds, it being possible to obtain the maximum output of the mill on account of the flexibility of the speed control.

When the plant was installed some doubt was felt as to the possibility of quick reversing, but in operation it was soon found that the electric plant was capable of handling material more quickly than similar steam-driven mills and more quickly than the material can be handled by the tables. After the plant had run for some time it was demonstrated that the electric equipment was not the weakest link in the chain. The following brief description of the mill and electrical apparatus will show, to some extent, the nature of the problem involved in the electrification and the methods adopted to ensure successful operation.

The mill is of the 2-high universal type, designed for rolling plates up to 30in. wide from slabs up to a maximum of 10in. thick. The main horizontal rolls are 24in. diam., and have a face of 34in. The vertical rolls, of which there are four, two on either side of the main rolls, are 14in. diam. and have a face of 13in. The mill was designed to roll plates of all thicknesses, and, on account of its flexibility, is used to a very great extent for handling small orders. The motor generator set, for supplying power to the main roll motors, is erected in the same room as the main roll motors. Apart from the method of driving, the mill is not appreciably different from similar steam-driven installations.

The slabs are heated in two furnaces and are carried by an approach table to the mill. When rolled, the plates are taken in two hot beds, and after cooling to a shearing table, where they are cut to size and are then ready for straightening and shipment. The mill tables are operated by four 50 h.p. mill motors, the control being located at one side of the mill, close to the control for the main motors. The mill and the motor room are spanned by a 300-ton crane, which is capable of handling all parts of the equipment, with the exception of the flywheels of the motor generator set.

In Fig. 1 a general view of the mill and motors is given, which shows the appearance of the complete equipment. The motors are enclosed in a separate room to protect them from

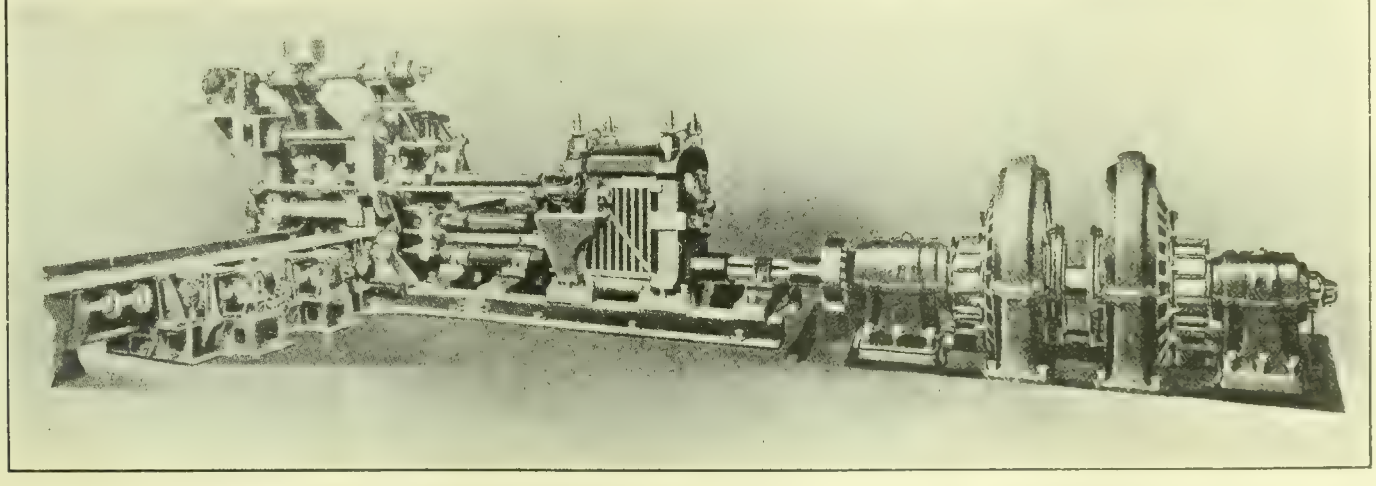


Fig. 1. Universal Plate Mill showing the Motor Drive. Illinois Steel Company.

* Paper read before the American Institute of Electrical Engineers, April, 1912.

the mill dust. In the illustration the auxiliary motors for the setting of the rolls are shown, that for the horizontal rolls being mounted to the left of the mill housings and that for the vertical rolls to the left of the pinion housings.

The setting of the horizontal rolls is varied by means of an electrically-driven screw-down, the screws being operated by a 50 h.p. mill type motor. The setting of the vertical rolls is controlled by means of a 30 h.p. mill type motor, the position

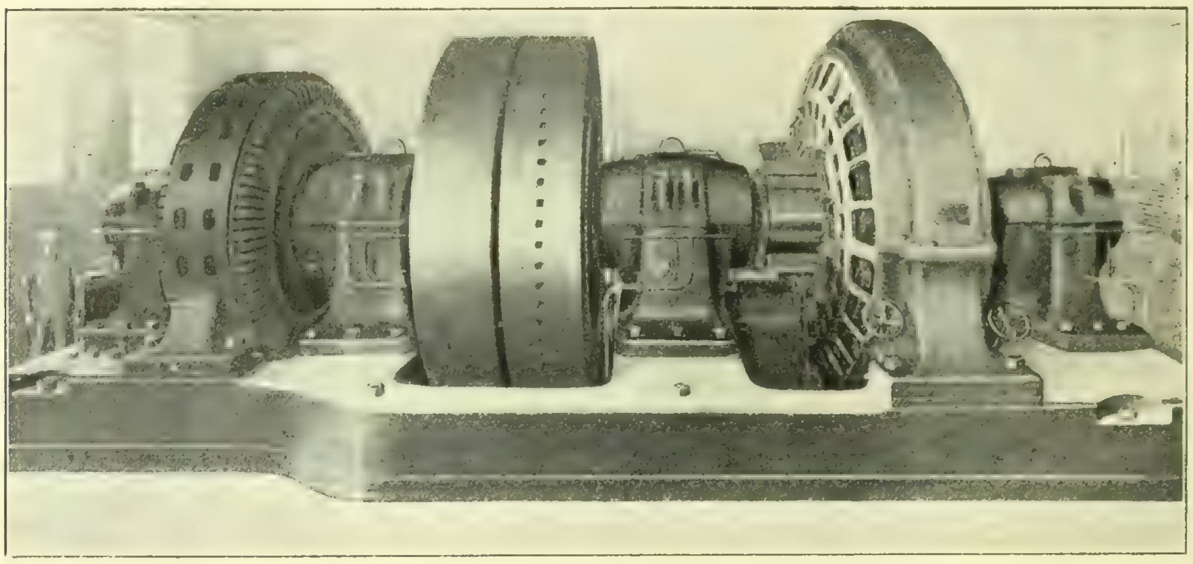


FIG. 2.—MOTOR GENERATOR SET INSTALLED IN THE PLANT OF THE ILLINOIS STEEL COMPANY.

of the rolls being shown by the usual micrometer type of indicators. The main rolls are connected to the pinion housing by suitable spindles, arranged to allow a movement of about 12in. The lower pinion is driven from the roll motor through a coupling of the usual mill type, arranged to allow for considerable wear in the pinion shaft bearings. No flexibility is allowed for in the drive from the motor to pinions. The mill was designed for a maximum speed of 150 revs. per minute, but it has been found in practice that about 100 revs. per minute is all that can be conveniently used, on account of the comparatively short plates rolled.

The capacity of the mill varies considerably on account of the material rolled, and depends more on the product required than on its capacity for rolling, and therefore definite figures cannot be given for the output for any particular product. The performance of a mill of this type cannot be compared with that of a blooming mill rolling practically one size of

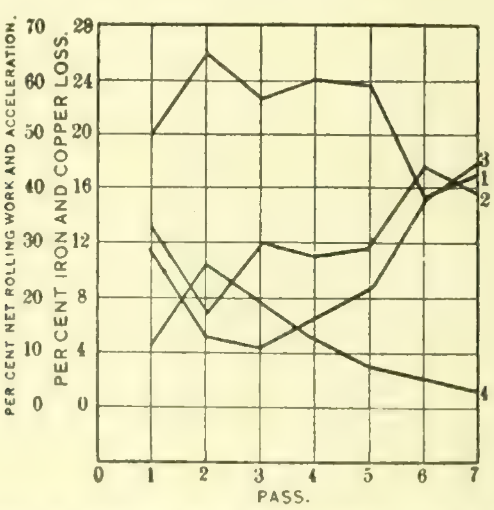


FIG. 3.—ANALYSIS OF POWER INPUT TO ROLL MOTORS WHEN ROLLING PLATE (See Fig. 6)

1.—Percentage of net rolling work to total input. 2.—Percentage of acceleration work to total input. 3.—Percentage of friction and iron loss to total input. 4.—Percentage of copper losses to total input.

material. The equipment of this mill had to be sufficiently large to handle the heaviest slabs that can be rolled, although the work is comparatively light most of the time and consequently the tonnage suffers.

In deciding upon the system to be used for driving the mill, and the control of the motors, the experience that had been gained in the design of large hoisting plants of the Ilgner type was drawn upon. In 1903 experiments had been made to determine the possibility of rapid reversing and the sensitiveness of this system of control, on a large hoisting plant. The results obtained indicated that, from the standpoint of control, this system gave all that could be desired, providing the proper provision was made to obtain a rapid change in the generator field. The ordinary solid field generator cannot follow rapid change in the excitation on account of the eddy currents which are set up and which oppose any change of field strength. It is, therefore, necessary to design the machine with a completely laminated magnetic circuit so as to overcome this characteristic of the ordinary generator when working under the conditions met with in such service. The importance of having the voltage of the generator follow the changes of excitation quickly is very great from an operating standpoint and this condition has been very well fulfilled in the Illinois Steel Company's installation.

The roll motors are connected to a double commutator generator without any starting resistance, each motor being connected to one commutator. This generator is driven by means of a 3-phase induction motor and a 100-ton flywheel is mounted on the same shaft. The roll motors are separately excited, the excitation being constant, with speeds up to 100 revs. per minute, and the polarity is not changed. The direction of rotation and speed of the roll motors is controlled by changing the polarity of the generator and varying its field strength, thereby varying the voltage applied to the armatures of the roll motors. This system avoids rheostatic losses, except in the field circuit, and enables any desired speed to be obtained, independent of the load.

The load on the generator naturally varies rapidly over a large range, the rate of change being at times 3,000 h.p. to 4,000 h.p. per second during acceleration and 8,000 h.p. to 10,000 h.p. per second when braking. From the standpoint of the power supply, such a load would be highly undesirable, even for a very large power house, and could not be handled at all by gas engine driven stations of moderate capacity, such as usually found in steel mills. In order to equalise these fluctuations, the flywheel was provided to deliver energy during the

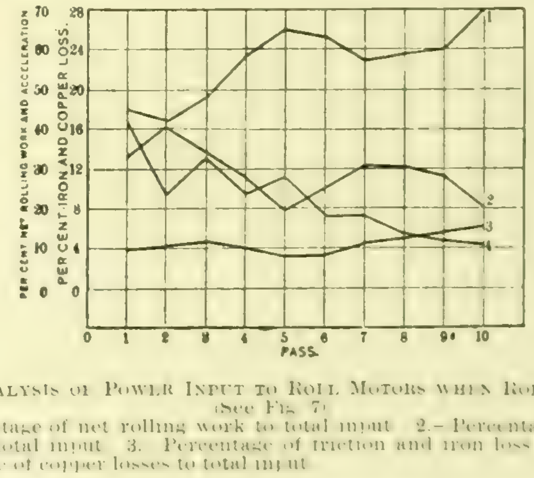


FIG. 4.—ANALYSIS OF POWER INPUT TO ROLL MOTORS WHEN ROLLING PLATE (See Fig. 7)

1.—Percentage of net rolling work to total input. 2.—Percentage of acceleration work to total input. 3.—Percentage of friction and iron loss to total input. 4.—Percentage of copper losses to total input.

periods of great demand and to store energy during periods of light load, and so that the flywheel may give up some of the energy stored in it the speed must be reduced, and to store energy the speed must be increased.

To enable the flywheel to assist the 3-phase motor in driving the generator, an automatic slip regulator was provided, which introduces resistance into the rotor when the current reaches a certain value, the speed being thereby reduced, and a portion of the energy stored in the flywheel is used for driving the generator. When the load on the generator is reduced, the resistance is automatically cut out, the speed consequently increasing and energy is thereby stored in the flywheel. In practice the maximum load on the line due to the reversing set is approximately one fifth of the maximum load of the generator. By properly setting the regulator in

relation to the work to be done the input to the motor generator can be maintained practically constant. It will be noted that the driving motor of the set is considerably smaller than the generator, which is due to the fact that the latter must be designed to carry the high peak loads, and as the heating of the armature is due principally to the copper loss, which varies as the square of the current, a much greater capacity is required to deliver a certain amount of power than would be necessary if the load were constant. The load on the induction motor does not vary greatly, and consequently it is designed to carry only the average load.

To protect the generator and driving motor against excessive overloads, due to stickers or cold slabs, overload trips for

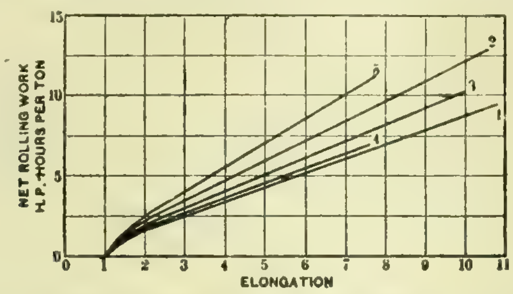


FIG. 5.—TYPICAL TESTS, SHOWING POWER REQUIRED TO ROLL PLATES FROM SLABS.

	Slab, ins.	Plate, ins.	Temperature. Degrees Fah.
1........	4 × 21½ × 95	to ⅜ × 21¼	2,160 to 1,536
2........	4 × 21½ × 60	to ⅜ × 21½	2,172 to 1,578
3........	4 × 8 × 100	to ⅜ × 8⅝	2,208 to 1,944
4........	6 × 9½ × 90	to ¾ × 10	2,076 to 1,800
5........	6 × 7¾ × 82	to ¾ × 8	2,016 to 1,692

the circuit breakers are provided in each armature circuit, which are arranged to open the circuit at a load corresponding to, approximately, 8,000 h.p. The primary circuit of the induction motor is provided with the usual instruments and overload protection. Speed meters showing the speed of the rolls, and double reading ammeters are provided on the operating pulpit, for the guidance of the operator. It has been found, however, that the electrical equipment is capable of performing heavier work than the mill, so that the operators are controlled during rolling more by the limitations of the mill than those of the electrical equipment.

The driving motors have a nominal rating of 2,000 h.p. each, making a total of 4,000 h.p. for the set. The motor was divided into two units with the object of reducing the armature diameter, and consequently the inertia, and at the same time to facilitate handling the heavy current which at 8,000 h.p. is about 11,000 amperes. They are designed for a normal armature voltage of 75, and 220 volts excitation.

When the plant was designed it was proposed to increase the speed from 100 to 150 revs. per minute for the longer passes, and, so as to ensure that the flux in the motor fields would follow the quick changes of the exciting current, the magnetic circuit was laminated. Experience gained from the operation of the plant has shown that this refinement was unnecessary although required in order to meet the original guarantees for acceleration and reversal asked for.

The two armatures of the machines are mounted on one shaft, supported by two bearings, the field frames being mounted side by side on the bedplate. The laminations are supported by a cast-iron frame which is split horizontally to facilitate repairs. The machines are of the commutating pole, compensated type, the compensating windings being embedded in the face of the main poles. The armatures, which are 7ft. 6in. diam., were specially constructed to stand the severe shocks anticipated with this class of work and to be capable of withstanding the severe stresses due to the rapid reversing and acceleration. On this account, very great attention was paid to the methods of supporting and holding the armature windings, a special steel ring being provided to support and fasten the end connections rigidly where they connect to the commutator lugs.

Although very high efficiency in the motors of such an installation is not of very great importance, considering the other losses, yet it is desirable, inasmuch as it affects the heating of the machines, and a well-designed machine will naturally have high efficiency.

The generator of this set is of the double-commutator type, and embodies some design features of special interest. It was decided to use a double-commutator type machine, so as to reduce the current to be collected from a single commutator, thereby allowing a single comparatively high speed machine to be used. The field is of the laminated type, so built that it will answer changes of field current very rapidly, this being necessary to obtain quick reversing and speed changes. The machine is of the commutating pole compensated type, similar to the roll motors, the diameter of the armature being the same. The normal full speed of the generator is about 375 revs. per minute and the minimum speed about 300 revs. per minute. At 375 revs. per minute the voltage of the generator with full field is, approximately, 600.

The generator is designed for a normal capacity of approximately 3,000 kw. and a maximum capacity of about 6,400 kw. Special attention was given to the design of the generator, to ensure good commutation under the severe conditions of operation. The commutating pole and compensating windings are not shunted, care being taken to render this unnecessary, so as to avoid any trouble due to difference in the self-induction of the windings and shunt affecting the division of the current with rapid changes of load. The necessity of commutating the maximum current with a weak field requires that the closest attention be given to commutating characteristics of the generator. The motor for driving the generator and flywheel has a normal rating of 1,300 h.p., and is designed for 3-phase, 25-cycles, 6,600 volts, eight poles. It is of the wound rotor type, the rotor circuit being controlled by an automatic slip regulator, previously referred to, and is of the usual standard construction.

The flywheel of this set presents some interesting features, as, owing to difficulties in transportation and in obtaining reliable steel castings, the wheel was built of comparatively thin punched laminations on a steel spider, the sheets being bolted between cast-steel end rings. The peripheral speed of

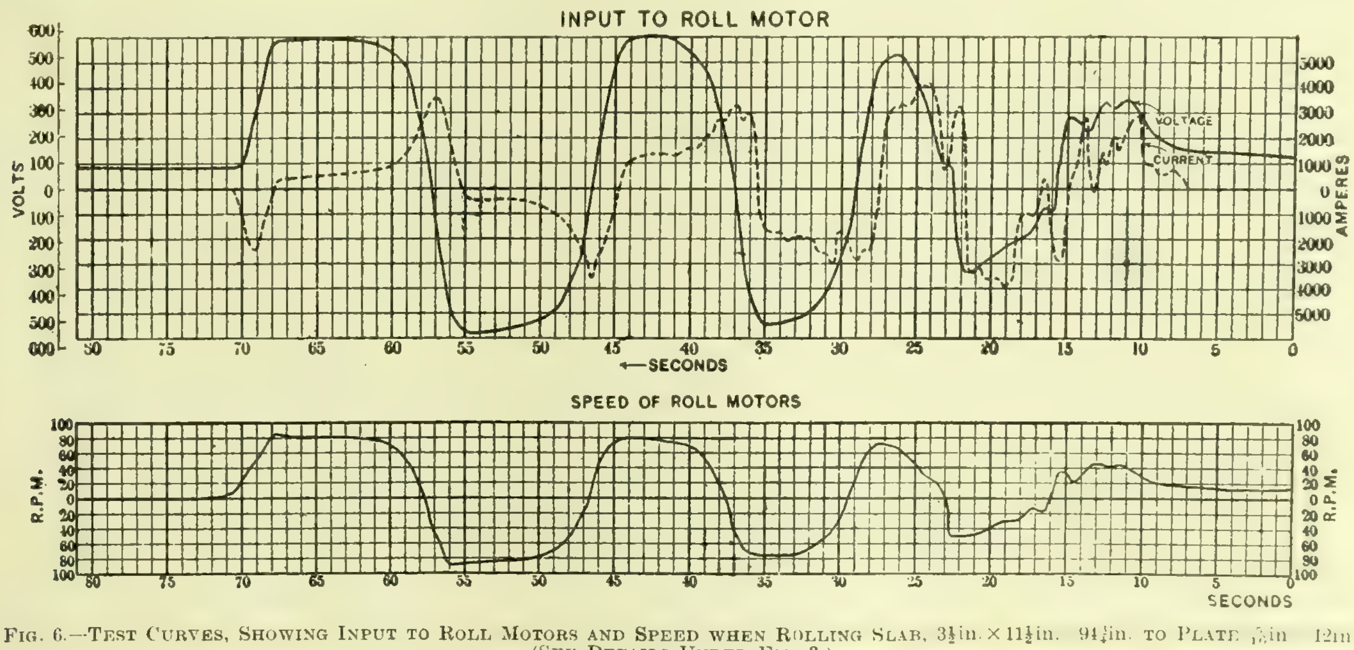


FIG. 6.—TEST CURVES, SHOWING INPUT TO ROLL MOTORS AND SPEED WHEN ROLLING SLAB, 3½in. × 11½in. 94¼in. TO PLATE ⅜in × 12in. (SEE DETAILS UNDER FIG. 3.)

the wheel at 375 revs. per minute is 15,500ft. per minute. In order to facilitate handling, the wheel is built in two parts, each weighing 100,000lbs., the total weight therefore being 100 tons. The flywheel effect of this wheel is 5,500,000ft.-lbs., and under normal conditions of operation, the speed of the set seldom falls below 320 revs. per minute, and the input does not as a rule exceed about 900 kw. The energy stored in the wheel at full speed is 250,000 h.p. seconds, and the amount given up when the wheel slows down to 300 revs. per minute is 90,000 h.p. seconds.

A view of the complete machine is shown in Fig. 2. The rotating parts are supported by four bearings, the flywheel having a bearing on either side and a separate shaft. The shafts for the motor and generator are supported at one end by a bearing, and at the other are bolted to the flywheel shaft. The maximum bearing pressure has been limited to approximately 80lbs. per square inch. Both machines and the flywheel are mounted upon a single base plate, which is securely fastened to the foundation by numerous bolts. All bearings are water-cooled and oiled from a central gravity oil system so as to ensure a continuous supply of oil to all wearing parts. In order to facilitate starting the set, a pneumatic barring gear is provided, controlled by a hand-operated triple valve.

For controlling the excitation of the generator, a special controller, operated on the principle of a Wheatstone bridge, was designed. The current handled by this controller is, approximately, 50 amperes, with maximum excitation, which pointer was recorded by causing a spark to pass from the end of the pointer through the paper to an insulated plate. In designing these instruments provision was made to avoid introducing errors in the readings due to the static effect of the high-tension current for the spark. The speed recording instrument for the roll motors had a centre zero so as to record both directions of rotation.

The speed of the motor generator set was also recorded, to determine the amount of energy given up or absorbed by the flywheel during the period of test. The instrument used was similar to that adopted for the recording of the motor speed, except that provision was not made for recording the speed in both directions. In order to obtain a large reading for a comparatively small change of speed, a battery was connected to oppose the magneto, and the meter recorded the difference in the potential of the magneto and the battery. All the instruments, including the oscillograph and the speed meters, were provided with a time-recording device, all of these attachments being controlled by a single contact-making clock.

The input of the motor generator set was determined by means of a wattmeter of the same type as the speed meters. In addition to the above apparatus, provision was made for recording signals from the mill. In the mill, records were obtained as to the size and weight of material rolled and the reduction per pass, and at the same time readings were taken to determine the temperature of the metal. These tests gave, simultaneously, readings of the input to the roll motors and the input to the motor generator set at the speed of the set

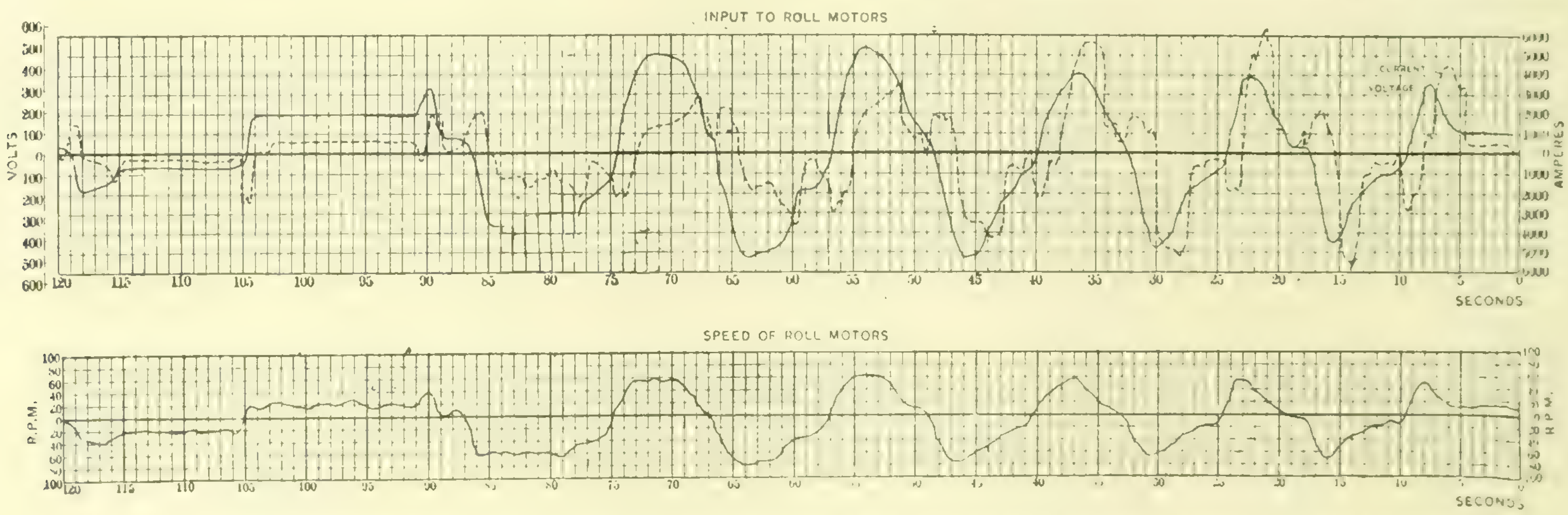


Fig. 7.—Test Curves, Showing Input to Roll Motors and Speed when Rolling Slab, 3in. × 30¼in. × 75¼in. to Plate [illegible] in. × 30in.

can be readily handled by a controller of the face plate type. The slip regulator for automatically varying the rotor resistance, so as to limit the input, consists of a number of pneumatically operated switches, arranged in groups, their operation being controlled by two relays. One of these relays causes the switches to drop out when the current in the primary of the motor reaches a certain value, and so long as this relay is open the switches will continue to drop out successively. When the current reaches a normal value the relay closes and no further switches are opened. When the current falls below the normal, the second relay drops, and causes the switches to automatically close in the proper order, and in this way the input to the motor, under normal operating conditions, is maintained approximately constant.

After five years operation of the plant it was decided that it would be advisable to make a complete set of tests, to determine not only its operating characteristics, but also whether such an installation could be improved upon and how closely the designed capacity approximated to the actual operating conditions. Owing to the difficulty in obtaining suitable apparatus to make such tests, most of the instruments were specially designed and built for this test. The current in the motors varies, under normal conditions, so rapidly that ordinary indicating or recording instruments were not suitable and it was, therefore, decided to use an oscillograph for recording the direct current voltage and current. The speed of the roll motors was recorded by means of a special graphic recording meter, controlled by a suitable magneto, driven from the motor shaft. The recording instrument was especially designed so as to be capable of following rapid changes in speed, and to avoid errors usual with graphic instruments. It was decided to avoid the use of a pen for recording and the position of the and motors. With this information, together with the known characteristics of the apparatus, and the data obtained as to the work done by the mill, it was possible to obtain a complete analysis of the power requirements and operating characteristics. While it is not possible within the scope of this paper to go into detail as to these tests, a few characteristic curves are given which may be of interest.

Fig. 6 shows the power required for rolling a slab, 3½in. by 11½in. by 95in., weighing 1,080lbs., to a plate $\frac{5}{16}$in. thick by 12in. wide, and 1,060in. long. From these curves it will be seen that the maximum current was approximately 1,100 amperes, and the maximum braking current about 2,350 amperes. The maximum speed of the rolls during this test was 86 revs. per minute during the sixth pass, whereas in the first pass the maximum speed was 50 revs. per minute. The total time required from beginning to end of the test was 58 secs., showing a maximum capacity when rolling this size material of approximately 30 tons per hour. The temperature of the metal varied during the test from 1,920° Fah. to 1,800° Fah.

In Fig. 8 is shown an analysis of this test, which gives the relation between the total input to the roll motors and the various items. It will be seen that the percentage of net rolling work averages about 55 per cent. The input required for acceleration is about an average of 30 per cent. The loss due to friction of the mill and from loss in the motors is approximately 10 per cent. The reason for the very large drop in the percentage of net roll work in the last two passes is the fact that the draft was comparatively light on these two passes.

The comparatively large proportion of the input required for acceleration shows the importance of keeping the inertia as low as possible, and the great advantage of the voltage control system is that it enables a considerable proportion of this

energy to be recovered. In this particular test, the total energy required to accelerate the motors for the seven passes was 11,800 h.p. secs., and there was returned by the motors to the generator 8,317 h.p. secs., or somewhat more than 70 per cent. It should be noted that with this system the energy taken from the generator is only half what it would be if rheostatic control were used, and that with the latter system none of the energy would be recovered. In this test if rheostatic control had been used, the total energy required for acceleration would have been 23,600 h.p. secs., which would have increased the total net input to the motor about 50 per cent.

In Fig. 7 are shown the curves when rolling a slab 3in. by 30in. by 76in. weighing 1,960lbs. to a plate ⅜in. thick by 30in. wide. The total time of the test was 100 secs., indicating a maximum capacity of the mill when rolling these slabs of approximately 36 tons per hour. It will be seen from these curves that the maximum loads are considerably higher than shown in Fig. 6. In this case, the maximum current input is slightly in excess of 6,000 amperes, and the braking current reaches a maximum of, approximately, 3,150 amperes. The maximum speed of the mill did not exceed 75 revs. per minute during any pass. The temperature of the metal during this test varied from approximately 2,040° Fah. to 1,300° Fah.

In Fig. 4 is shown an analysis of this test, from which it will be seen that the percentage of net rolling work to the total input gradually increased, and the percentage of power required for acceleration decreased. The copper losses decrease on account of the maximum current being smaller, and naturally the friction loss increases as the mill is running the greater percentage of the time. The percentage of energy returned by the roll motors was about 62 per cent. of the input for acceleration.

In Fig. 5 are shown some curves of the net rolling work per ton plotted against elongation, and it will be seen that the variation is considerable. The difference in the total power required may show a much greater variation than given but these curves will indicate in a general way how the net rolling work varies with the displacement of the metal. In a test made when rolling a certain slab, in 7 and in 15 passes, the net rolling work showed a difference of about 10 per cent., but the total input varied about 50 per cent., due to the reduced capacity of the mill when rolling at the lower rate. Such points as these show the importance of a very close examination of operating conditions when designing a mill of this kind, and to ensure success an electrically-driven reversing rolling mill requires very careful engineering, as the problem is not so much to get a mill that will work, as to get one that will work economically.

In this mill it is the general practice during the earlier passes to have the feed rolls running at full speed in the opposite direction to main rolls, so that when the slab leaves the mill it is returned in the shortest possible time. In spite of this, the main motors are easily capable of reversing in ample time. An examination of a large number of tests on this and other mills shows that the average rate of acceleration used does not exceed about 20 revs. per minute of the rolls per second, the maximum being about 30 revs. per minute per second. The rate of retardation is, however, very much greater and generally varies between 40 revs. and 50 revs. per minute per second.

The overall efficiency of the plant depends in the first place upon the size of equipment to the material to be rolled. As already pointed out, a mill of this kind cannot be compared to one rolling only a single product, in which case the operating characteristics can be very accurately predicted. As this mill will be often underloaded, the efficiency naturally suffers, which is true, independent of the system of driving.

The results obtained from this mill indicate that, although the equipment was built six years ago, it compares very favourably with some of the latest designs, and is quite capable of meeting the most severe service it may be called upon to perform. In new designs, certain features would be improved upon, with the object of somewhat simplifying the equipment from a manufacturing standpoint, but it is not believed that any great improvement could be made from an operating standpoint, as since it has been in regular service the electrical equipment has given no trouble. The experience gained has shown that the engineers of the Illinois Steel Company were thoroughly justified in undertaking this pioneer installation without having any precedent whatever to work upon.

THE WORKS OF THE WESTERN ELECTRIC COMPANY.

THE members of the Institute of Marine Engineers recently paid a visit to the works of the Western Electric Company, Ltd., Silvertown. When the company was formed, about 15 years ago, its operations were devoted almost exclusively to the construction of telephone and telegraph cables. Subsequently, the manufacture of apparatus was taken up, and this part of the business has been developed to such an extent that the output is now equal to, if not more than, that of the cable department. The works extend over a total area of 1½ acres, and give employment to about 3,500 persons. The buildings are of modern design, well lighted and heated. For the manufacture of telegraph and telephone cabling, gutta-percha has been largely superseded for insulating purposes by paper-covered conductors, stranded together to form a cable of the required thickness, which is afterwards rendered water-tight by a lead sheathing. In the insulating-room, which was first visited, special machines cut the paper into strips, which are woven round the copper wires spirally and bound loosely with cotton. The loose covering of paper provides an air space which reduces the condenser effect and gives better insulation. Both paper and cotton are coloured, and arranged in sequences so that in a cable with a large number of strands no difficulty is experienced in picking out a specific conductor at both ends of the cable. In this department are about 300 machines, each capable of insulating five wires at the same time. In the stranding-room, which was next visited, are several large stranding machines, one machine being about 150ft. in length. By this machine the insulated conductors are arranged in twisted pairs, the first section of the machine stranding about three pairs, the next section adding about a dozen pairs, and so on, until at the final stage as many as 300 pairs or 600 separately insulated conductors can be bound into one cable. The cable itself is then bound in a paper covering. Paper being a hygroscopic material, it is necessary, before the lead sheathing is applied, to extract the moisture from the coverings, and this is accomplished in the drying ovens, with a normal temperature of about 240° Fah. From these ovens the cables are fed into lead presses, working at a pressure of two tons per square inch. The lead, in a plastic state, is forced around the cable, and issues through a die in the form of the lead sheathed cable in common use. Wires which require constant handling, such as those in telephone exchanges, have a cover of yarn or manilla woven round them, and several machines for this purpose were examined. As an alternative to lead covering, rubber or bitumen is used for certain conditions. The bitumen in this case is fed on to the conductor under pressure, passing through the centre of a hollow extrusion screw. For exposed wires a steel tape armouring is provided in addition. The armouring machine was shown at work, the lead sheathing being first covered with yarn and the steel strip laid on in double layers, one overlapping the other. The power plant was next inspected. There are three Babcock & Wilcox water-tube boilers, with chain grate automatic stokers, and Green's economisers. The steam pressure is 150lbs., and the daily coal consumption from 15 to 25 tons. Electric current is supplied at 220 volts by two W. E. Co. generators of 1,600 amps and one generator of 600 amps, driven by three condensing engines direct-connected, two of 600 h.p., and one of 225 h.p. The total output is 8,700 kilowatt-hours per day. The whole apparatus of modern telephony, from the smallest details to the large exchange switchboards are manufactured by the company. A large number of machines are used for stamping out the smaller parts, and among the numerous machines inspected may be mentioned a press for forming the ordinary telephone receiver tube, the bell mouth and the end bulb being formed at the one operation. The tool making and repairing shops also contain a large complement of lathes, milling, slotting and other machines. As would be expected where much of the work is repetition, many of the machines are automatic. Several screw cutting machines were seen, the screw being turned out complete with very little attention when the machine is once adjusted. Other departments visited included the wood working, lacquering, electro and copper plating and polishing, and finally the department where the parts are assembled and the instruments put together. Great interest was shown in the details of the receivers and transmitters, the arrangements and mechanism of switchboards and other matters which were fully explained and demonstrated

THE DIESEL ENGINE FROM THE USER'S STANDPOINT.*

BY WM. J. U. SOWTER.

THE Diesel engine is coming into such general use for the purpose of the generation of electrical energy that a few notes on its advantages, cost of running, and maintenance may be of interest.

The quantity of cooling water required is considerably less than that required by suction gas or steam plants. With an inlet temperature of 50° Fah. and an outlet temperature of 140° Fah., about 3 gallons per brake horse-power are required. Taking the case of a 250 b.h.p. engine, and assuming the loss due to evaporation and leakage to be 10 per cent., the cost of water at 6d. per 1,000 gallons will amount to 0·45d. per hour. The Diesel engine is capable of working satisfactorily and economically on a wide range of fuels without any alteration or adjustment. The standard fuel is crude Texas or Roumanian oil, which may be purchased at prices ranging between 35s. and 70s. per ton. The oil can be purchased in London at about 40s. per ton. The following is a specification of a suitable oil which the author has adopted with satisfactory results: (1) The oil shall be crude, refined, or a residue of petroleum. (2) It shall be free from tar, bitumen, or solid hydrocarbons, sand, fibrous matter, or foreign solid impurities. (3) The oil shall not contain more than one-half of 1 per cent. of water, nor $1\frac{1}{2}$ per cent. of sulphur, and shall be free from acid. (4) The viscosity shall be such that the oil will flow in a continuous stream with 1ft. head through a $\frac{1}{4}$in. copper pipe 6ft. long without being heated. (5) The calorific value shall not be less than 18,000 B.Th.U. per pound. Many other liquid fuels may be used, such as residue shale oil, gasworks tar oil, or creosote oil.

Contrasted with steam plant, there is but little difference in fuel consumption per brake horse-power hour between large and small Diesel engines, nor does the fuel consumption increase largely per unit of energy as the load is decreased on the engine. It is apparent from the foregoing remarks that it is unnecessary from the point of view of fuel economy to install large engines when a greater number of small engines will suit the circumstances of any particular case better, desirable as the former procedure may be so far as capital cost per kilowatt of plant installed is concerned. The following figures show the cost of fuel per unit generated with oil at the prices mentioned, and at various loads, for a 50 b.h.p. engine coupled to a 33 kw. generator:—

Load.	Dynamo Efficiency. Per Cent.	Price of Fuel per Ton.			
		40s.	50s.	60s.	70s.
Full	88	0·161	0·201	0·242	0·281
Three-quarter ...	86	0·178	0·210	0·252	0·295
Half	83	0·208	0·261	0·314	0·365
Quarter	78	0·307	0·384	0·462	0·538

Steam plant, if not properly maintained, becomes more and more uneconomical as time goes on, but still the plant continues to run as though all were in order, with an increased fuel consumption; on the other hand, internal-combustion engines—and particularly the Diesel engine—must be maintained in thorough good order, otherwise there will be great difficulty in getting them to run at all; therefore, those in charge of such plants are bound to see that they are carefully attended to, and when in good order the fuel consumption must always be normal, while, as we have seen, steam plant, if in bad order, can still be run, but at great expense as regards fuel.

The capital cost of a Diesel engine direct coupled to a generator is considerably greater than a gas or steam driven generator of similar capacity; but when the cost of complete plants, comprising either gas or steam, are compared, there is but little difference in the price per kilowatt. A Diesel station, however, requires less land and buildings than similar stations employing steam or gas plant, so that the difference, if any, is in favour of the Diesel plant. The following are approximate prices for small plants delivered and erected on purchaser's foundations complete with oil storage tanks, piping, &c., and may be taken as fairly representative:—

Size in Kilowatts.	Price.	Price per Kilowatt.
100	£1,950	£19·5
150	2,600	17·3
200	3,260	16·3
300	4,380	14·6
400	5,300	13·3

The useful life of generating plant is an important factor for consideration, and one which must of necessity be taken into account in considering the working costs of any undertaking. It has been said from time to time that the stresses set up in an engine of the Diesel type are extremely violent, and in order to support that view attention has been drawn to the heavy and solid construction of the engine. As a matter of fact, however, the stresses are no more severe than those met with in ordinary gas-engine practice. The solidity of the parts is really due to the fact that the engine is single acting, and gives only one impulse per two revolutions as compared with two impulses per one revolution, in the case of the single-cylinder double-acting engine; hence the parts must necessarily be proportionately strong. The driving parts of, say, a 50 b.h.p. Diesel engine require to be of the same strength as similar parts of a single-cylinder double-acting steam engine of 200 b.h.p. The author is of opinion that the life of the Diesel engine should be equally as long as that of a well-built steam engine. The only expensive part likely to require replacement is the cylinder liner. It is essential that the compression should be maintained, and all the author can say on this point at present is that he has had an engine running for over two years and that no appreciable wear of either the liner or piston rings has yet occurred. It appears, therefore, that the life of the liner may be computed at at least 10 years. The valves are fitted into removable casings, which can be renewed at quite a small cost. As most of the other parts, such as springs, pump plungers, air pipes, and so on, are quite light, cheap, and easy to replace, it appears that the cost of maintenance of this type of engine must be very much less than a complete steam plant, considering that the engine takes the place of a steam engine, boiler, steam pipes, feed pumps, economiser, chimney, and the numerous small items incidental to a steam installation, all of which require frequent attention.

Although the Diesel engine possesses considerable advantages, it is undoubtedly true that in order to secure reliability first-class attention is necessary. The various points which need regular attention can only be ascertained from practical experience, but, when that experience has been gained and intelligently applied, there is no reason why the running and reliability of the plant should not be at least equal to steam, and vastly superior to gas plant. Smooth running very largely depends upon the man in charge of the plant, and it may safely be said that 90 per cent. of the trouble experienced in the running is due to the neglect of attendants. It may be assumed that Diesel engines require considerable supervision, and that it is advisable to employ men of skill and experience rather than mere labourers. Even taking this into consideration, the cost of labour on moderate-sized plants is substantially less than that necessary with steam plant.

It is of importance that a suitable grade of oil should be chosen; the oil must be a pure mineral one with a high flash point. Suitable oil, however, is not necessarily expensive; the author is using ordinary crank-chamber oil, costing 1s. 5d. per gallon, with perfectly satisfactory results. Although it is claimed that the cost of lubrication of Diesel plant is no greater than that of a good steam engine, such is not the author's experience, the cost in his case being about 50 per cent. greater. While efficient lubrication is essential, the use of an excessive quantity of oil should be avoided. The piston and gudgeon pin are lubricated by a pump, which forces the oil through a hole in the liner and piston to the pin, and also through an angular space between the liner and cylinder casting. There are generally about six holes, about $\frac{1}{8}$in. in diameter, drilled through the cylinder at this point, and through which the oil is forced to meet the piston. Should the oil be dirty, or contain carbon, these small holes readily become blocked, cutting off the supply of oil to the piston. Oil after

* Abstract of paper read before the Dublin Section of the Institution of Electrical Engineers.

collection from the crank pit contains a certain amount of carbon, and should be placed in a settling tank, preferably heated by a steam coil, or, if a supply of steam is not available, an electric heating arrangement of some kind. After a sufficient time has elapsed for settling, the oil should be drawn off from the top and passed through a good filter before use. The author has found that it is practically impossible to remove the whole of the carbon from the oil, and consequently if the oil is used repeatedly, more and more carbon will be fed into the cylinders and other parts until there is a sufficient accumulation of carbon to cause a stoppage of the lubricating passages. As a seizure of the piston might cause serious damage to the engine, and as it is naturally necessary to economise in lubricating oil as much as possible, the author recommends that the piston should be drawn every six months, and the lubricating passages cleaned. The carbonisation of oil may also cause trouble in the air-compressor cylinders. Before the author realised this possibility, filtered oil was always used in the compressor, and probably to excess. In course of time the high-pressure air pipe leading from the compressor to the intercooler blew off at the joint, when it was discovered that the pipe was completely blocked with solid carbon.

Owing to the high compression which must be maintained, it is necessary to keep the valves quite tight, otherwise leakages will occur reducing the compression, which renders it very difficult to start the engine, and when started proper combustion of the fuel is not secured. The author suggests a system whereby each valve is examined and ground in at stated intervals. He has found that, under the conditions in which he is working, the valves will run without any attention for the following periods: Exhaust, 600 hours; air, 2,000 hours; fuel, 600 hours, and starting, one year. In order to ensure that the valves are maintained in good order the running hours of the plant should be logged and a record kept of the date each valve was examined and ground in; it is then an easy matter to see when each valve is due for attention. Spare valves and casings are supplied with each engine, which can be changed in a few moments, and the valve and casing removed can be ground in at the attendant's leisure. The needle or fuel valve is so adjusted that the fuel spray is blown into the cylinder two or three degrees before the crank reaches the top centre on the compression stroke. It is very important that this valve should be properly set and quite tight; if there is any leakage, fuel will be admitted at the wrong time, resulting in irregular running of the engine. This pulveriser is liable to become choked if the fuel is dirty and insufficiently filtered; it should therefore be examined and cleaned at the same time as the needle valve. A clogged pulveriser may cause difficulty in starting or reduced output owing to insufficient fuel passing to the cylinder.

A considerable quantity of vapour is carried into the compressor, the quantity depending upon the humidity of the atmosphere. When the air from the compressor is cooled in the intercooler, the vapour is condensed and, unless the drain on the intercooler is blown down frequently, water is carried over into the air-storage receivers. The water naturally causes rusting of the interior surfaces and also, as the air in the bottles will consequently damp, rusting of the steel pipe leading to the starting valve may occur; the rust is carried along from the receivers and pipe to the starting valve where it will accumulate, eventually causing the starting valve to stick. If this occurs, the contents of the bottle may be lost before the valve can be shut. The only precaution necessary to avoid this annoying experience is to see that the intercooler drain is blown down at regular intervals, say every half-hour, particularly in damp weather. The air-storage receivers are provided with siphons and drains, and should be drained every day. The compressor high-pressure suction and delivery valves require grinding in about every 600 running hours, and the low-pressure valves about every 2,000 hours. If the intercooler drain is not blown down frequently enough, or if too much lubricating oil is used, the valves may hang up. This can usually be remedied by repeatedly blowing down the intercooler drain until the accumulation of oil and water is removed. It is well to draw the compressor pistons every six months, and clean off the accumulation of carbonised oil which is deposited on the top. It is also advisable to clean the air inlet and passages to the low-pressure valves at the same time.

Defective starting is generally due to one of the following causes: (1) Low compression; (2) defect in oil pump or oil supply; or (3) incorrect adjustment of fuel, air, or exhaust valves. Low compression is most commonly due to a bad condition of the valves, and is an indication that they require grinding in. It may happen that if the engine is overheated, due to defective water circulation or overloading, the valve casings may be distorted, resulting in a leakage between their joint faces and seatings in the cylinder head. If no leakage is apparent from examination, the application of the indicator will speedily determine whether the compression is low. The fuel oil pump is usually arranged so that it can be disconnected from the engine and fitted with a temporary means of operating it by hand for the purpose of pumping up the delivery pipes with oil after they have been disconnected for any reason. Also the delivery pipe from the fuel pump is fitted with a by-pass worked from the starting lever controlling the fuel and starting cam levers. The by-pass is so arranged that when the engine is started on compressed air no oil is delivered into the fuel valve casing until the starting lever is put into the running position. If no such by-pass were fitted, the needle valve casing would be filled with fuel pumped in while the engine was running on compressed air, and when the starting lever was thrown into the running position, and the fuel valve opened at its proper time, too large a charge of oil would be admitted to the cylinder, which might cause damage. If it is suspected that fuel oil is not reaching the cylinders the fuel pump should be overhauled and its valves, as well as the by-pass valves, examined and ground in if necessary. If the by-pass valves are not perfectly tight oil may leak away instead of passing into the fuel valve, when starting would naturally be difficult, or even impossible. The setting of the needle valve may readily be tested by barring round the engine until the crank is near the firing centre; compressed air should then be admitted to the blast pipe, the indicator cock opened, and the engine slowly barred round until air commences to issue from the indicator cock. This is the point at which the fuel valve commences to open, and should correspond with the maker's setting marks. The air and exhaust valves should commence to open at the proper time, and in order to ensure this, most makers stamp on the engine the clearance there should be between the cams and rollers at a marked point. These clearances should be checked periodically, and adjusted if necessary. If the engine is kept in good order, and the above points carefully attended to, there should be no difficulty experienced in starting easily and certainly.

The exhaust should be smokeless; black smoke may be emitted if the blast pressure is too low, or if the engine is over loaded. If all is in order the exhaust should be colourless, indicating perfect combustion of the fuel. The exhaust gases escape from the engine at a pressure of about 40lbs. per square inch, and it is necessary that adequate measures should be taken to allow the escaping gases to expand gradually, or nuisance may be caused to the surrounding neighbourhood. For most situations the cast-iron silencers provided with the engines will be quite effectual, but the author had some trouble due to the fact that private residences are in close proximity to the works. The exhaust, therefore, was led to a large concrete pit, which removed all cause for complaint. It is the intention of the author to lead the exhaust from a 150 b.h.p. engine, shortly to be installed, to the base of an existing chimney-stack 120ft. high, which should deal with the difficulty in an effectual manner. In steam-driven stations, where extensions are carried out by adding Diesel engines the use of exhaust boilers would be a further source of economy, enabling the waste heat from the exhaust of the Diesel engines to be utilised on the steam side. Exhaust boilers also are a useful means of providing hot water in factories where such is required for the process of manufacture, and Diesel engines are installed for the provision of the necessary power required.

Personal. — The position of head of the designing department of Messrs. Harland & Wolff's shipyard, Belfast, formerly occupied by Mr. Thomas Andrews, one of the victims of the "Titanic" disaster, has been filled by the appointment of Mr. Henry Harland, a nephew of the late Sir Edward Harland, one of the founders of the firm. Mr. Harland, who is about 30 years of age, learned the business of shipbuilding in the yard at Belfast, passing through all the departments before proceeding to China five years ago to be manager of a yard there.

THE CARBONISING OF STEEL BY THE USE OF GASES.

BY E. F. LAKE.

HISTORY has well established the fact that for at least 1,000 years bars of steel were heated in close contact with charcoal or other materials, and carbon added to the metal in that manner. It often took from 10 to 12 days to get the carbon to penetrate more than a thin layer that formed the outer skin of the piece. Muffle furnaces were later brought into use, and these much shortened the time in which the carbon would penetrate to a certain depth and also increased the depth of penetration. The main principles of the process, however, are the same now as they were centuries ago.

While armour plate and many other products are manufactured by the carbonising process, a great majority of the steel products now have the carbon raised or lowered to the proper percentage while they are in the molten state. At present, therefore, the carbonising process is only used for specific kinds of work. It is the only method by which a single piece of steel can be given an extremely hard outer surface, with its accompanying brittleness, and still have a soft, tough centre or core, so that it will bend and not easily break. Thus the carbonising process is used for manufacturing a large variety of steel parts for numerous machines, instruments, &c., and its use is on the increase.

Several different methods are used for introducing the carbon into the steel, and others may be devised in the future. The Harveyising process, that is especially applicable to armour plate, places a layer of charcoal between two plates and then heats them in a pit furnace to a temperature that will cause the steel to absorb carbon from the charcoal. The weight of the upper plate keeps the charcoal in close contact with the surfaces of both plates and facilitates the soaking in of the carbon. This method is only suitable for large work, and the depth of penetration is very unequal over the entire plate surfaces. The Krupp process for armour plate uses a gaseous hydrocarbon to replace the bed of charcoal. Electricity has also been used to heat the plates after placing carbonising materials in contact with them.

Practically only two methods are used for carbonising small pieces. The older method consists of packing the work in some carbonaceous material, within an iron box, and sealing the cover with fireclay or other refractory material so that the air will not get in or the carbon escape. This is then placed in an oven and held at a carbonising temperature for a time sufficiently long to allow the carbon to penetrate to the required depth. The other method consists of placing the pieces to be carbonised in a retort and then filling this with a carbonaceous gas while the work is held at a carbonising temperature.

All of these methods are but variations or slight improvements of the process used by ancient steelmakers, when they dug a hole or pit in the hillside, heated the metal in the presence of charcoal, and thus caused it to absorb carbon. The Harvey process improved on this by digging its pit in the floor of the steel mill and making the charcoal before it was placed between the armour plates. The Krupp process varied this by making a carbonaceous gas from the solid materials and injecting this into the pit in place of the charcoal. The gas method used for small pieces improved the Krupp process by using a muffle furnace instead of a pit in the floor.

The vast improvements that have been made in machinery, together with the advance in chemistry and in the methods of producing all useful articles, have made this latter method of carbonising with gas a distinct process by itself. It has only been perfected and given a commercial application in the past five years, and thus should be considered as a new process. Since its advent much experimentation has been conducted with different kinds of gases, and these compared with the solid carbonaceous materials and methods of carbonising with them.

These investigations have all proved that carbonising with gas in a muffle furnace is far superior to any method or process that uses solid substances. The carbon penetrates the metal in much quicker time than when solid materials are used, it can be made to penetrate to a greater depth, the percentage of carbon in the muffle can be maintained at an established point, owing to the fact that fresh gas is continually flowing in, while the used gas is escaping, whereas, when the work is packed in sealed boxes, no carbon can be added to that which is first placed there; uniform results can be obtained with different lots, owing to the ease with which gas is controlled, and a uniform depth of penetration and percentage of carbon will be obtained over all the exposed surfaces of the pieces, and in all the pieces in the retort or muffle. Aside from this, the labour of packing the work in iron boxes and then sealing on the cover is entirely dispensed with.

The carbonaceous gases that have been experimented with for carbonising are carbon monoxide, carbon dioxide, illuminating gas, methane, ethylene, and gases made from liquids like petroleum, naphtha, and gasolene. Below is given a list of these gases, with the percentage of the carbon and the depth of penetration:—

Kind of Gas.	Time in Hours.	Depth of Case in Inches.	Carbon Content. Per Cent.
Illuminating	4	None.	None
Illuminating and ammonia	4	0·008	0·78
Illuminating and ammonia	8	0·012	1·14
Carbon monoxide	0	0·016	1·36
Carbon monoxide and ammonia	4	0·016	1·45
Acetylene	4	No demarcation	0·41
Acetylene and ammonia	4	0·012	0·98
Methane	4	No demarcation	0·26
Methane and ammonia	4	No demarcation	0·32
Naphtha and ammonia	4	0·014	1·02

The science of chemistry has made such a great advance in the past century that we now have quite an extensive knowledge of the materials that will cause carbon to penetrate a solid body of iron or steel from the outside, or that may be used to add carbon to the molten metal. Nearly every carbonaceous material has been investigated and the amount of carbon that each will cause the different iron products to absorb has been recorded. The speed and depth of penetration have also been investigated. In thus adding it, the carbon enters into solid solution with the iron. Many of the other elements that are used in the manufacture of the ordinary or alloyed steels either retard or aid the penetration of carbon.

Manganese has a tendency to make the carbonised surface brittle when it has been hardened, and thus render it liable to chip off, peel, and break, with slight shocks. The manganese in carbonising steel is usually kept below 0·20 per cent., and seldom exceeds 0·50 per cent. Manganese, however, aids in the penetration of the carbon, and for that reason should be kept as high as possible.

Nickel usually has a tendency to obviate the brittleness that is produced in steel by carbonising, and also makes it more homogeneous. When a 2 per cent. nickel steel is properly heat-treated and carbonised the tensile strength can be made to nearly double that of ordinary carbonised steels. Nickel, however, retards the penetration of carbon; thus it will take considerably longer to carbonise nickel steels to a required depth than those that do not contain nickel. Some very recent experiments on steels containing from 2 to 30 per cent. of nickel showed that when using pure ethylene and carbon monoxide, the maximum carbon content in the zone of cementation diminishes as the percentage of nickel increases, and becomes very marked when there is more than 5 per cent. of nickel. Variations in the percentage of carbon in the different layers were also much less than in carbon steel.

Silicon when added to steel will raise the tensile strength about 80lbs. for each additional 0·01 per cent. until a silicon content of 4 per cent. has been reached, and will lower the elongation and reduction of area. Thus, while silicon is desirable for its strengthening properties, it retards the penetration of carbon to a greater extent than any other element. When steel contains 4 per cent. of silicon it is almost impossible to make carbon enter it. With 1 per cent. of silicon the speed of penetration is only about one half that of a normal steel. Thus the silicon has to be kept low in steels that are to be carbonised.

Chromium increases the rate of penetration more than any other element except manganese. It also greatly refines the grain and prevents the development of the crystalline structure in steels that are being heat-treated, and tends to produce a mineral hardness. Thus greater strength and

wearing qualities can be obtained with chromium steel than with any of the others, and the carbon will penetrate it more freely and evenly while being carbonised. When the chromium is too high, however, the steel cannot be cut with any machine tools, and hence parts that are to be machined must be kept low in chromium. The percentage of carbon in the zone of cementation is also greater in chromium steels than in ordinary carbon steel.

Tungsten and molybdenum are about equal with chromium in regard to increasing the rate of penetration, but these elements are only used in high-speed tool steels, and carbonising has been resorted to in only a very limited way for cutting tools. Many kinds of such tools could doubtless be well made by the carbonising process, but each time they were ground would reduce the percentage of carbon in the cutting edge, and this would soon reach a point that would make it impossible to harden the tools sufficiently to cut other metals.

Vanadium, titanium, aluminium, and like purifying elements produce high dynamic qualities and give to the core of carbonised steels a high resistance to shocks. This is due to the fact that they have an affinity for oxygen, hydrogen, nitrogen, and like gases, and remove these from the metal. In the small percentages in which they are used for scavenging they neither retard nor promote the penetration of carbon when carbonising steel.

The following table shows the influence of different elements on the speed of penetration of the carbon when carbonising a steel whose other elements were uniform, *i.e.*, the carbon, phosphorus, sulphur, &c., were in the same percentage throughout all of these tests:—

Per Cent.	Element in Alloy.	Penetration of Carbon per Hour in Inches.
0·5	Manganese	0·043
1·0	Manganese	0·047
2·0	Nickel	0·028
5·0	Nickel	0·020
0·5	Silicon	0·024
1·0	Silicon	0·020
2·0	Silicon	0·016
4·0	Silicon	0·000
1·0	Chromium	0·039
2·00	Chromium	0·043
0·5	Tungsten	0·035
1·0	Tungsten	0·036
2·0	Tungsten	0·047
1·0	Molybdenum	0·036
2·0	Molybdenum	0·043

It is of the utmost importance to know the analysis of the carbonaceous materials that are to be used, and the influence on the speed of penetration; the depth of penetration; the percentage of carbon that will be in the various layers of the metal; the evenness with which the carbon penetrates the entire surface, &c. From all that can be gathered, carbon monoxide is far ahead of any of the solid materials in the specific direct carburising effect it has upon steel. It has also proved itself to be better than any other gaseous material. The depth of carbonisation that can be obtained in a given time is greater with it than with anything else that has been tried. Moreover, the percentage of carbon and the depth of penetration can be controlled at will by the use of this gas in its pure state or in combination with other elements. This is something that is very difficult to do with any of the other carbonising materials, and especially with the solids.

In using carbon monoxide, however, one should know its chemical composition, as well as other conditions under which it is used, before trusting it too far. Pure carbon monoxide would without question be the best carburising material if it were not for two conditions: The first is that it causes the carbon to penetrate the steel so rapidly that it leaves a distinct division between the core and the carburised zone. When the carbonised piece is hardened, therefore, the carburised outer shell has a decided tendency to crack and peel off. The second is that pure carbon monoxide increases the tendency toward oxidation, and steel parts often show a decided scale on their surface.

Such conditions can be overcome or regulated by mixing with the carbon monoxide small quantities of hydro-carbons of known composition, or solid carbon in a properly divided state. These might be injected during all or only a portion of the carbonising time. A combination of the solid and gaseous processes has been made, therefore, in one style of furnace. This is done by sending a current of carbon dioxide through a cylinder that is filled with wood charcoal and in which the work is packed. Thus, when the work is at the carbonising temperature, a mixture of carbon dioxide and carbon monoxide is rapidly formed, and there is no possible excess of carbon monoxide. While the gas entering the apparatus is dry carbon dioxide, that which issues therefrom is almost pure carbon monoxide; it contains less than 3 per cent. of carbon dioxide, while its volume is about double that of the gas introduced.

When carbonising agents are based on the simple simultaneous action of carbon and carbon monoxide they will have a great speed of penetration in the carburised zone, great uniformity in the penetration of carbon in this zone, the peeling tendency will be largely overcome, and there will be a greater possibility of pre-determining the percentage and depth of carbon that will be obtained within a given time. The gases can be controlled by diluting with nitrogen, by limiting the contact of the solid carbon with the surface of the steel, by varying the carbonising temperature; and absolute security can be obtained against the introduction into the steel of any foreign substance other than carbon. The surface of the carbonised pieces can be much better preserved and the necessity of grinding and machining them afterwards overcome, and they can be prevented from becoming deformed and changed in volume. A large part of this is due to the fact that the carbonising gas can be sent into the furnace in a continuous stream that can be regulated so that the used gas will not exhaust until all of the carbon has been used up.

In conjunction with this latter gas process, compression has been used, and experiments already conducted have proved that characteristics of the carburised zone vary in proportion to the variation in the pressure of the carbonising gases. The carbonising gas was obtained by sending a slow current of carbon dioxide through a mass of wood charcoal in which the work was packed, in the same manner as in the latter furnace. When this gas was compressed in the carbonising retort and the steel therein was maintained at a carbonising temperature, it was found that the increase of pressure increased the depth of penetration obtained within a given time, and also gave a more uniform distribution of the carbon within the carburised zone.

Of the solid carbonaceous substances, many materials have been tried. Some of these are: Charcoal, bone, horn, burnt sugar, charred leather, ferrocyanide, potassium cyanide, anthracite, and graphite; and of gaseous substances: acetylene, petroleum, naphtha, and gasolene. In various combinations with the above materials, black oxide of manganese, ammonia, bicarbonate of soda, borax, and other elements have been used. After much experimenting, it has been found that a mixture of bone and bone charcoal—the latter being a residue from previous operations—is without doubt as good a solid carbonising material as can be obtained for steel. Thus, if 40 per cent. of new bone is added to 60 per cent. of the burnt bone taken from the boxes after carburising, it will give as deep and rapid a penetration as any of the solid carbonising materials. It will also give as good results as can be obtained with any combination of the various materials mentioned above, if not better.

In the throwing out of useless materials and the elimination of those with a weak power for carburising, chemistry with its great advances has performed a very useful labour for the steel industry. Notwithstanding this, however, the materials mentioned above are so numerous that every little while an attempt is made to impose upon the steel industry and machine manufacturers a special, new, secret compound that is heralded as a wonderful discovery. New developments like the gas processes are often used as an opportunity to promote such practices. Almost as far back as we can trace the steel business we find that the carbonising process has been "faked," and it stands in the same relation to steel-making that the gold brick does to the agriculturist. Claims are sometimes made that low-grade steel, wrought iron, or even cast iron can be changed into high-quality tool steels by some kind of roasting or baking process. A favourite scheme is to get manufacturers to make milling cutters or similar tools from wrought iron or machinery steel and then take

them and convert them into tools that will nearly equal high speed steel.

Cast iron, as is well known, contains from 3½ to 4 per cent. of carbon. To convert cast iron into steel it is necessary to remove at least one half of the carbon. The days of the conjurer and alchemist being past, it is impossible to change this element into any other element. No method has been discovered by which this carbon can be removed from the iron without melting and boiling the metal and thus oxidising it out, or else leaving the metal impregnated with cavities. Other impurities also have to be removed before this product can be made into a high grade steel. Therefore, when any one claims to have a process that will transform cast iron into steel by baking it in an oven for a few hours, it is useless to waste any more time with him or give his process a second thought. It may seem idle to mention such claims, but it is not many months since I was in an office on Broadway in which such a proposition was being exploited. It had been promoted for a year previous to that in London and before that in Germany.

Wrought iron is the opposite of cast iron in one regard, *i.e.*, instead of containing more carbon than steel it contains less. Usually the carbon is below 0·10 per cent. This product, therefore, can be carbonised so that the outer surface can be hardened and thus made brittle, while the inner core will be soft and non brittle. In fact, wrought iron is made into blister bar, containing about 1·00 per cent. of carbon, by a carbonising process. Wrought iron, however, contains a considerable percentage of slag, is not nearly as strong as tool steels, and in no way can be compared to them in hardness, &c. To remove this slag takes materials and labour, and consequently wrought iron is cheaper than high grade steel; especially is this so of tool steels, which have most of the impurities removed.

The same thing holds good of making machinery or low grade steel into high-grade tool steel. The difference in price between high grade and low grade steels is due to the amount of labour or materials that have been used to remove the impurities. Low-grade steels contain high percentages of such injurious elements as phosphorus and sulphur, and these are reduced to low percentages in high-grade steel. Oxygen, hydrogen, nitrogen, and other gases which may be segregated in large enough volume to form miniature blowholes, gas bubbles, &c., or present in the form of occluded gases have also proved to be very injurious elements in steels. No process has been discovered by which these can be removed from the metal without remelting it, even though it may have the carbon percentage increased by a baking process and thus made stronger.

We can take various complicated combinations of the different elements, reduce each element to a pure state, and then weigh or measure it. We have also learned the affinity that one element has for another and how to bring different elements together when they have enough affinity to form compounds. Likewise, we know how to remove one or another of the injurious elements from complicated compounds.

Nowhere, however, in the history of the world has it been shown that it is possible to change one element into another, and until this is done we do not see how it is possible to transform metals in such a manner that any of the solid elements that are injurious can be removed from the metal without a remelting. To remove them from the solid metal would mean to create a void where they existed. This void would cause a break in the cohesion of the different molecules and thus cause a weakening of the mass. In fact, the impurities do that at the present time, and thus low grade steels are weaker than high grade steels.

Carbon is an element that flows in iron somewhat in the manner in which an electric current flows through a copper wire. Thus, if a steel plate containing 1·00 per cent. of carbon is attached to a plate containing 0·50 per cent., it is only a question of time when both plates will contain 0·75 per cent. of carbon. At atmospheric temperature this movement of the carbon is extremely slow, and hence not useful for any practical purpose. As the temperature is raised there is an increase in the speed of its travel, and when steel is heated to 1,650° Fah. it very readily absorbs carbon. Some of the other elements can be injected into steel in this manner, but they would have to be added to the elements that were already present in the metal and not change these into something else. Hence the metal would remain low grade, even though it were made to resemble high grade steel.—*The Iron Age.*

JUNIOR INSTITUTION OF ENGINEERS.

A PARTY of members of the Junior Institution of Engineers recently paid a visit to the new engineering workshop and laboratory, and the electrical laboratory of The Polytechnic, Regent Street. Under the guidance of Prof. H. J. Spooner the party was conducted round the engineering workshop and laboratory, being shown in the engineering workshop the machine tools, fitters' benches, and erecting shop, which covers an area of 62ft. by 42ft., in the sub basement. The machines are driven from three lines of shafting, each being driven by an electric motor fixed above ground to give a clear floor space. Steel stanchions support longitudinal and transverse beams quite clear of the ceiling above, and these in their turn support all the hangers for the main and counter shafts, an arrangement which allows the lathes and machines to be placed in almost any position on the floor, and with this method of supporting the overhead machinery there is an entire absence of transmitted vibration to the floors above. With the exception of a few of the best lathes and machines removed from the old workshop, the whole of the contents of the new shop, including many modern high speed tools, is new equipment from the works of some of the most famous English, American, and continental makers of machine tools.

The mechanical engineering laboratory is adjacent to the workshop, and has an area of 62ft. by 16ft., in addition to the boiler-room. It consists of the following sections: Material testing, prime movers and heat, hydraulics, experimental mechanics, &c. The material testing laboratory contains a 100,000lbs. Olsen improved motor driven automatic and autographic testing machine, with accessories, and special arrangements for testing ferro-concrete beams and stanchions; a special 15-ton Wicksteed testing machine; an 8,000lbs. Avery testing machine, for testing wood, brick, stone, wire, and cement; Sankey's hand metal bending machine; test pumps for testing the strength of cylinders, pipes, and fittings, up to 2 tons per square inch; Thurston's patent oil tester; Boult's patent cylinder lubricant tester; disc friction machine for measuring the coefficients of friction materials at high and low speeds, &c. The prime movers and heating laboratory contains a very large number of important machines, among which may be mentioned a 30 b.h.p. compound experimental steam engine, installed for experimental and research work; 10 b.h.p. new design gas engine, specially arranged and fitted for research work; a Day 5 h.p. 2-cylinder valveless 2-stroke petrol engine, &c. The hydraulic laboratory has a representative collection of machines, such as a treble barrel vertical motor driven experimental pump; Thomson vortex turbine; friction in pipes and fittings set, six different sizes; pitot tube and venturimeter; orifice tank set; fan testing set, specially designed; &c. The experimental mechanics laboratory contains apparatus for experimenting on the efficiency of machines, including wheel and axle, differential wheel and axle, screw jacks, worm and worm wheel, apparatus for determining velocity and acceleration curves, modulus of elasticity, Searle's apparatus, deflection of beams, cantilevers, and springs, whirling of shafts apparatus, &c.

Mr. Hibbert conducted the party round the electrical workshop and laboratory, of which he is the head, and supplied the following particulars. Power is obtained from the mains of the Marylebone Borough Council at 480 volts. By means of a series of eight motor generators the laboratory is supplied with direct, alternating, and polyphase currents. Each motor generator has its distributing switchboard, and all parts of the laboratory are served from any machine. The laboratory itself contains series, shunt, and compound motors, single, 2-phase and 3-phase motors, rotary converters, transformers, oscillographs, telephone exchange (including a small working automatic exchange), arc lamps, and all the usual appurtenances. Suitable switchboards for starting, regulating, synchronising, are fixed near each machine or combination, and arrangements are made for interconnecting, so that groups of machines are able to work in conjunction.

At the conclusion of the visit a hearty vote of thanks was proposed by the Chairman, Mr. Walter T. Dunn, for all the arrangements that had been made for showing the members round, to which Prof. Spooner and Mr. W. Hibbert replied.

A 3,300-TON TESTING MACHINE.

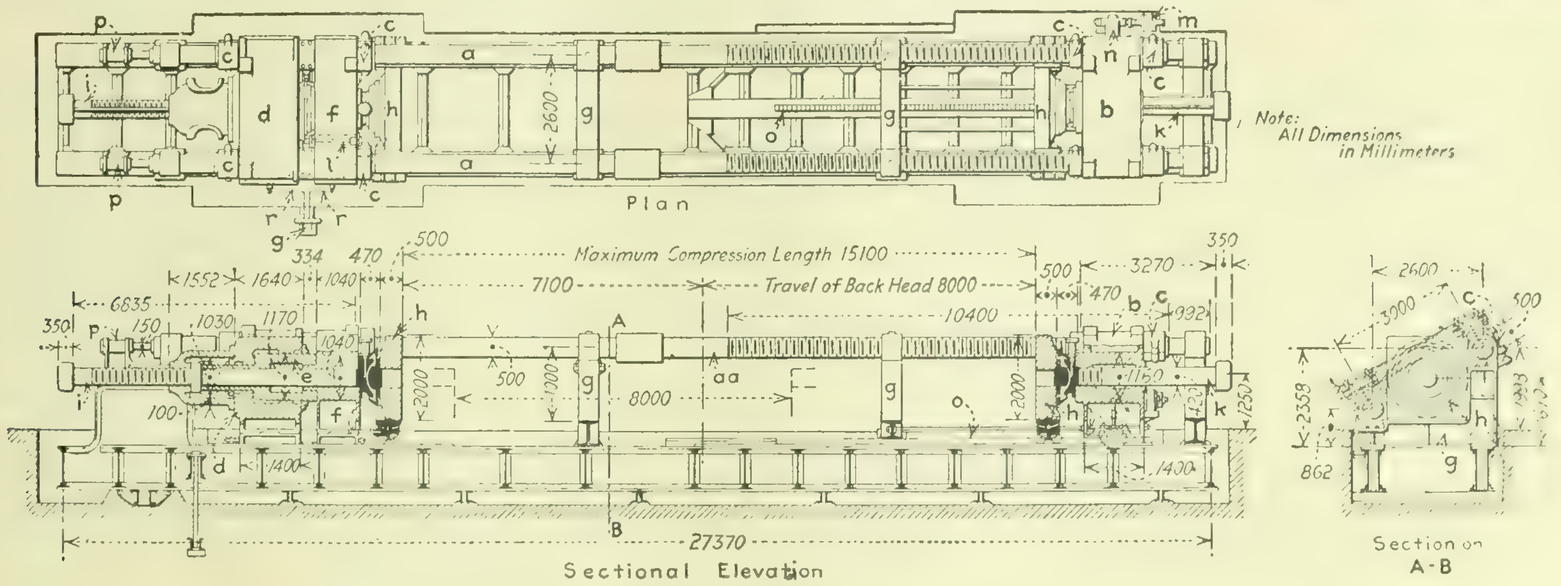
A very large testing machine is now being erected at the Prussian Testing Institution, at Gross Lichterfelde, Germany. It is intended primarily for the purpose of making tests of full-size structural members. The firm of Hanel & Lueg, of Dusseldorf, built the machine, after designs made by Dr. Seifert, president of the association of bridge builders, in conjunction with officials of the Testing Institution The machine has a capacity of 6,600,000lbs. in compression, taking members up to 49ft. long, and a capacity of 3,300,000lbs. in tension, taking members within a length range of 26ft. to 12½ft. It is a horizontal hydraulic machine. If we except the 5,000-ton machine built two years ago for the U.S. Geological Survey and now being erected at the Pittsburg testing station of the Bureau of Standards, the Berlin machine is the largest compression machine in the world. Some of its main dimensions are approximately as follows: The compression cylinder has an outside diameter of 75in. and a bore of 48in., and weighs 44 tons; the screw spindles (two) are 19in. diam. and 82ft. long over all, and made in two sections whose combined weight is 44 tons; the back head weighs about 35 tons; the entire machine is 95ft. long by about 14½ft. wide, and its longitudinal axis is 50in. above floor level.

Referring to the illustration of the machine taken from "Stahl und Eisen," of March 7th, 1912, it will be noted that the spindles *a* are not in the same horizontal plane, but the front spindle is low and thus the working aperture of the machine is made more accessible. The bed of the machine is formed by a frame of heavy plate girders connected by transverse diaphragms. The spindles are made in two parts each, joined by couplings; they are supported at one end in fixed supports and at other points by supports resting on the frame by wheels. For making compression tests the cylinder *d* and the back head *b* are locked to the spindles, while for tension tests the cylinder is free but the ram *e* is connected to the spindles; in the latter case the bearing plates used for compression testing are removed and tension bars *i* and *k*, which are housed centrally in cylinder and rear head, are slid forward and fitted with grips or other means for attaching the test piece. The ram has a crosshead *f* for fixing it to the spindles. This crosshead also contains two pull-back rams *l* for making the return stroke of the main ram. Two-part nuts *c*, operated by screw gearing, are provided at both ends of the machine for locking the heads to the spindles. The back head can be moved 25ft. along the spindles by the motor *m*, geared to a pinion which engages a rack *o* set along the centre of the bed-frame. The bearing plates *h* for compression tests are square, about 6½ft. on a side. They have spherical seats and the friction of these seats is reduced by an oil film, to make the plates perfectly self-aligning. When the bearing plates are in position, the tension bars *i* and *k* must be pulled back to the position shown in the drawing.

The principal parts of the machine, such as cylinder, crosshead, yokes, bearing plates, and back head, are steel castings. The spindles, tension bars, and plunger are steel forgings. The plunger is packed with leather cup packing. To absorb the energy of rupture of test pieces, hydraulic brakes *p* are fitted to one end of the screw spindles. A maximum pressure of 200 atmospheres is provided for in the brake cylinders.

The main cylinder is supplied with pressure water by a special pumping plant. The pressure used is 400 atmospheres for compression, and 200 atmospheres maximum for tension tests. A low pressure supply of 56lbs. per square inch is available for idle movement of the plunger. Two pressure gauges for indicating the pressure in the main cylinder, and a gauge for measuring the pressure in the pull back cylinder, form the indicating equipments of the machine, together with further gauges for the accumulator, &c.

According to a recent article by Prof. A. Martens, director of the Prussian Testing Institution, a volumetric load gauge of 3,300 tons capacity has been designed, and is being built for trial use in this machine. Should this apparatus prove successful the load indications of the machine in compression tests can always be obtained through the volumetric gauge with a high degree of precision, and dependence need not be placed on the gauge readings of cylinder pressure.—"Engineering News."



New German 3,300-ton Testing Machine

THE STRUCTURAL COMPOSITION AND PHYSICAL PROPERTIES OF STEEL.*

BY PROF. ALBERT SAUVEUR.

Structural Composition of Slowly Cooled Steel. Bearing in mind that hypo-eutectoid steel is composed of free ferrite and pearlite and that hyper-eutectoid steel consists of free cementite and pearlite, and knowing the proportion of carbon in pearlite (0·85 per cent.) and in cementite (6·67 per cent.), the structural composition of any steel may be readily calculated, provided we know the percentage of carbon it contains. In case of hypo-eutectoid steel we have the following equations:

$$(1)\quad F + P = 100$$

$$(2)\quad \frac{E}{100} P = C$$

in which F represents the percentage of free ferrite in the steel P the percentage of pearlite, E the percentage of carbon in pearlite, and C the percentage of carbon in the steel. The first equation expresses the fact that the steel is composed of ferrite and pearlite, and the second equation the fact that all the carbon in the steel is included in the pearlite. Assuming, for instance, that pearlite contains 0·85 per cent. carbon and the steel 0·50 per cent. carbon, the resolution of these two equations indicates that steel of that grade has the following structural composition:

F = per cent. free ferrite = 41·8

P = per cent. pearlite = 58·2.

In case of hyper-eutectoid steel the following two equations may be written:—

$$(1)\quad P + C_m = 100$$

$$(2)\quad \frac{E}{100} P + \frac{6\cdot67}{100} C_m = C$$

in which P represents the percentage of pearlite, C_m the percentage of free cementite E the percentage of carbon in pearlite.

* [illegible]

C the percentage of carbon in the steel. The first equation expresses the fact that hyper-eutectoid steel is composed of pearlite and free cementite, and the second the fact that the carbon in the steel is distributed between the pearlite and the free cementite, forming E per cent. of the pearlite and 6·67 per cent. of the cementite. Assuming the value of E to be 0·85 and the steel to contain 1·25 per cent. carbon, these equations give for a steel of that grade :—

$$P = \text{per cent. pearlite} = 93$$
$$Cm = \text{per cent. free cementite} = 7.$$

Supposing that pearlite or eutectoid steel contains 0·85 per cent. carbon, since the whole of that carbon is present in the cementite plates of pearlite, and since cementite contains 6·67 per cent. carbon (as called for by its chemical formula, Fe_3C), the percentage of cementite in pearlite may be readily calculated as follows :—

$$\frac{6\cdot67}{100} \times \text{per cent. cementite} = 0\cdot85$$

$$\text{hence per cent. cementite} = 0\cdot85 \times \frac{100}{6\cdot67} = 12\cdot74$$

$$\text{and per cent. ferrite} = 100 - 12\cdot74 = 87\cdot26,$$

or, roughly, 1 part by weight of cementite to 6·6 parts by weight of ferrite. If it be considered, however, (1) that the exact carbon content of pearlite is not, and hardly can be, known, (2) that it varies somewhat both with composition and treatment, and (3) that in commercial steel it is probably not far from 0·85 per cent., we are fully warranted to assume, for the sake of the great simplicity it introduces in the calculations, that pearlite contains exactly 1 part by weight of cementite to 7 parts by weight of ferrite, which would be the case if the eutectoid point corresponded to 0·834 per cent. carbon, as indicated below :—

1 part cementite + 7 parts ferrite yields 8 parts pearlite, or 12·50 per cent. cementite + 87·50 per cent. ferrite = 100 per cent. pearlite ;

and since cementite contains 6·67 per cent. carbon, 12·50 per cent. cementite will contain 6·67 × 12·50 = ·834 per cent. carbon. Assuming, then, that such is the carbon content of eutectoid steel, so that 1 part of cementite gives exactly 8 parts by weight of pearlite, and noting that the carbon in the steel produces exactly 15 times its own weight of cementite,* the calculation of the structural composition of any steel becomes extremely simple.

In case of hypo-eutectoid steel (steel containing less than 0·834 per cent. carbon) we have

per cent. total cementite = per cent. total carbon × 15
and per cent. pearlite = per cent. total cementite × 8 ;

or, more simply,

per cent. pearlite = per cent. carbon × 120
i.e., $P = 120\,C$

and, of course, per cent. ferrite = $F = 100 - P$.

With hyper-eutectoid steel (steel containing more than 0·834 per cent. carbon) the figuring is as follows : since 8 parts of pearlite contain 7 parts of ferrite and since in hyper-eutectoid steel the totality of the ferrite (total ferrite) is included in the pearlite (there being no free ferrite), we have

per cent. pearlite = $P = \frac{8}{7}$ total ferrite,
or, since total ferrite = 100 − total cementite,
$P = \frac{8}{7}$ (100 − total cementite).

But total cementite = carbon × 15, hence

$$P = \tfrac{8}{7}(100 - 15\,C)$$
$$\text{or } P = \frac{800 - 120\,C}{7}$$

and, of course, free cementite = $Cm = 100 - P$.

Summing up, in order to find the percentage of pearlite in hypo-eutectoid steel it will suffice to multiply its carbon content by 120 ($P = 120\,C$), the balance of the steel, consisting, of course, of free ferrite ($F = 100 - P$) ; to find the percentage of pearlite in hyper-eutectoid steel, the percentage of carbon in the steel should be substituted for C in the formula :—

$$P = \frac{800 - 120\,C}{7}$$

and the balance of the steel will be made up of free cementite ($Cm = 100 - P$).

Taking, for instance, a steel containing 0·50 per cent. carbon, its structural composition will be—

120 × 0·50 = 60 per cent. pearlite, and
100 − 60 = 40 per cent. ferrite.

If a steel contains 1·25 per cent. carbon the resulting percentage of pearlite will be

$$\frac{800 - 120 \times 1\cdot25}{7},$$

or nearly 93 per cent., and the free cementite (Cm), 100 − 93 = 7 per cent.

Chemical v. Structural Composition.—Disregarding the existence of impurities, the ultimate analysis of steel reveals the presence of so much carbon and so much iron. The proximate chemical analysis of steel reveals (in steel slowly cooled from a high temperature) the presence of so much iron and so much carbide of iron, Fe_3C. In a similar way we may consider two different structural compositions, an ultimate and a proximate

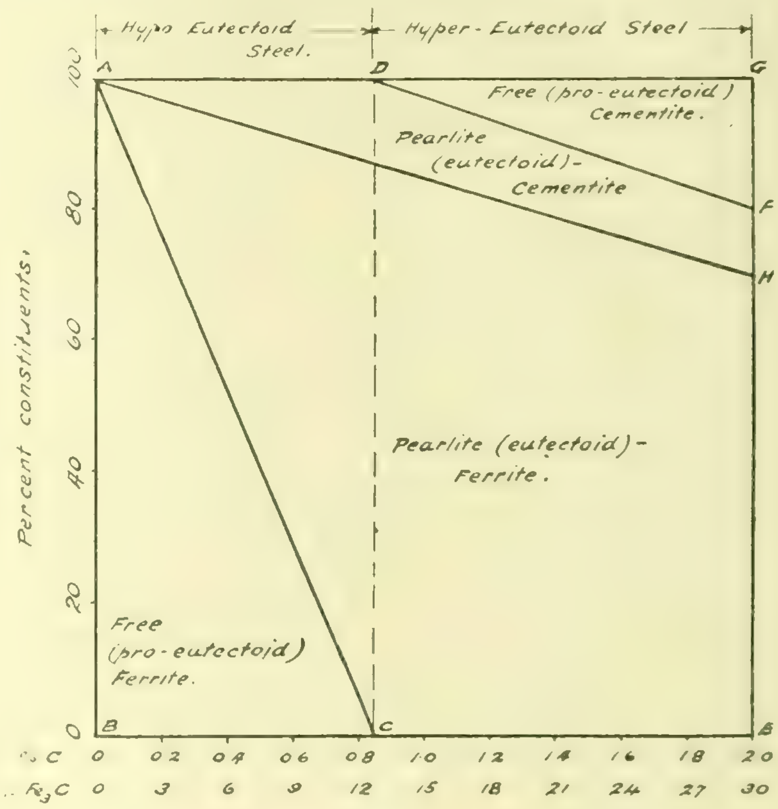


FIG. 1.

one. The ultimate structural composition reveals the presence of so much total ferrite and so much total cementite, while the proximate structural composition informs us of the percentages of pearlite, free ferrite, and free cementite in the steel. It will be evident that the chemical proximate composition is identical to the ultimate structural composition, the names of the constituents only being different—iron and carbide in the first case, ferrite and cementite in the latter. These various compositions are tabulated below :—

			Constituents.
Chemical Composition	ultimate :	Fe	C
	proximate :	Fe	Fe_3C
Structural Composition	ultimate :	total ferrite	total cementite
	proximate :	pearlite	free ferrite, free cementite.

It is apparent that the proximate structural composition affords more valuable information than is obtainable through the other three kinds of analyses, for not only does it indicate the chemical nature of the proximate constituents but also their structural association and occurrence, upon which depend, to a very great extent, the physical properties of steel.

The structural composition, both ultimate and proximate, of slowly-cooled steel is shown diagrammatically in Fig. 1, which will be readily understood. ABC represents the free ferrite in

* This follows from the composition of Fe_3C indicated by the atomic weights of iron and carbon :—

(3 × 56) iron + 12 carbon = 180 Fe_3C,

hence one part carbon produces $\frac{180}{12}$ = 15 parts Fe_3C or cementite.

hypo-eutectoid steel, *ACD* the pearlite in hypo-eutectoid steel, *DCEF* the pearlite in hyper-eutectoid steel, *DFG* the free cementite in hyper-eutectoid steel, *ABEH* the total ferrite in any steel, *AHG* the total cementite in any steel, *ACEH* the pearlite-ferrite in any steel, and *AHFD* the pearlite cementite in any steel.

Physical Properties of the Structural Constituents of Steel.—It will be evident that the physical properties of commercial ferrite must resemble closely those of wrought iron and of very low carbon steel. Ferrite, therefore, is very soft, very ductile, and relatively weak, having a ductility corresponding to an elongation of at least 40 per cent. and a tensile strength of some 50,000lbs. per square inch. It is magnetic, has a high electric conductivity, and is deprived of hardening power, industrially speaking at least, since carbonless iron cannot be materially hardened by rapid cooling from a high temperature.

The properties of pearlite are evidently those of eutectoid steel in its normal—*i.e.*, pearlitic—condition, from which we may infer that pearlite has a tenacity of some 125,000lbs. per square inch, an elongation of some 10 per cent., that it is hard, and that it possesses maximum hardening power.

With the exception of its very great hardness, little is positively known as to the physical properties of cementite. It may be assumed, however, that so hard and brittle a substance must greatly lack tenacity. Its tensile strength probably does not exceed 5,000lbs. per square inch, and may be considerably less, while its ductility must be practically nil. It possesses no hardening power. These properties of the constituents of steel in its normal condition are tabulated below.

Constituents.	Tensile Strength. Pounds per square inch.	Elongation. Per cent. in 2in.	Hardness.	Hardening Power.
Ferrite	50,000±	40+	Soft	None
Pearlite	125,000±	10±	Hard	Maximum
Cementite ..	5,000 (?)	0	Very hard	None

Tenacity of Steel v. its Structural Composition.—Knowing the physical properties of the three constituents of steel, it should be possible to foretell with some degree of accuracy the physical properties of any steel of known structural composition, on the reasonable assumption that these constituents impart to the steel their own physical properties in a degree proportional to the amounts in which they are present. The properties of steel made up, for instance, of 50 per cent. ferrite and 50 per cent. pearlite should be the means of the properties of ferrite and of pearlite. Let us assume such reasoning to be correct, and let us apply it to the tensile strength, first of hypo-eutectoid steel and then of hyper-eutectoid steel.

The tensile strength (T) of any hypo-eutectoid steel will be expressed by the following formula in function of its structural composition; that is, in function of the percentages of ferrite (F) and pearlite (P) which it contains :—

$$T = \frac{50{,}000\,F + 125{,}000\,P}{100}$$

in which 50,000 represents the tensile strength of ferrite and 125,000 the tensile strength of pearlite.

Or simplifying :

$$T = 500\,F + 1{,}250\,P$$

or again in terms of pearlite alone, since $F = 100 - P$

$$T = 500\,(100 - P) + 1{,}250\,P$$

$$\text{or } T = 50{,}000 + 750\,P$$

or finally, in terms of carbon, since $P = 120\,C$

$$T = 50{,}000 + 90{,}000\,C$$

On applying this simple formula to steels containing respectively 0·10, 0·25, and 0·50 per cent. carbon, we find for these metals tensile strengths, respectively, of 59,000lbs., 72,500lbs., and 95,000lbs. per square inch. These values agree closely with our knowledge of the average tenacity of such steels when in a pearlitic condition, and prove the value of the formula derived from the considerations outlined above as to the relation existing between the physical properties of steel and its structural composition. It should be borne in mind that in working out this formula it has been assumed that pearlite contains 0·834 per cent. carbon.

The values obtained for various eutectoid steel should be accurate only for steel in its pearlitic condition. It should be noted, however, that steels forged and finished at a fairly high temperature are practically in this condition, so that the formula may be used, and fair results expected, to calculate the tensile strength of such hot forged steels. If the steel be forged until its temperature is quite low, and especially if it be cold worked, it is well known that its tensile strength is generally increased. Neither can the formula be used, of course, in the case of hardened steel or of steel castings. It may, however, be applied to steel castings which have been properly annealed, when the tensile strength may be brought up to the level of steel forgings finished fairly hot.

Again, the formula is of value only in case of commercial steels containing the usual proportions of impurities, especially of manganese. It applies only to steels in which the percentage of manganese varies roughly with the carbon content from some 0·20 to 0·80 per cent. The presence of a larger proportion of manganese would increase the tenacity materially.

Passing to the tensile strength of hyper-eutectoid steel, our ignorance as to the tenacity of cementite does not permit the writing of a formula with the same degree of confidence. Let us assume, tentatively, however, that cementite has a tensile strength of 5,000lbs. per square inch, and then proceed as we did in the case of hypo-eutectoid steel.

The tensile strength of any hyper-eutectoid steel may be expressed by the following formula in terms of the percentages of pearlite (P) and cementite (Cm) which it contains :—

$$T = \frac{125{,}000\,P + 5{,}000\,Cm}{100}$$

or simplifying

$$T = 1{,}250\,P + 50\,Cm$$

or, in terms of pearlite only, since $Cm = 100 - P$,

$$T = 1{,}250\,P + 100\,(50 - P)$$

$$T = 5{,}000 + 1{,}200\,P$$

or since, as previously shown,

$$P = \frac{800 - 120\,C}{7}$$

$$T = 5{,}000 + 1{,}200\,\frac{800 - 120\,C}{7}$$

or simplifying

$$T = \frac{995{,}000 - 144{,}000\,C}{7}$$

or approximately $T = 142{,}000 - 20{,}600\,C$.

Applying this formula to steels containing, respectively, 1·25 and 1·50 per cent. carbon, we find for their respective tensile strength 116,250 and 111,100 per square inch, which are fair values for the average tenacity of pearlitic steels of those degrees of carburisation.

Steel of Maximum Strength.—From the preceding considerations it seems evident that eutectoid steel must possess maximum tensile strength, since the influence of the presence of ever so small an amount of free ferrite in hypo-eutectoid steel or of free cementite in hyper-eutectoid steel must necessarily be a weakening one, because of the relative weakness of free ferrite and free cementite as compared to the strength of pearlite. By most writers, on the other hand, steel of maximum tenacity is often stated to contain in the vicinity of 1 per cent. carbon—that is, to be slightly hyper-eutectoid.

It is not clear, however, that the results upon which the statement is based were obtained in testing steel in its *pearlitic condition*. On the contrary, it seems probable that a large number of the steels tested were in a sorbitic rather than in a pearlitic condition because of relatively quick cooling through the critical range. And, while it appears that pearlitic steel must have its maximum tenacity when composed entirely of pearlite, it may well be that when in a sorbitic condition maximum strength corresponds to a higher degree of carburisation—*i.e.*, 1 per cent.—because sorbite may contain, and indeed often does contain, more carbon than pearlite. Indeed, the cases on record show that when the steels were made pearlitic through very slow-

cooling maximum tenacity corresponds closely to the eutectoid composition. Arnold, for instance, tested a series of very pure carbon steel and after slow cooling in the furnace from 1,000 C. he found a very sharp maximum in the tenacity corresponding to 0·89 per cent. carbon. On cooling these same steels in air, on the contrary, and therefore making them sorbitic, maximum tenacity corresponded to 1·20 per cent. carbon. Harbord likewise ascertained the tenacity of very pure steels, and found that after slow cooling (in the furnace) from 900 C. the maximum tenacity corresponded to 0·947 per cent. carbon.

Ductility of Steel v. Its Structural Composition.—From the known ductility, as expressed by its elongation under tension, of ferrite and the known elongation of pearlite, respectively 40 and 10 per cent. in two inches, it should be possible to work out a formula expressing the ductility of any hypo-eutectoid steel in the annealed (pearlitic) condition. In terms of ferrite and pearlite the ductility should be

$$D = \frac{40\,F + 10\,P}{100}$$

or simplifying

$$D = \cdot 4\,F + \cdot 1\,P$$

or, in terms of pearlite alone, since $F = 100 - P$,

$$D = \cdot 4\,(100 - P) + \cdot 1\,P = 40 - \cdot 3\,P$$

and since $P = 120\,C$, the ductility in terms of carbon will be

$$D = 40 - 36\,C$$

Pearlitic steels, for instance, containing 0·25 and 0·50 per cent. carbon should have elongations, respectively, of 31 and 22 per cent.

Reduction of Area v. Structural Composition of Steel.—In a similar way we may calculate the reduction of area of any slowly cooled (*i.e.*, pearlitic) hypo-eutectoid steel, on the assumption that pearlite has a reduction of area of 15 per cent. and ferrite a reduction of 60 per cent. The reduction of any steel will then be, in terms of ferrite and pearlite :—

$$R = \frac{60\,F + 15\,P}{100} = \cdot 60\,F + \cdot 15\,P$$

or, in terms of pearlite alone, since $F = 100 - P$,

$$R = \cdot 60\,(100 - P) + \cdot 15\,P = 60 - \cdot 45\,P\,;$$

or, finally, in terms of carbon, since $P = 120\,C$,

$$R = 60 - 54\,C.$$

Pearlitic steels, for instance, containing 0·25 and 0·50 per cent. carbon should have reductions of area, respectively, of 46·5 and 33 per cent.

Examination of Coal by X-Rays.—At a meeting of the North of England Institute of Mining and Mechanical Engineers, held at Newcastle on Saturday last, a paper by Mr. F. C. Garrett, D.Sc., and Mr. R. C. Burton, B.Sc., on "The Use of X-Rays in the Examination of Coal," was read. The authors stated that shortly after Rontgen's discovery, it was suggested that the rays might be utilised for determining the amount of inorganic matter contained in coal, it being thought that the opacity would be directly proportional to the ash content of the sample. The inorganic minerals commonly associated with coal, however, differ so greatly in their permeability that it was very soon found that the opacity depended on the nature as well as on the amount of mineral matter, and the method proved to be of no practical value. Although the X Rays cannot tell the amount of ash which a sample of coal will yield, it was thought that they would probably reveal its distribution in the coal, and might throw some light on the structure of the coal itself. Samples from a number of different seams were obtained, and the examination of these has given results. The study of a number of radiographs leads the authors to conclude that, although the true coal substance is almost transparent to X Rays, there are small, yet noticeable, differences between different coals, and even in different parts of a small specimen, and to hope that a full investigation of these may throw some light on the structure and perhaps on the origin of different coals. At this early stage it is not permissible to draw any conclusions as to the structure of coal, but it was hoped by the writers that the publication of their notes might lead to suggestions which would be of assistance in the further investigation of the matter.

INDUSTRIAL AND TRADE NOTES.

British Locomotive Exports.—During the present year the exports of locomotives from the United Kingdom have been fairly well maintained, the value of the engines shipped to April 30th having been £713,150, as compared with £708,987 in the first four months of 1911 and £591,537 in the first four months of 1910.

Birkenhead Engineers' Dispute.—Satisfactory terms have, we understand, been arranged between Messrs. Cammell, Laird, and Co., of Birkenhead, and their engineers. Arbitration has been arranged, with the result that the men returned to work on Monday last. They have been out on strike for several weeks.

A New Floating Dock.—The Admiralty have, we learn, placed the order for a floating dock to lift vessels up to 2,200 tons displacement with Messrs. William Hamilton & Co., Ltd., of Port Glasgow. The dock is intended for the use of torpedo boat destroyers and light craft generally.

Locomotives for the Argentine.—Messrs. R. Stephenson & Co., Ltd., of Darlington, have received an order for 10 large tank locomotives for the Buenos Ayres Great Southern Railway Company, Ltd. This order is practically a repetition order for 10 similar engines which Messrs. Stephenson are now completing for the same company.

Manufacture of Steel Pipes and Tubes in Japan.—For some years past there has been talk of establishing a company in Japan for the manufacture of steel pipes and tubes, and of late the project seemed to assume more definite shape when a well known Japanese firm were said to be making all preparations for manufacture by the Mannesmann process. This venture, however, according to H.M. Commercial Attaché at Yokohama, seems to have been postponed, and another set of promoters, including some prominent men, is discussing the possibility of forming a company and starting work in September, 1913.

Gas and Oil Engines in Japan.—The trade in gas and oil engines in Japan continues to increase, according to H.M. Commercial Attaché at Yokohama. The United Kingdom enjoys about 70 per cent. of the business, most of the rest, especially in the case of the larger engines, being taken by Germany. Small gas engines are now found in all parts of the country, as the Japanese are gradually beginning to appreciate their advantages. There are several kinds of Japanese engines on the market, but although they are cheap they are not economical.

Small Switches and their Circuits.—We have received from Messrs. A. P. Lundberg & Sons, 477, Liverpool Road, London, N., a most instructive catalogue of their specialities relating to switches and switch gear, or, rather, it would be more correct to term it a text book, so exceedingly full is it of descriptive, illustrated information, and so well is it portrayed. In fact, the literary presentation of the subject is the work of the well known writer on electrical subjects, W. Perren Maycock, M.I.E.E., and no pains have been spared to make it both instructive and useful. It is a long way superior to the ordinary class of trade catalogues, and should appeal strongly to all who are in any way interested in electrical accessories of this kind.

British Coal Exports.—A White Paper just issued gives details of the shipments of coal abroad, coastwise and in bunkers, from each port of the United Kingdom during 1910 and 1911. The total coal exports from the United Kingdom in 1911 were 64,599,266 tons, as against 62,085,476 in 1910, Cardiff heading the list of ports with 16,127,777, Newcastle and the Shields totalling to 12,198,[illegible]. Of the total exports, 25,029,865 tons went to Russia, Scandinavia, Germany, Holland, Belgium, Iceland, and the whale and deep sea fisheries, the bulk coming from the East Coast ports, and 31,330,571 to other European countries and Mediterranean ports. The shipments of coal coastwise totalled 22,[illegible]5,021 tons in 1911, against 21,676,715 in 1910; and the shipments of bunker coals were—foreign voyages 19,204,189 tons, coastwise voyages 2,131,925.

Decline of Shipbuilding Industry in the United States.—According to a report by H.M. Consul-General at Boston, the shipbuilding industry in the United States showed a decline during the past five years of 17 per cent. in value of materials, 14 per cent. in the aggregate wages paid, and 2[illegible] per cent. in the number of men employed. The cause is generally held to be high wages and high cost of construction combined with a [illegible] to [illegible] due to unrestricted competition in the ocean traffic. Maine's shipbuilding record in 1911 emphasizes the decline of that once great industry, the entire output of the State, including all sorts of craft of all sizes, falling below 10,000 tons, whereas in times past the new tonnage ranged from 30,000 to 40,000, and occasionally reached as high as [illegible] or 70,000 tons.

Russian Iron and Steel Production.—During the past year the iron and steel industries in Russia made good progress. The total production of pig iron in 1911 was 3,521,000 tons, an increase of 538,000 tons over the production in 1910. It is interesting to note that the production of steel ingots for several years has been considerably in excess of the pig-iron production, the balance being accounted for by excess of pig iron imports over exports, imports of scrap and similar materials, and (last year) reduction in stocks of pig iron. The total steel output during 1911 was 3,874,000 tons, as compared with 3,476,000 tons in 1910. Of the total of steel produced last year about five-sixths was open-hearth steel. The total output of finished iron and steel amounted to 3,258,000 tons last year, this being well above any previous figure.

Canadian Railroads in the States.—All the great Canadian railway systems possess or control a considerable mileage in the United States, a policy which is imposed upon them no less by the exigencies of trade exchange between the two countries as also by general geographical and economic considerations. While Canada desires first and foremost the expansion of trade east and west along railroads (for the construction of which millions of English capital have been borrowed) at the same time opportunities to foster trade north and south have not been neglected. The United States railways also have 1,485 miles of track in Canada, on the other hand the Canadian railways have not less than 7,197 miles of track in the United States, divided as follows: The Canadian Pacific Railway, 5,391; the Grand Trunk, 1,636, and the Canadian Northern, 170 miles. The two last named railways are at present engaged in securing the control of lines which will give them greater facilities of outlet to the east through the United States, with terminals on Atlantic ports. This inter-change of railroad is likely to increase very much in British Columbia, into which province several United States railway companies are seeking to extend their systems.

Midland Ironworkers' Wages.—The Ironworkers' Association has initiated a movement for higher wages for puddlers which is shortly to come before the Midland Wages Board. One of the results of the great activity of the iron trade is a scarcity of puddlers, the demand for men at present being very great, and as they have a number of grievances, in addition to the question of wages, it is felt that the present affords a good opportunity to improve their position. The Midland Wages Board covers not only the counties of Staffordshire, Shropshire, and Worcestershire, but Sheffield, Lancashire, and South Wales, so that several thousands of workmen are affected by the movement. At a largely attended meeting of ironworkers held on Saturday last at Wednesbury, specially called to consider the question of puddlers' wages and hours of employment, it was decided to forward the requisite three months' notice to terminate the present iron trade sliding scale, in order that the rates and conditions under which the puddlers work could be revised. In the judgment of the trade, the limit of a puddler's working day should not be more than 10 hours, and that he is, under present circumstances, entitled to a tonnage rate of not less than 10s. per ton. The rate ruling at present is 9s. 3d. per ton.

Trade with Japan.—H.M. Commercial Attaché at Yokohama, in a report on the trade of Japan in 1911, refers to the new Japanese tariff. He states that, taken altogether, there seems no reason to be pessimistic about future prospects. It is probable, nay, certain, that with the enforcement of the higher rates of duties certain classes of business will die out, but in their place others of equal if not greater importance will arise. It will perhaps be necessary to work harder and to be satisfied with a smaller percentage of profit than in the past, and business will have to be searched for and the peculiar conditions of the market studied. If possible, it is highly advisable that a manufacturer who hopes to do a large business with Japan should pay a visit to the country. Thanks to the Siberian railway, the trip need be neither long nor expensive. Several manufacturers who have adopted this course have stated that the results have been most satisfactory. The firms in Japan who act as agents are generally most efficient, but as in many cases they do business in a large number of articles they cannot be expected to be absolutely conversant with all the details pertaining to the various goods which they sell. It is to the advantage of the agents, therefore, as well as to the maker of the goods, that a periodical visit should be paid by an expert who can explain matters to the firm's customers and listen to their suggestions and complaints.

Electro-Metallurgical Industry in France.—H.M. Consul at Lyons (Mr. E. R. E. Vicars), reporting on the trade of that district during 1911, states that the most important development in the electro-metallurgical industry during 1911 related to the production of aluminium and its by-products, the French manufacturers of which have formed themselves into a company called "L'Aluminium français," with a share and debenture capital amounting to £680,000. The new company have acquired the exclusive rights all over the world in the Serpeck process of aluminium manufacture. This process, by which the production of nitrates forms part of the manufacture of aluminium, consists in the treatment of bauxite, the raw material of aluminium, in the electric furnace with air and coke, so as to fix the nitrogen, thus producing a nitride of aluminium. This product is then treated with a solution of caustic soda, which produces aluminate of soda and ammonia gas. From the aluminate of soda is extracted pure alumina, from which aluminium is obtained by the usual electrical process; while the ammonia gas is treated with sulphuric acid and produces sulphate of ammonia. The process is thus closely allied with that in use for the production of nitric acid and nitrates by the union of oxygen, nitrogen and steam in the electric furnace. Large works, utilising 40,000 h.p., are about to be established by the aluminium combine for the purpose of manufacturing under this process. The company are also said to contemplate the erection of rolling and drawing works near Chambéry. It is understood that the United States rights have been conceded to a subsidiary company with large financial resources, and that licenses will probably be granted by the parent company for working the patent in other foreign countries. The production of ferro-alloys and patent steels in the electric furnace grows apace in the Lyons district, 12 factories being now engaged in this branch of the industry.

INTERNAL-COMBUSTION ENGINES ON SHIPS.

At a meeting of the North-east Coast Institution of Engineers and Shipbuilders, Sir Marcus Samuel, in the course of a discussion, stated that he had been favoured with particulars of the latest oil ship, the "Jutlandia," built by Messrs. Barclay, Curle, & Co. The oil consumption was 10 tons per day, as compared with a coal consumption of 42 tons per day. In the oil ship, the wages of the engineering staff were computed at £86 per month, as against a similar item in the steamer of £114, with a consequent saving in the catering of the oil ship as compared with the steamer of £15. The cargo deadweight of the oil ship for a voyage of 6,850 nautical miles was 7,105 tons, as against the steamer's 6,210 tons. He went on to say that owners must not despair because the price on rail of oil at storage works on the North-east Coast of England was 70s. a ton. They must remember that we were going through a period unequalled in the oil trade, owing to scarcity of tankers caused by the delay in building these vessels through labour troubles. Time would change all that; and when producers knew that there was to be a reliable and constant demand for oil on the Tyne, sufficient oil would be provided to take them to the nearest oiling station. He expressed his firm conviction that, in a very short space of time, internal-combustion engines would be evolved as greatly superior to those already constructed as the modern locomotive was to Stephenson's engine.

TEMPERING OF ALUMINIUM BRONZES.

According to A. Portevin and G. Arnou, in "Comptes Rendus," aluminium bronzes containing 89-90 per cent. Cu consist of a eutectoid in a more or less fine state of division, according to the rate of cooling, and an excess of the Cu-rich α constituent. Heating for a sufficient time above the transformation temperature followed by quenching, results in the disappearance of the α constituent and the structure becomes wholly martensitic, resembling that of hardened steels. Experiments have been made on the effect of tempering on the structure and properties of two industrial alloys containing 89·84 and 18·80 per cent. Cu, 9·95 and 10·02 per cent. Al, and 0 and 1·11 per cent. of Mn respectively. Brinell and Shore hardness tests made on quenched specimens subsequently tempered for 10 min. at temperatures between 400° C. and 700° C. in a molten salt bath showed that up to 400° C. the hardness was increased. This increase was accompanied by a diminished elongation in a tensile test and an increased fragility under shock. Above 500° C. the hardness diminished to below its original value, the elongation increased and the fragility decreased. Similar phenomena occur in hardened steels and bronzes, all of which exhibit martensitic structures.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Economisers for furnaces and steam boilers. Reynolds. 775.
Balancing the thrust of propeller shafts. Kneen. 3615.
Valve mechanism of internal combustion engines. Barker and Clarke. 8892.
Conveyers. Donald & Donald. 11257.
Prevention of "over windings" in mines. Daglish & Beck. 11282.
Gas turbine. Blake. 11289.
Internal combustion engines having rotary valves. Jouffret. 11300.
Rotary internal combustion engines. Inshaw. 11346.
Methods of raising or forcing liquids. Humphrey. 11527.
Cooling the pistons of internal combustion engines. Sheppard and Sheppard. 11591.
Automatic couplings for railway vehicles. Smith. 11698.
Apparatus for the conversion of motion according to one law into motion according to another law. Barr & Stroud. 11772.
Steering gear for vessels. Wykeham-Martin. 11878.
Apparatus for measuring mechanical power output. Marks. 12025.
Winches. Holloway. 12071.
Process for solidifying petroleum or petrol. Blackler. 12291.
Mechanical stoking apparatus. Neil. 12946.
Water tube boiler. Musgrave. 12953.
Tools for scaling tubes. Boilers Scalers, Ltd., and Brindley. 12975.
Couplings for railway vehicles. Wallander. 13232.
Apparatus for signalling on trains and for stopping trains. Konig and Kinzel. 14487.
Jaw chucks. Jackson. 14536.
Construction and manufacture of wrought metal wheels. Challiner and Challiner. 15701.
Valve mechanism of internal combustion engines. Sangster. 16245.
Starting gas and other internal combustion motors. Bellamy. 16287.
Furnaces for extracting volatile metals from their ores. Zavelberg. 16821.
Explosion motors. Conaghy. 17628.
Method of silencing the exhaust gases of internal combustion engines. Clarke. 17910.
Screw cutting stocks and dies. Frey. 18032.
Water tube steam boilers. Todd. 18635.
Lubricating wheels of railway and tramway. Edgar Allen & Co., and Wells. 18714.
Gas calorimeters. Macklow Smith & Pullen. 19051.
Power-operated throttle and stop valves. Alley. 19073.
Distributing valves for internal combustion engines. Itala Fabrica di Automobili. 19455.
Carburetters for internal combustion engines. Austin. 19759.
Gearing of wind mills. Fortescue. 21063.
Process and apparatus for casting metals. De Buigne. 21167.
Barring engines. Hargreaves & Bruce. 21473.
Friction clutches. Isfort. 21578.
Rivet or bolt beheader. Ogden. 21901.
Tube rolling mills. Stuting. 22180.
Change speed gearing. Bramley Moore. 22459.
Sand blast apparatus. Sauer. 22668.
Processes and apparatus for screening ore. Stanley. 22683.
Apparatus for cleaning the tubes for water heaters or economisers. Evans. 24071.
Pressure equalising devices for fluids. Reisert. 24143.
Controlling apparatus for fluid pressure motors. Herr. 24155.
Manufacture of steel bars. Riley. 24389.
Emergency brake for tramcars. McDermid & Jewson. 24504.
Accessory for screw cutting lathes. Bau. 24881.
Mechanical ore roasting furnaces. Harris. 25142.
Starting mechanism for internal combustion engines. Painchaud. 25486.
Rope laying machines. Lake. 25507.
Combined steam and gas generator. Marischka. 25684.
Reversing gearing. Budde. 26004.
Couplings or connections for flexible tubing. Price. 26232.
Casting apparatus. Johnson. 26414 and 26417.
Apparatus for generating acetylene gas. Dargue. 26631.
Screw propellers for aerial navigation. Soc. Anon. des Ateliers d'Aviation Louis Breguet. 27021.
Lifting jacks. Dunlap. 27156.
Production of high-grade steel and slag, rich in soluble phosphates in an open hearth or electric furnace. Deutsch-Luxemburgische Bergwerksund Hutten Akt.-Ges. and Vogler. 27400.
Centrifugal governors. Bates. 27928.
Water cooled rotary distributing valves for internal-combustion engines. Itala Fabrica di Automobili. 27932.
Brake apparatus for railway vehicles. O'Donnell. 28979.
Rotary motors. Bucher. 29002.
Metallic packings for pistons and rods. Redford. 29350.

1912.

Train signalling systems. Sindeband & Woticky. 228.
Spring coupling for shafts. Robert Bosch. 439.
Ball bearings. Deutsche Waffen und Munitionsfabriken. 2323.
Apparatus for starting internal combustion engines. Unterberg and Helmle. 2865.
Toothed reduction gearing. Westinghouse. 3205 and 6822.
Controlling mechanism for hoisting apparatus. Becat. 3435.
Piston draining device. Schmidt. 5645.
Process for hardening low carbon steel. Geb. Schubert. 5702.
Means for securing railway rails to sleepers. Haarmann. 6560.
Tool for use in making joints in driving belting. Gunn. 7329.
Apparatus for testing air and gases. Arndt. 8199.

ELECTRICAL, 1911.

Electric welding or soldering. Kjellberg. 3762.
Electric switches. British Thomson Houston Company, and Wedmore. 3877.
Method of and means for varying electrical capacity and induction. Isenthal. 11209.
Electro magnetically operated devices for controlling electric circuits. British Thomson Houston Company. 11349.
Systems of electric motor control. British Thomson Houston Company. 11351.
Electric lighting of motor road vehicles. Grafton. 13888.
Electric motor starters. Barbour. 14032.
Switches for controlling the electric lighting systems of automobiles. Brooks & Holt. 15508.
Arc lamps. Engineering and Arc Lamps, Ltd., and Dowdell. 16678.
Distributors of magneto electric machines for internal combustion engines. Brooks & Alston. 16878.
Reversing switches for electric motors. Easton Lift Company, and Huggett. 16919.
Telegraphic systems. Faiella. 17151.
Telephones. Gwozdz. 17278, 17300, 17429, 17530, 17587, 17595, and 17820.
Electrical switches. Railing & Ide. 18584.
Electric motor driving for machine tools. Feyer. 19162.
Plug and socket connections for electric circuits. Lucas and Jenkins. 21419.

1912.

Mounting of filaments for incandescent electric lamps. Deutsche Gasgluhlicht Akt. Ges. (Auerges.). 873.
Telephone exchange systems. Jensen. 4984 and 5877.
Electrodes for arc lamps. British Thomson Houston Company. 6500.

METAL QUOTATIONS.

TUESDAY, JUNE 4TH.

Aluminium ingot	67/- per cwt.
" wire, according to sizes, &c. ......from	102/- "
" sheets " " ...... "	120/- "
Antimony .... £27/-/- to	£28/-/- per ton
Brass, rolled	8½d. per lb.
" tubes (brazed)	10⅞d. "
" " (solid drawn)	9d. "
" " wire	8⅝d. "
Copper, Standard	£77 10/ per ton.
Iron, Cleveland	53/7½ "
" Scotch	59/7½ "
Lead, English	£17/5/- "
" Foreign (soft)	£16/17/6 "
Mica (in original cases), small	6d. to 2/ per lb.
" " " medium	2/6 to 4/- "
" " " large	4/6 to 8/6 "
Quicksilver	£8/5/- per bottle
Silver	28 1/16 d. per oz.
Spelter	£26/2/6 per ton.
Tin, block	£203/-/- "
Tin plates	14/9 "
Zinc sheets (Silesian)	£29/-/- "
" (Stettin; Vieille Montagne)	£29/7/6 "

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Water Supply.

The summer meeting of the Institution of Water Engineers, held last week, directs attention to the subject of water supply, especially water supply for town service. Last year, with its long drought, brought the importance of this subject home to both engineers and laymen with a directness which has not been without its effect. Steam users found their boiler feed water deteriorating in quality and their cleaning and repair bills rising in consequence; whilst the boiler insurance companies found it necessary to strengthen the stringency of their inspections and the plainness of their warnings against the use of bad feed waters. Town supplies were also seriously tried, with the result that this year finds an unusually large number of waterworks contracts, particularly pumping contracts, being placed.

This last few years have witnessed a considerable advance in the science of water supply. There has been, for instance, a growing recognition of the fact that water is supplied not merely as a drink, but also very largely as an instrument of industry. This broadening of the outlook has been accompanied by a striking advance in the science of water purification, so that the needs of industry cannot be said to have adversely affected the vital importance of the health point of view. On the other hand it must be recognised that waters for drinking and for washing and industrial uses are not necessarily the same in quality, and the question arises whether or not the two classes ought not to be separated, a relatively small supply of potable water of undoubted purity being distributed to all consumers, together with a larger supply of cheaper water for other purposes. In some cases this question does not arise. In Manchester, for instance, the water is of first-class quality for both drinking and general purposes, but in Paris much of the water is drawn from contaminated sources and has to be specially purified before it is fit for drinking, although probably all the water could be used without purification, beyond perhaps a little settling or filtration, for boilers, washing, and general

industrial purposes. A somewhat different illustration of the same problem is furnished by hard waters from the chalk districts. The general opinion among medical men is that these waters are as healthy as soft waters, although some hold that they encourage gouty diseases. There is, however, no doubt whatever that for industrial purposes a hard water is seldom as good as a soft one. If softening is adopted it is simplest to use the softened water for all purposes, but it is conceivable that this might not always be the case.

There is no rule as to the suitability of various sources of water. In general deep wells or boreholes and mountain waters are good for drinking; the former because the water is thoroughly filtered before entering the well, and the latter because, although often largely surface water, it is usually comparatively free from agricultural contamination There are exceptions, and it by no means follows that other sources necessarily give impure waters. Further, a water may be satisfactory for drinking and yet unsatisfactory for other purposes. Deep-well waters, for instance, are often hard owing to the water dissolving various salts in its percolation through the rocks. Mountain waters are also occasionally hard, and not infrequently impregnated with peaty acids, which have a corrosive effect. This corrosive effect, it may be noticed, is very marked on lead, so that moorland waters may be bad for drinking purposes, and artificial hardening or neutralisation with lime is then often resorted to as a corrective, particularly in order to remove the lead-solvency. This, for instance, is the case at Burnley, Wakefield, Sheffield, and other northern towns. For some industries, especially bleaching and dyeing, a clean, soft water supply is necessary, and the same is true in a greater or less degree for most industrial purposes. An exception seems to be found in certain supplies which are almost repulsive in their filth. Thus the water of the Irwell and Ship Canal at Manchester, notoriously filthy and moderately hard, is credibly stated to be of excellent quality for boilers, and tales are told of boilers using this water for many years without ever requiring internal inspection and cleaning, beyond simple flushing out. Water softening is becoming more and more common, although as yet mainly resorted to by private firms. A few towns soften their water supplies, and there is no doubt that this practice will increase when the great value of softened waters is realised. For washing of all kinds the water must either be softened artificially before use or by the soap during the washing process. To remove 10° of hardness requires about 17lbs. of soap, costing four or five shillings per thousand gallons. Seeing that the water itself probably costs between 6d. and 1s. and that it could be softened in bulk by the supply authority for about 1d. or 2d., it is clearly highly uneconomical to use hard water. Further, the quality of the product is inferior in colour when washed in hard water. When we come to feed water for boilers it is not quite so easy to calculate the monetary value of soft water as compared with hard, but there are certainly tangible advantages, especially when boilers of the water-tube type are used. A good deal has been written about the falling off in efficiency which results when the boiler heating surface becomes coated with a moderate thickness of scale due to the use of hard or dirty water, but this falling off is generally much exaggerated. Still, there is some falling off, and it cannot be satisfactorily overcome except by a removal of the cause. More important disadvantages attending the use of hard feed water are the increased cleaning required by the boiler, the greater risk of overheating and consequent troubles, and the shortened life of the boiler. Boilers of the Lancashire or Cornish type suffer least from hard waters because they can be more readily cleaned, and because their large water spaces are less restricted and circulation retarded by deposit. Another source of loss which has often to be incurred when hard water is used is that occasioned by blowing down the boiler at periodic intervals in order to reduce the concentration of the dissolved salts and the precipitation of some of them. Generally there is now a strongly growing feeling in favour of softening hard waters, although water-softening is not without its difficulties.

For domestic use purity is essential, and in this case purity is largely a matter of bacteriological condition. The science of water purification is still quite young, but already great steps have been made. Waters which are tainted with harmful bacteria can be purified by storage, filtration, or by chemical and other treatments. It has been conclusively proved that storage is a powerful bacteriological purifying agent, and hence as a practical measure river water, which is often more or less suspect, may be first passed into a reservoir sufficient to hold, say, three weeks' supply. Filtration, whether by slow gravity sand filters or by rapid pressure filters, also has a remarkable influence on the more harmful bacteria in water. The precise nature of the purifying process is still a matter for dispute, but the facts are undisputable, and with care filtration will purify all ordinary river waters. Chemical treatment of water has to be carefully done, as the resultant solutions are necessarily extraordinarily weak and there is a natural tendency to overdose the filter beds or tanks in which the process is attempted. Allied to chemical means is the ozone process, in which both bacteria and minute organic matters are destroyed by bubbling ozonised air through the water. Recently the actinic light rays from mercury-vapour lamps have been successfully employed to destroy bacteria. With all these methods to choose from it is now possible to purify ordinary river waters, even when distinctly tainted with sewage, and render them quite suitable for drinking. Trade wastes offer a more serious problem. Mainly this problem seems to be chemical and only occasionally bacteriological, and although chemistry is a much more advanced and older science than bacteriology, in this branch it is much in the rear. Still, there is no reason to think that the end of progress has been reached, and the time should not be far distant when a moderately dirty and impure water supply can be effectively purified for domestic as well as trade use. Naturally-pure waters will, of course, always be sought after, but the spread of industry and population tends to restrict the available supplies, whilst at the same time demanding an increase, so that one may confidently predict the perfection and extension of water purification and the freer use of such waters for both domestic and industrial purposes.

Mail Train's Excessive Speed at a Curve.— There has just been issued Lieutenant-Colonel E. Druitt's report on his enquiry into an accident which occurred at Eaglescliffe North Junction on the North-eastern Railway, on April 5th last, when the 4-5 a.m. mail train from York to Newcastle, after passing the junction, left the rails, and the third carriage from the engine caught fire. One passenger complained of being shaken, and the guard in charge of the train suffered from shock. Colonel Druitt regarded the accident as due to the excessive speed of the train, causing the carriages to rock considerably going round a sharp curve, and recommended that the speed through the junction should not exceed 15 to 20 miles an hour.

THE TROLLEY VEHICLE SYSTEM OF RAILLESS TRACTION.*

BY HENRY C. ADAMS, A.M.INST.C.E., M.I.M.E., A.M.I.E.E.

(Concluded from page 704).

THE "R.E.T." system differs considerably from all the foreign systems previously described. It was designed by the Railless Electric Traction Company, now the R.E.T. Construction Company, specially to suit British conditions, and was first tried on the experimental length at Hendon in September, 1909. In an improved form it has been installed by this company upon the only two systems at present working in this country, namely, Leeds and Bradford, and is now being installed at Dundee and Rotherham.

FIG. 12.—R.E.T. CONSTRUCTION COMPANY'S DOUBLE TROLLEY.

The positive and negative overhead wires are placed parallel about 13½in. apart and 21ft. above the surface of the ground. Four wires are provided so that a continuous service can be maintained in each direction. At Leeds they are all placed close to each other and suspended from 18ft. bracket arms; the two inside wires being positive and two outer negative. The Bradford overhead work is on the span-wire system. The cars are fitted with double trolley booms of the under-running type, and placed side by side as shown in Fig. 12. The weight in the most modern type is about 3 cwts. These trolleys permit the car to deviate within a width of 15ft. on either side of the centre of the wires as measured to the centre of the vehicle, but longer booms can be made if desired. The cars run without difficulty with the trolley boom at right angles to the direction in which the car is travelling. The tension in the springs is rather lower than usual in tramway practice and gives an upward pressure of about 12lbs., this being all that is necessary, because besides the usual raising springs there are additional springs working in a horizontal plane and controlling the pivot of the trolley base so as to relieve the trolley wheels of excessive side pressure and to ensure the trolley head remaining in contact with the wires. Each trolley boom is capable of swinging quite independently of the other. The facility with which the cars can be run in and out of the traffic and the rapid swerves across the road which they can make at high speed without displacing the trolley are remarkable and one would hardly expect such perfect flexibility unless they had actually seen the system at work. The only difficulty which has been experienced since the lines were opened was at the terminal circles during the first few days and before the drivers had become accustomed to turning the cars on a curve approximating to that of the overhead work. Fig. 13, which is taken from the "Light Railway and Tramway Journal," shows a car drawn up to receive passengers on the opposite side of the road to that on which the poles are erected.

The route at Leeds is 3¾ miles long, going from the City Square to Upper Moor Top at Farnley. The fare for the whole distance was originally 3d. but is now 2d., and the journey averages 24 minutes. At the city terminus the cars pass round a triangular block of buildings and at the other end the overhead wires at the junction of two cross roads form a circle around which the cars pass. For the first seven-eighths of a mile the trolley omnibuses pass along a road in which the trams run and on this section the omnibuses use the same positive wires as the tramway cars. The omnibuses are fitted with a skate hinged to the chassis, and consisting of a rail cleaner, a brush, a guide wheel to fit the groove of the tram rail, and a copper contact piece, by means of which after the negative trolley has been lowered, the return current can be conveyed to the tram rails when it is desired to run the omnibuses along a tram route where there is no negative wire. In this way the omnibuses, using one boom only, can run over any part of the tramway system. The skate allows a maximum deviation of 5ft. on either side of the rail into which it may be fitted. The omnibuses pass under four railway bridges varying in height from 14ft. 9in. to 16ft.

The route at Bradford is 1¼ miles long from Laisterdyke to Dudley Hill through a thickly populated district and connecting at each end with an existing tramway service. The fare for the whole distance is 1d. and the journey occupies 10 minutes. The cars use the tramway depôt at Thornbury; the omnibus wires being suspended from the bracket arms carrying the tramway wires between the depôt and Laisterdyke. The overhead wires form a circular curve at the Dudley Hill end of the route, but at Laisterdyke the wires form an open-angled triangle at the intersection of a branch road. When the car arrives at the terminus it travels round one side of the triangle into the side road, then the trolley booms are changed on to the other side of the triangle and the car backs into the main road, where the trolley booms are again moved on to the wires forming the third side of the triangle, when it is ready to commence the return journey.

The motors consist of two Siemens interpolar traction motors with shunted fields, each having a capacity of 20 h.p. at 525 volts and a speed of 1,050 revs. per minute; being equivalent to an omnibus speed of 10 miles per hour. They drive, by means of a propeller shaft and worm gearing, on to countershafts parallel with the rear axle, from whence the power is transmitted to the wheels through a case-hardened sprocket wheel and roller chain enclosed in a dust-proof case. Each motor is arranged to drive one rear wheel. The controller is of the Siemens series-parallel magnetic blow-out type provided with special arrangements for cutting out either motor as desired, but having no provision for rheostatic braking. The main barrel has five running positions, namely:—

FIG. 13.—LEEDS CAR DRAWN UP AT SIDE OF ROAD.

(1) Motors in series, full field, resistance all out.
(2) Motors in series, field shunted 50 per cent.
(3) Motors in parallel, full field, resistance all out.
(4) Motors in parallel, field shunted 25 per cent.
(5) Motors in parallel, field shunted 50 per cent.

There is one important provision in the design of the cars which may be pointed out, and that is the precaution taken to nullify the effect of any leakage of current which may occur in some unexpected manner. In a tramcar all metallic parts

* Abstract of paper read before the Society of Engineers, March 4th, 1912.

are bonded to each other and to the underframe, whence contact is made through the wheels to the rails so that the whole vehicle is maintained at the same potential as the rails; but in a trolley omnibus this cannot be done, as the rubber tyres effectually insulate the vehicle from earth, therefore all handrails, &c., require to be specially insulated. In this connection it may be mentioned that the Railless Electric Traction Company have patented a system of three overhead wires (two positive and one negative) and special trolley head which ensures that the car can be kept in electrical connection with the negative wire, and the wheel selected for the negative connection cannot come in contact with the positive wire.

The chassis is shown in Fig. 14. The wheels are 32in. and 36in. diam., of artillery pattern, and fitted with solid rubber tyres, single on the steering wheels and twin on the rear wheels. The wheel base is 13ft., and width between centres of rear wheels 6ft. 3in. There are two mechanical brakes, one

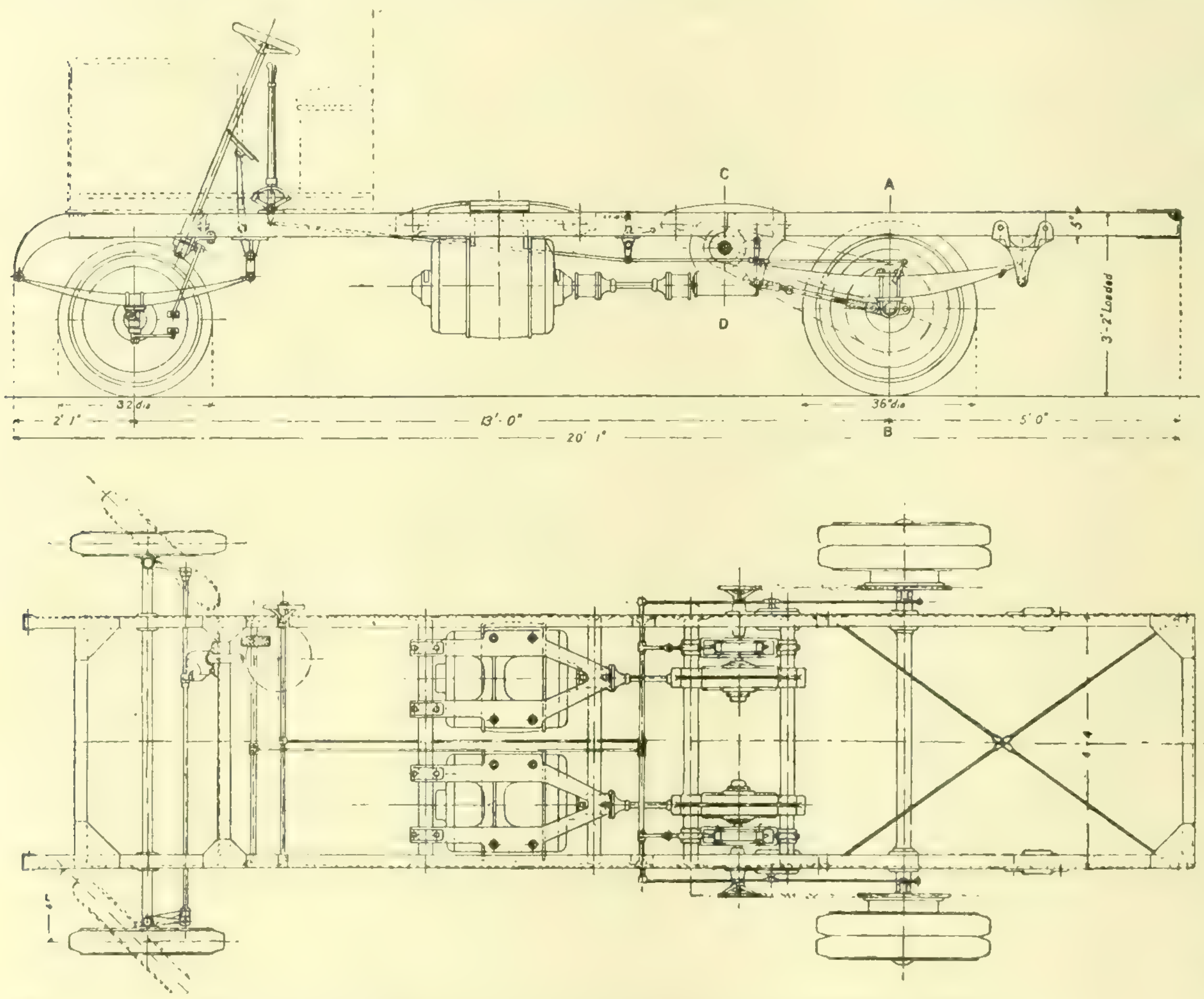


FIG. 14. SIDE ELEVATION AND PLAN OF CHASSIS OF RAILLESS TROLLEY CAR.

operated by a foot pedal and acting upon a drum on the countershaft and the other operated either by foot pedal or hand lever, acting upon drums on the rear wheels, with a ratchet arrangement for holding the brake on when desired.

The car bodies, which were built by Hurst, Nelson, & Co., have a seating capacity for 28 persons and are of single-deck type. The entrance to the Bradford cars is from the rear, while admission is gained to the Leeds cars by a door from the driving platform. This latter was to obviate the necessity for a conductor, but the service has proved so popular that it has been found desirable to carry a man to collect the fares, &c. The seats are arranged so that the passengers face in the direction they are travelling. The driver's platform is enclosed and provided with adjustable side windows and hinged wind screens, while the space enclosed by the dash is water-tight and affords room for passengers' luggage. The weight of the latest type of car, unloaded, is 3 tons 12 cwts., and when loaded, about 5 tons. They are 20ft. 3in. long, and have an overall width of 7ft. The height to the driver's platform is 3ft. 6in. and to the top of the vehicle 10ft. 8in. The Bradford cars have been fitted with shock absorbers, consisting of four spiral springs under the body of the car, one at each corner. A side view of a Bradford car is shown in Fig. 15. The current consumption on the Leeds route is 0·87 unit per car mile, while on the Bradford route, which has steeper gradients, it is 0·95 unit per car mile including all transmission losses.

As regards capital cost there is, as would be expected, considerable variation in the figures. The first eight systems installed by the Mercedes-Stoll Company up to January, 1911, aggregate a route length of 17·26 miles and are worked by 30 cars each capable of seating from 18 to 24 passengers. The total capital invested in these lines amounts to £48,500, being at the rate of £2,800 per mile, or £1,600 per vehicle, but it must be remembered that should the traffic increase, additional vehicles can be put on the road for a further capital expenditure of say £600 each.

The total capital cost of the line from Ludwigsburg to Wurtemburg, working on the Lloyd-Köhler system, amounted to £16,000, being at the rate of £1,843 per mile, or £2,000 per passenger vehicle. The company estimates the cost of a scheme as follows: Overhead work, £900 to £1,100 per mile; cars, £900 to £975 each; trailers £340 to £380 each; garage and workshop, £400 to £700.

The estimated capital cost of the proposed scheme at Aberdeen for a route 1 mile 33 yards long and 2 cars is £3,050, being equal to £3,000 per mile of route, or £1,525 per vehicle.

The estimated cost of construction at Nuneaton is £9,000 for a route of $3\frac{3}{4}$ miles and 4 cars, being equal to £2,400 per mile of route, or £2,250 per vehicle running.

The capital expended on the 5-mile route at Drammen was £8,000, being equivalent to £1,600 per mile. The overhead wires are carried on span wires between the houses, and where this method is not convenient then on timber masts with side brackets.

The cost of $3\frac{1}{4}$ miles at Ramsbottom is estimated at about £9,250, being at the rate of £2,846 per mile including overhead equipment, 3 cars, depôts, shelters, and incidental expenses, against £28,000 (£8,600 per mile) for a system of electric tramways. Including the generating station, the cost will be £16,150, which is equivalent to £4,969 per mile of route.

At Stockport the railless traction scheme is estimated to cost £11,000 (of which £7,000 is for the overhead equipment), against £20,0000 or £25,000 for electric tramways.

Judged from the standpoint of seating capacity the price of railless vehicles is high, due perhaps to some extent to the high standard of luxury we have been trained to expect in public vehicles, and to the small number of them required at present. The price charged for a Railless Electric Traction Company's omnibus having a seating capacity for 16 passengers is £600, for 24 passengers £675, for 28 passengers £700, and for 30 passengers £750. The California open-type cars, seating 16 passengers, weigh about $1\frac{3}{4}$ tons, unloaded, and cost £520. The cost of an omnibus of the Mercedes-Stoll type seating from 18 to 24 passengers is about £600. The cost of a well finished vehicle to seat 24 and mounted on a "Brush" chassis is approximately £750.

The cost of obtaining the necessary Parliamentary powers depends entirely upon the amount of opposition offered to the Bill: it might vary between say £400 and £5,000. Reasonable periods to allow for the repayment of the cost of installation would be as follows. The cost of the Bill, 5 years; vehicles 10 to 15 years; overhead equipment and passenger street shelters, 20 to 30 years; lands, buildings, and underground cables, 40 years.

Ample data exist as to the cost of running railless schemes abroad, but the extent to which similar results will be realised in this country is more or less a matter of conjecture, as the only figures available are those relating to Leeds and Bradford and, interesting and useful though they are, it must not be forgotten that they cover only a short period. The receipts at

Leeds (R.E.T. system) have been at the rate of 10·75d. per car mile while the running costs are 4·50d., and the fixed charges, including interest, sinking fund and depreciation 1·80d., making a total of 6·30d. per car mile and showing a net profit of 4·45d. per car mile. The receipts at Bradford have been 8·25d. per car mile and the costs 6·0d., showing a profit of 2·25d.

Strict caution has characterised the estimates of the cost of working and of the probable receipts for schemes projected in this country; the one generally being taken as approximately balancing the other, with very little margin for repayment of capital charges. The point is, of course, that the proposed routes are very thinly populated at present, but it is expected that the provision of travelling facilities will encourage the development of the districts through which the omnibuses pass, and the systems will ultimately prove fully remunerative.

The number of passengers carried per car mile is generally low in railless schemes, the principal reason being that only single-deck cars are used, having a maximum possible seating capacity of about 28. These are amply large for ordinary working, but during the rush hours the capacity is too limited for the number then carried to raise the average to any considerable extent; consequently the margin between receipts and working expenses will in many cases be small, and very careful management will be necessary to ensure financial success. The general passenger fares proposed to be authorised in the various Bills before Parliament are at the rate of 2d. per mile. To a certain extent some improvement in the returns might be effected by putting on extra vehicles for an hour or so when required, but it involves capital lying idle during a great part of each day. Another objection to single-deck vehicles is the absence of any accommodation for smokers, but this could be overcome by forming two compartments as is proposed in the Rotherham cars, or by constructing an open platform at one end of the omnibus, as is done in some of the vehicles on the Continent. The Board of Trade have not hitherto favoured double-deck vehicles, but in the Hove Corporation Bill, and doubtless in others, it is sought to obtain powers to run such vehicles.

Trailer cars are used to a considerable extent on the Continent in connection with trackless systems; but although the London County Council are seeking powers, during the current session, to run trailers with the tramcars it is very doubtful whether such a course would meet with any support in a trolley omnibus scheme, at least at the present time. With trailers a tracking arrangement should be fitted so that they accurately follow all curves and windings of the tractor.

It is now generally conceded that owing to the smoother running of an electrically-driven vehicle the tyres wear better in such case than on a petrol-driven vehicle of equal weight. The Railless Electric Traction Company state that the tyres on their vehicles will be maintained in perpetuity at a charge of 1d. to 2d. per car mile, dependent upon the route and the nature of the road surfaces. Alternatively a set of new tyres would cost from £65 to £95 respectively. The author is informed that one of the largest tyre companies has undertaken to maintain the tyres on any of the Trackless Trolley Company's omnibuses (Mercedes-Stoll system) running on reasonably good roads at the rate of 1d. per car mile. On the Kalksburg line, 2·4 miles long, worked on this system, and having a maximum gradient of only 1 in 50, it appears from the report of the superintendent that it has only been necessary to replace the rear tyres on two of the four 22-passenger cars after having run 28,000 and 24,000 miles respectively. The tyres on the other two cars were still in good condition after having run 22,000 and 17,000 miles respectively. The Lloyd-Köhler Company guarantee their tyres to run 12,500 miles, but the average distance actually run by the tyres before renewal has been over 15,500.

It has been mooted by some District Councils that whereas the construction of a tramway reduces the cost of maintenance of a road, a railless traction scheme would considerably increase the cost. Of course if a private tramway company is called upon to maintain a width of say 16ft. out of a 30ft. road, it does not leave much for the Local Authority, and it is obvious that the cost to the rates is reduced, but the total cost is not usually affected to any appreciable extent. It is well known that the cost of maintaining country roads has considerably increased since the advent of motor-cars, the reason being that the common method of construction was unsuitable for such traffic. Now instead of prohibiting the use of motors, the roads in all parts of the country are being formed to carry them; and any road which can do this satisfactorily can also carry the light trolley omnibuses without further addition to the cost of maintenance. It is reported that certain payments for the use of the road have been demanded in some places, as for instance $\frac{3}{8}$d. per car mile in Rotherham by the West Riding County Council, $\frac{1}{2}$d. per car mile in Brighton by the Sussex County Council, while at Keighley the Rural District Council are asking for payment by the Town Council, and in connection with the Stockport scheme the Marple U.D.C. suggest that $\frac{1}{2}$d. per car mile should be allocated to the respective highway authorities for the maintenance of the roads. This point was, however, fought very hard in the Aberdare Bill in both Houses of Parliament, and in neither case would the Committee insert a clause requiring payment for the use of the roads. The petrol tax works out at about $\frac{3}{16}$d. per mile in the case of motor buses, which are very much heavier vehicles.

It may be said that the principal rivalry is between the motor omnibus and the trolley omnibus, because in many cases

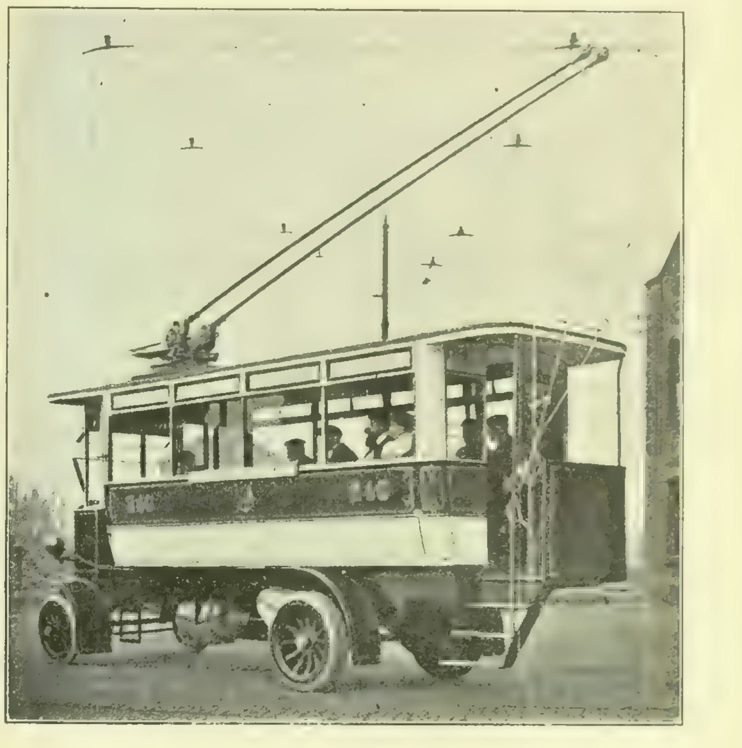


FIG. 15. SIDE VIEW OF BRADFORD CAR.

financial considerations alone would prohibit the construction of tramways. The main points to consider are the capital cost of installation, the cost of working and maintenance, reliability, and the public convenience. The author will content himself by giving utterance to the safe and by no means novel statement that there is no one method of traction that can be adopted with success under all conceivable circumstances. Each has its advantages, but which is the best to adopt in any particular case can only be arrived at after a careful investigation of all local conditions and with an intimate knowledge of the possibilities of the various systems; and, further, it by no means follows that the results obtained in one town will prevail in another. This system can be installed for a capital expenditure of about one-third to one-fifth of that required in the case of an ordinary overhead tramway system; and while the cost of maintenance of the road will not be unduly increased, and will continue more or less constant from year to year, it must not be forgotten that a tramway track requires entire reconstruction from time to time. On the other hand, the cost of maintenance of the vehicles with their rubber tyres would be higher than in the case of tramcars, and more electrical current would be consumed per passenger carried.

French Submarine Disaster.—Another was added on Saturday last to the long list of submarine disasters, the French boat "Vendemiaire" being cut in two by the battleship "St. Louis" while engaged in battle practice off Cherbourg. The vessel was totally lost with her crew of 26. She sank in about 28 fathoms of water, and it is feared that there is no hope of salving the wreck.

THE ELECTRIC FURNACE AND HIGH-GRADE STEEL.*

BY WILLIAM R. WALKER.

In the manufacture of steel by either the Bessemer or open-hearth process it is very difficult to remove the last traces of oxygen. In the basic Bessemer process the overblown metal, which is an extreme case of oxidation, contains only 0·06 per cent. of oxygen. Oxygen in combination with carbon (carbon monoxide), silicon, iron, aluminium, and manganese, and also the combinations of silicates with these oxides, are very deleterious in steel.

My investigations lead me to believe that in the manufacture of steel for the so-called heavy products and steel that is produced in large quantities, a combination of either the acid or basic Bessemer converter and the electric furnace will take a very prominent place. With this combination it is possible to produce steel extremely low in oxygen and other impurities at a cost that will not be prohibitive.

At the present time there are over 70 electric furnaces of various types producing electric steel in Europe and America. These range in capacity from 1 to 15 tons. There is now under construction in Germany a furnace of 25 tons capacity. A number of these furnaces are competing successfully with crucibles in the manufacture of very high-grade steel.

Generally speaking, electric furnaces may be divided into two groups: (1) Induction furnaces, in which the heat is supplied by a current induced in the bath. (2) Arc furnaces, in which the arc is struck, either between an electrode and the metal in the bath, or between two or more electrodes, so as to heat the metal only by radiation from the arc.

In operating the electric furnace at the present time, the most prominent methods or combinations are as follows: —

1. Oxidation of silicon, carbon, and manganese in an acid-lined Bessemer converter, and removing the phosphorus in the basic-lined electric furnace with an oxidising slag and then recarburising, and with the aid of manganese and carbon and a new reducing slag removing oxygen and sulphur and dead melting as in the crucible process.

2. Removal of silicon, carbon, manganese, and phosphorus in a basic-lined Bessemer converter and further removing phosphorus (if desired) in the basic-lined electric furnace with an oxidising slag, and then with the aid of manganese and carbon and a new reducing slag removing oxygen and sulphur and dead melting as in the crucible process.

3. Removal of silicon, carbon, manganese, and phosphorus in the basic open-hearth furnace and then recarburising, and in the basic-lined electric furnace with the aid of manganese and carbon and a new reducing slag removing oxygen and sulphur, and dead melting as in the crucible process.

4. Melting of cold scrap of inferior quality in a basic lined electric furnace; removing phosphorus with an oxidising slag and then recarburising and with the aid of manganese and carbon and with a new reducing slag removing oxygen and sulphur, and dead melting as in the crucible process.

5. Melting high grade materials in the electric furnace and dead melting as in the crucible process.

The phosphorus is removed in the basic electric furnace in the same manner as in the basic open-hearth furnace, that is, by the use of lime and oxide of iron, and the resulting slag containing the phosphorus is removed and a new slag formed consisting of burnt lime and fluorspar: and when the slag is melted, coke dust is added, which, coming in contact with the lime in the slag and the electric arc, produces carbide of calcium. The free carbon and possibly the carbide of calcium in the slag, with the aid of carbon and manganese in the bath, eliminates the oxygen from the steel.

As compared with the Bessemer and basic open-hearth processes, the electric has the following advantages: (1) The more complete removal of oxygen. (2) The absence of oxides caused by the additions, such as silicon, manganese, &c. (3) The production of electric steel ingots of 8 tons in weight and smaller that are practically free from segregation. (4) Reduction of sulphur to 0·005 per cent., if desired. (5) Reduction of phosphorus to 0·005 per cent., as in the basic open hearth process, but with the complete removal of oxygen.

* Paper read at the New York meeting of the American Iron and Steel Institute, May, 1912.

As evidence of the reducing properties of the slag in the basic electric furnace, it has been found that if oxide of manganese and oxide of iron are thrown on the molten slag, the oxides are reduced to the metallic state and the reduced metal goes into the bath. Blown metal from the acid Bessemer converter, containing only 0·10 to 0·20 per cent. manganese, has been completely deoxidised in the electric furnace without addition of manganese or aluminium, the usual amount of silicon being added in the steel ladle. Rails made from this steel are now in service. The composition of one heat of this steel is as follows: —

	Per Cent.
Carbon	·55
Manganese	·13
Sulphur	·017
Silicon	·19
Phosphorus	·022

These rails are comparatively soft, but are showing superior wearing qualities compared with the Bessemer rails in the same track and under the same service conditions.

Electric steel ingots crack much less in rolling than either Bessemer or basic open-hearth steel. Cold electric steel ingots when heated and rolled into rails roll extremely well.

At the present time there are approximately 5,600 tons of standard electric steel rails in service in the United States. These rails have been in the track about two years. During the past winter some of these rails have been subjected to very low temperatures—in some cases as low as 52° below zero, Fah., and are being exposed to all the possible conditions of severe service. It is too early to say much about the wearing qualities of these rails, but from present indications it would appear that rails made by the basic electric process can be made somewhat softer than by either the Bessemer or basic open-hearth process and show highly satisfactory wearing qualities. Up to the present time we have not heard of any basic electric rails in use in this country being broken in service.

For experimental purposes I have had made a small tonnage of electric steel rails, which have varied in analysis as follows: —

	Per Cent
Carbon	0·50 to 0·75
Manganese	0·13 to 0·80
Silicon	0·10 to 0·40
Phosphorus	0·02 to 0·06

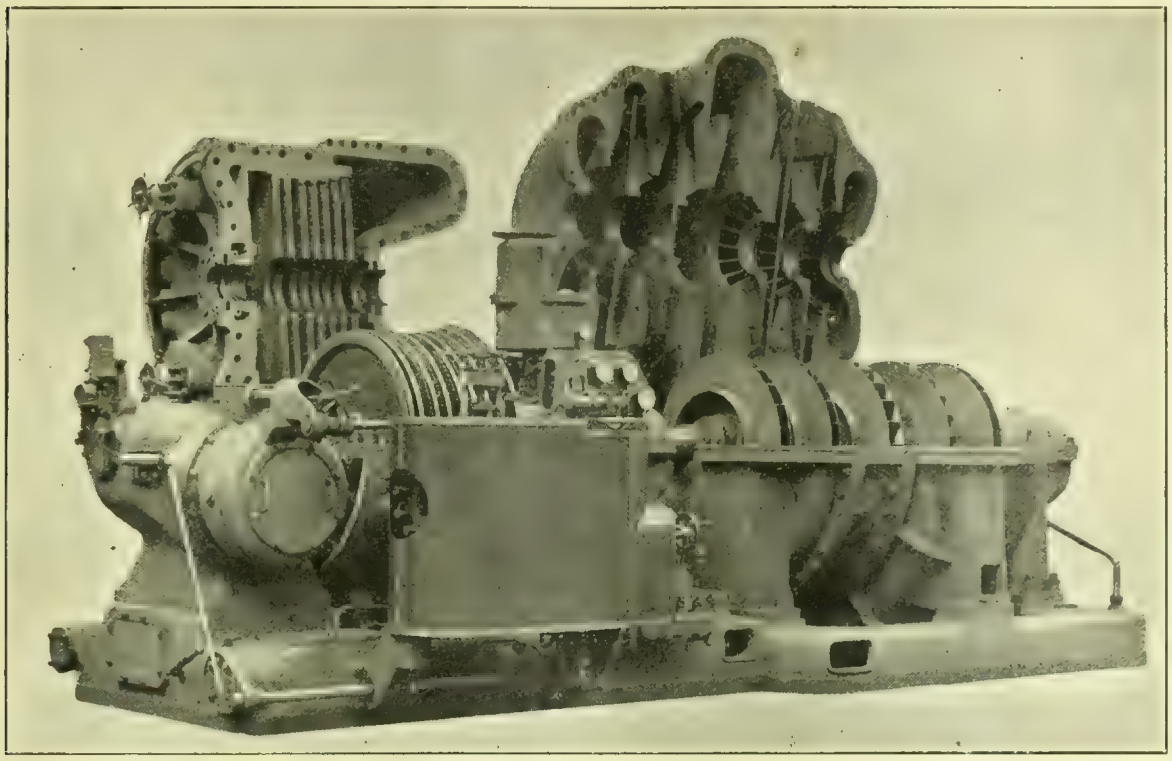
On account of the wide variation in the chemical composition of this steel, it would, in a paper of this nature and with the limited time at my disposal, be difficult, without going into considerable detail, to discuss the physical properties of these rails. It might be stated, however, that electric steel of a given tensile strength has a slightly greater amount of elongation than basic open-hearth steel, and that electric steel is somewhat denser than basic open-hearth or Bessemer steel. With the electric furnace it is possible to produce steel which when magnified 1,000 diameters shows no oxides or slag enclosures.

As high-grade electric steel can be produced at a lower cost than crucible steel, there has been a gradual increase in the production of electric steel for certain purposes where crucible steel was formerly employed and where it has been demonstrated electric steel can be successfully used. This increased production has not been so marked where the object has been the improvement of steel entering into products manufactured in large quantities where the expense involved for experimental work is very great, and where of necessity it takes several years to demonstrate if rails and other products made by the electric process are superior to those made by either the Bessemer or open-hearth process. From present indications it would seem probable that there will be a decided increase in the production of electric steel for these products in the near future.

Breakdown of a Locomotive.—An accident occurred to a locomotive on the Lancashire and Yorkshire Railway at Ramsbottom on the 4th inst. It appears that the 2.15 passenger train from Manchester to Colne had just pulled clear of Ramsbottom station when, apparently through a cylinder breaking, the whole of the motion of the engine dropped on to the bed of the line. It was fortunate that the train was moving slowly at the time, otherwise a serious accident might have resulted. No one was injured.

WESTINGHOUSE TURBO-BLOWERS AND COMPRESSORS.

THE recent commercial adaptation of the purely rotary air blower and compressor has marked an important epoch in the science of pneumatics, which cannot but have extremely beneficial results to those engaged in the iron, steel, and coal trades. In comparison with the old type of reciprocating steam-driven blowers and compressors, the new order of machines possesses the following undoubted advantages: An opportunity for using the exhaust steam from winding or other engines in mixed or low-pressure turbines; continuous delivery of air, thus avoiding pulsations and largely increasing the efficiency of production when used in blastfurnace work; space occupied smaller, capital expenditure less, and overall efficiency higher; when turbine driven, lighter foundations can be used, and condensing plant can be located directly underneath the turbine, thus shortening the exhaust pipe and saving space; small lubricating oil consumption; air delivered free from oil, which is of much importance in the majority of chemical operations.



THREE-STAGE WESTINGHOUSE TURBO-BLOWER, WITH TOP HALVES OF CASINGS RAISED.

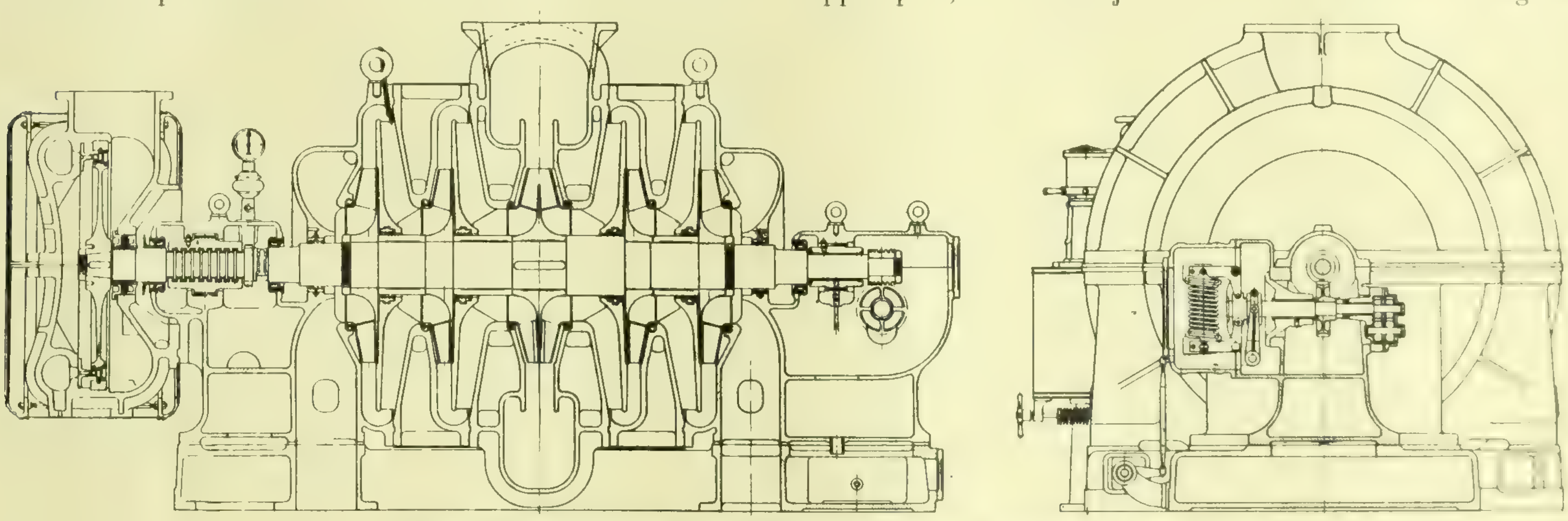
The uses of turbo-blowers include: Supplying air to blast-furnaces at from 6lbs. to 10lbs. per square inch gauge; supplying air to cupolas for iron melting at 3lbs. to 5lbs.; and putting gas under small pressures for lighting and metallurgical purposes.

The chief uses of turbo-compressors are: Compressing air for driving machine tools, namely, drills, riveters, caulkers, &c.; driving pneumatic mining plant, including coal cutters, drills, &c.; compressing ammonia in refrigerating work.

The latest development of turbo-compressor practice is instanced by the supply of a 20-stage single-flow machine to the New Hucknall Colliery. This compressor has been built by the British Westinghouse Electric and Manufacturing Company, Ltd., and is designed to supply 7,500 cub. ft. of free air per minute at 80lbs. per square inch gauge. The air passes through the 20 impellers in succession, 10 impellers being placed in each of two casings, the number of impellers being too large to be all carried on one shaft. Each casing consists of a series of diaphragms, together with the inlet and outlet ends. There are four sets of impellers of different diameters, there being five impellers of each diameter. Air enters at the largest diameter, which is situated at the inner end of one casing, and flows outward to the outlet end at the outer end of that casing. Thence the air is conveyed to the inner end of the other casing, again flowing outwards to its final high pressure outlet at the outer end of this casing. The end thrusts on the shafts are thus nearly balanced by allowing the air to flow outwards in each casing, so that the thrust of each shaft is inwards, and the shafts are allowed to butt against each other. Any small unbalanced thrust is taken care of by the design of the balance pistons, which are fitted with labyrinth packing glands.

With regard to the internal conformation of the compressor casings, a high efficiency is secured without the use of guide blades in the diffusers, and thus the unpleasant whistling noise common to most rotary compressors is, it is claimed, entirely eliminated. The low-pressure outlet and high-pressure inlet are connected by intermediate piping, and if the final pressure is to be high an intercooler can be connected in here.

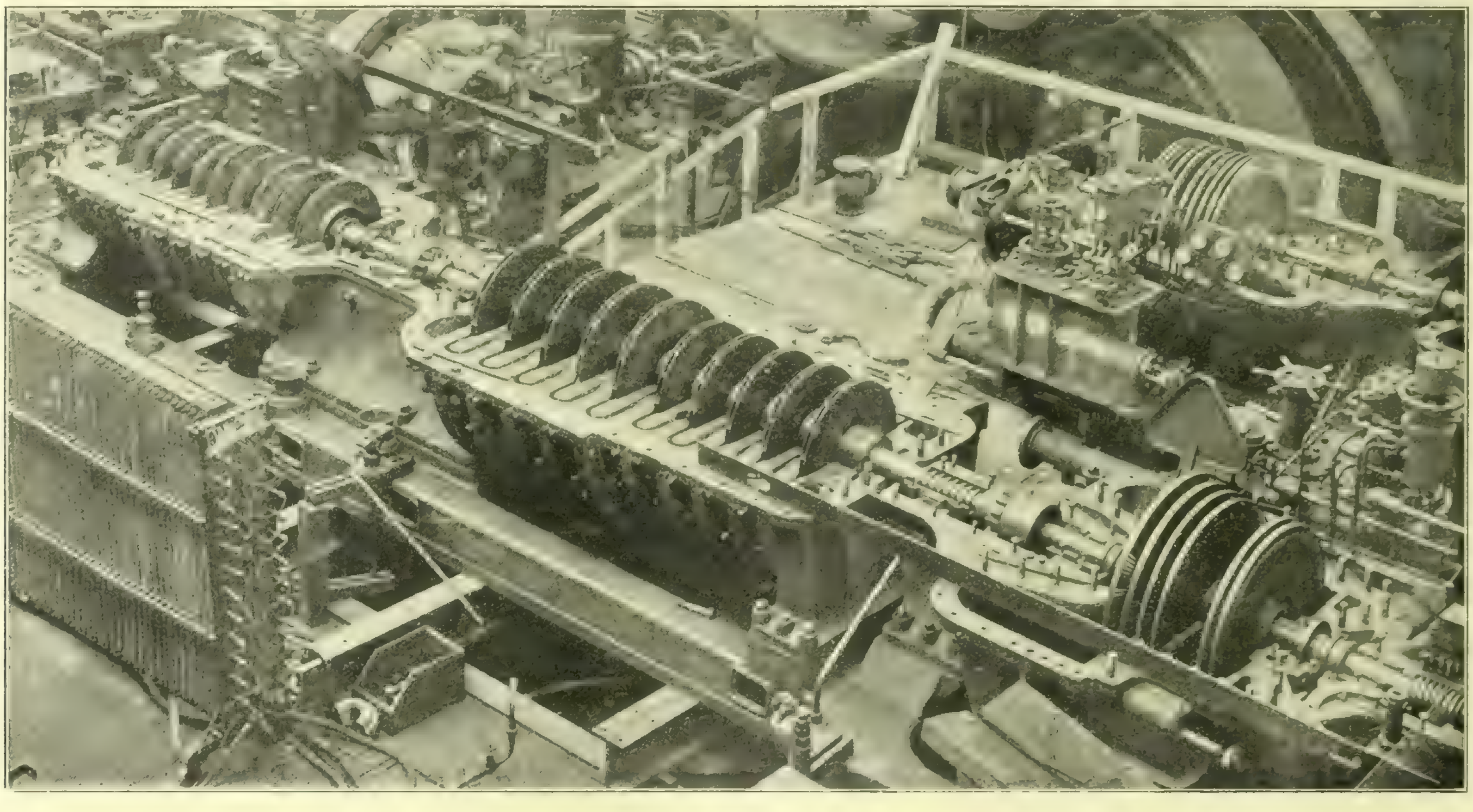
The cooling of the air as it passes through the casings is accomplished by a very effective system. This cooling is rendered necessary both in order to prevent an excessively high temperature and in order to reduce the power required for compression. The cooling spaces in the upper and lower halves of the casings are not broken by the lifting of the upper part, the water jackets in the two halves being connected by external connections. The water jackets surround the impeller chambers, the diffusers, and the return passages, whilst the hollow partitions separating the return passages from the diffusers are also supplied with circulating water. Each diaphragm has its own separate supply of water which enters from an external manifold. A largely increased cooling surface is attained by the employment of hollow guide vanes, and this practice conduces to no small extent to the efficient operation of the machine.



THREE-STAGE WESTINGHOUSE DOUBLE-FLOW TURBO-BLOWER. SECTIONAL VIEWS.

The compressor for the New Hucknall Colliery is driven by a mixed-pressure impulse type Westinghouse Rateau steam

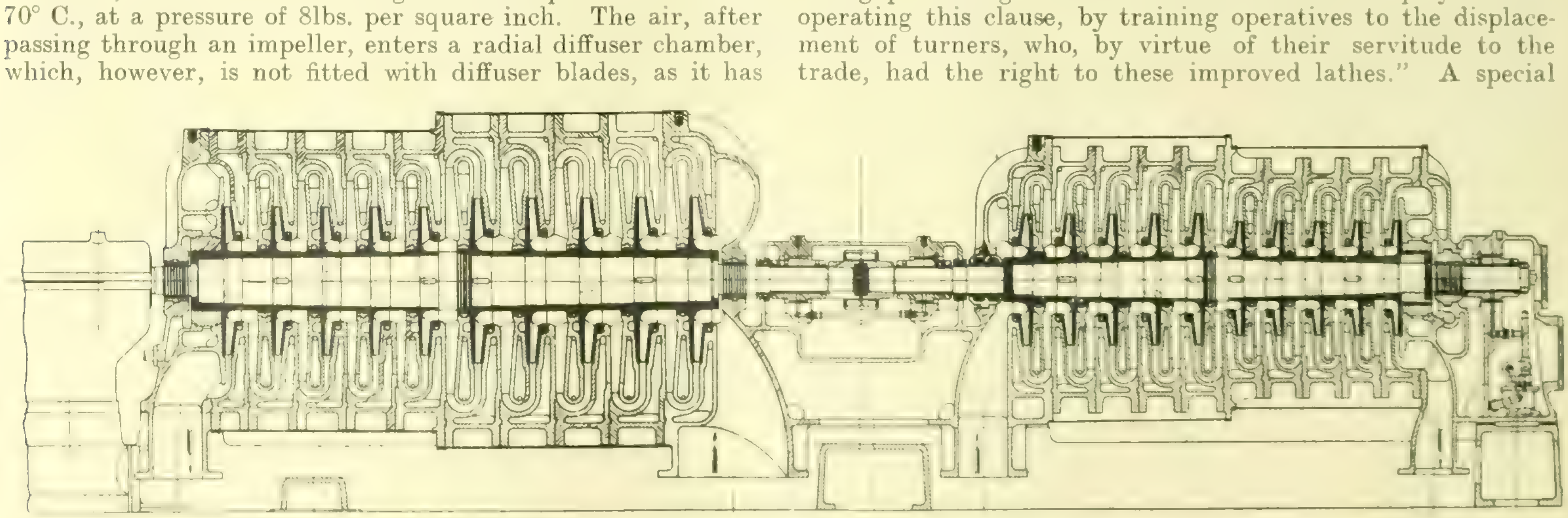
turbine, which is mounted on a common bedplate with the compressor, to which it is direct coupled. The turbine is designed to generate 1,480 h.p. when running on the exhaust steam from the winding engines, which were before exhausting to atmosphere. Governing is so arranged that should the supply of exhaust steam fail partially or entirely, high-pressure steam is admitted with no speed variation and without a drop in pressure. The compressor is normally governed by the air pressure, the speed-governing gear being out of action until the speed rises 8 per cent., when steam is shut



TWENTY-STAGE WESTINGHOUSE SINGLE-FLOW TURBO-COMPRESSOR, FOR NEW HUCKNALL COLLIERY. VIEW SHOWING MACHINE, WITH TOP HALVES OF CASINGS REMOVED, ON TEST PLATE.

off, and the turbine is kept running at this speed without being shut down.

Westinghouse turbo-blowers are usually designed as double-flow machines with a delivery of 25,000 cub. ft. of free air per minute, having an inlet at each end and an outlet in the centre. No water cooling is applied in the standard machines, and the air is discharged at a temperature of about 70° C., at a pressure of 8lbs. per square inch. The air, after passing through an impeller, enters a radial diffuser chamber, which, however, is not fitted with diffuser blades, as it has



TWENTY-STAGE WESTINGHOUSE TURBO-COMPRESSOR. LONGITUDINAL SECTION.

been found that these do not materially improve the efficiency in apparatus dealing with air, whilst they are also liable to set up a disagreeable whistling noise. From the diffuser chamber the air is turned inwards through a return passage to the inlet of the next impeller, and as the air in passing through the diffuser has a considerable amount of whirl, the return passage is fitted with guide blades to convert the motion into a radial one at the inner end of the guide passages, so that the air enters the next impeller in a truly axial direction. The double-flow arrangement has the advantage of being perfectly balanced; that is to say, there is no resultant end thrust on the shaft.

THE MANNING OF MACHINE TOOLS.

THE report of the Amalgamated Society of Engineers for June contains an account of the central conferences which have been held with the employers for the purpose of endeavouring to draft a new clause in the 1907 Terms of Agreement covering the selection, training, and employment of operatives and the manning of machine tools. The operation of the existing clause has created a good deal of dissatisfaction among the men, and a number of conferences on the subject have, during the past few months, been held. On December 21st, 1911, the council of the A.S.E. "entered a strong protest against the manner in which employers were operating this clause, by training operatives to the displacement of turners, who, by virtue of their servitude to the trade, had the right to these improved lathes." A special central conference was thereupon arranged in order to discuss the question. Special meetings of the kind took place at York on February 29th, April 16th, and May 8th, and at these, proposals and counter proposals were discussed.

Clause 7 of the 1907 Terms of Agreement is as follows: "Employers have the right to select, train, and employ those whom they consider best adapted to the various operations carried on in their workshops, and to pay them according to their ability as workmen

"Employers, in view of the necessity of obtaining the most economical production, whether by skilled or unskilled workmen, have full discretion to appoint the men they consider suitable to work all their machine tools and to determine the conditions under which they shall be worked.

"The Federation recommend their members that when they are carrying out changes in their workshops which will result in displacement of labour, consideration should be given to the case of the workmen who may be displaced, with a view if possible of retaining their services on the work affected or finding other employment for them."

On May 8th the representatives of the men proposed the following as a more suitable clause:—

"The employers have the right to select, train, and employ those whom they consider best adapted to the various operations carried on in their workshops. The unions claim, and the employers agree, that the exercise of this right should not result in the discharge of workmen who have served a satisfactory apprenticeship.

"The unions disclaim any desire to restrict the adoption of improved machines or methods so as to limit output. The unions claim, and the employers agree, that when improved machines or methods are introduced the employer shall give preference of employment on the work in question under the altered conditions to such of his workmen who have served a satisfactory apprenticeship and who may be displaced.

"The employers agree that in carrying out changes in their workshops which will result in the displacement of workmen, consideration shall be given to the case of those displaced with a view of retaining their services on the work affected or finding other employment for them."

After considering this the employers submitted the following, which was, they said, their final proposal, and must be accepted or rejected as it stood:—

"The employers have the right to select, train, and employ those whom they consider best adapted to the various operations (including machine work) carried on in their workshops, and to determine the terms and conditions under which such operations should be carried on.

"The unions claim, and the employers agree, that when improved machines or methods are introduced the employers shall give preference of employment under the altered conditions to such of their workmen as have served a satisfactory apprenticeship and whom they consider suitable for, and who may be willing to undertake, the work in question.

"The employers agree that in carrying out changes in their workshops which result in the displacement of workmen consideration shall be given to the case of those displaced with a view of retaining their services on the work affected or finding other employment for them."

The objection of the men's representatives to this was that it "left the decision, as before, in the hands of the employer, and maintained what had been claimed and often repeated during these conferences—absolute freedom of management."

The representatives of the employers were informed therefore that it was "absolutely impossible to accept their proposal." Eventually it was formally "agreed that the machine questions on the agenda of December 21st, 1911, and the Blackburn machine question at present pending should be considered as questions on which the constitutional procedure has been exhausted."

All the districts which have had machine claims rejected by the employers in central conference are at liberty therefore to enforce them by means of strikes if they so choose. It is also within the right of the federated employers to lock out if districts are selected by the unions in which to fight out the issue, and the situation therefore is very delicate.

Junior Institution of Engineers: Visit to Sheffield.—In connection with the Junior Institution of Engineers a week-end visit to Sheffield has been arranged. The party will leave London for Baslow on Friday evening, June 21st, and will visit Haddon Hall and other places of popular interest on the Saturday, and on Monday the party will leave Baslow for Sheffield, visiting the works of Messrs. Firth & Sons, Ltd., in the morning, and the works of Messrs. Cammell, Laird, & Co., Ltd., in the afternoon, returning to London in the evening. A movement is on foot to form a local section of the institution in Sheffield, and it is thought that probably this visit will have the result of establishing the section.

IRON CORROSION INVESTIGATIONS.*

BY OLIVER P. WATTS.

IN Vol. 8 of the Transactions of this society, C. F. Burgess called attention to the remarkable reduction in the corrosion of iron by sulphuric acid brought about by the addition of a small amount of arsenious oxide to the acid. Later he explained the protective action as follows: "The explanation which has been offered for this phenomenon is that the iron receives, by contact with the solution, an extremely thin coat of arsenic, which resists the action of the acid, and protects the underlying metals." He also gave experimental proof that the iron was coated with arsenic.

It has long been known that by dipping clean iron into solutions of suitable composition and concentration thin coatings of gold, silver, platinum, copper, and several other metals may be deposited on the iron. It is generally conceded that such coatings are not sufficiently continuous and impervious to protect the underlying metal from corrosion, even though the metal forming the coating may itself be thoroughly resistant to the corrosive agent. Instead of being a protection, such coatings are usually considered to be stimulators of corrosion.

Since all metals which thus deposit upon iron when it is immersed in a solution of the metallic salt are electronegative to iron, a short-circuited voltaic cell is formed, of which the iron is the anode and the metal deposit is the cathode. So long as any iron remains in contact with the electrolyte it would seem, except for certain considerations which will be presented later, that the corrosion of the iron ought to be stimulated by this condition, and that the only way in which such a coating could afford good protection would be by covering the iron completely, so that no electrolyte could come in contact with it.

Speaking of the effect of other metals in contact with iron, W. H. Walker says: "Tin is a metal which, like copper, accelerates the corrosion of iron by aiding in the oxidation of the hydrogen set free by the reaction." M. P. Wood calls attention to the injurious action of metals: "The use of anti-corrosive or anti-fouling paints, containing salts of any metal, is attended with the greatest danger to the coated (iron or steel) structure. These pigments are extremely sensitive to the presence of saline elements in moisture, their action being to rapidly dissolve portions of the iron and to deposit the metal which they contain upon the surface of the plates, and these deposits, exciting energetic galvanic action, cause corrosion and pitting to go on with alarming rapidity. Both mercury and copper salts are offenders in this way."

It appears, then, that arsenic is unique among the metals which precipitate themselves upon iron from solution, for arsenic protects iron almost completely from powerful corrosive agents, while the other metals are generally considered to aggravate corrosion and rusting. The protective action of arsenic cannot be due to any superior power of resisting attack by sulphuric acid, for silver, platinum, and gold are even more resistant, and yet accelerate the corrosion of iron. It is evident that these other metals do not form continuous and impervious coatings over the iron, else they would protect it. It is difficult, perhaps even impossible, even with the aid of the electric current, to deposit from solution a thin coating of one metal upon another so perfectly as to protect the underlying metal from corrosion by an acid ordinarily capable of attacking it.

It is almost incredible that a thin, yet perfect and non-porous, metallic coating should be deposited by a process which depends for its operation upon the dissolving of the underlying metal. The protective action of coatings of copper, silver, &c., thus deposited on iron is about as effective as would be expected from a knowledge of their method of formation. They are continually being undermined by the corroding of iron anode at points not yet covered, until the copper or silver becomes detached, to have its place taken by a new coating, and so on, as long as any of the salt of the depositing metal remains in the solution. If the coated

* Abstract of paper read before the American Electro-chemical Society, April, 1912.

metal be removed to an acid, the corrosive action is similar, except that the renewal of the coating can take place only at a rate not greater than that at which the detached metal re-dissolves in the acid.

If the coating of arsenic is so porous and imperfect as the action of acids shows the coating of copper, for example, to be, how can the arsenic protect the iron any better than copper does? It occurred to the writer that the explanation lay in a high over-voltage or excess potential of hydrogen on arsenic, and the experiments which follow were undertaken to discover whether this is the explanation of the singular and mysterious protective action of arsenic. If the above explanation is correct, among the metals which deposit upon iron when it is immersed in a solution of their salts those having a high over-voltage for hydrogen should protect iron, and those of very low over-voltage should aggravate corrosion.

If an electrode of platinum coated with platinum-black be immersed in normal sulphuric acid the electrode will be electro-negative to the solution by about 1·14 volts. If now a small but slowly increasing electromotive force be applied between this electrode and an insoluble anode it will be found that the platinised cathode becomes progressively electro-negative with regard to the solution. When a certain difference of potential between the cathode and the solution is reached, bubbles of hydrogen begin to appear on the cathode. If a cathode of smooth platinum is used, hydrogen will not appear on this until it has become 0·09 volts more positive than the other cathode was when hydrogen first appeared on it. Similarly zinc must be 0·70 and mercury 0·78 volt more positive than the platinum-black before hydrogen appears upon them. This excess of potential required to cause a visible liberation of hydrogen upon a cathode of any particular metal, over the potential required for the liberation of hydrogen upon platinum coated with platinum-black, is known as the over-voltage of hydrogen upon that metal. In Table I. are given the single potentials in normal solutions of the sulphates of the metals, and the over-voltage of hydrogen, as stated by different observers.

TABLE I.—*Single Potentials in Normal Solutions of Sulphates of the Metal and Over-voltage of Hydrogen.*

	Single Potential.	Over voltage in Normal Sulphuric Acid.			In 5 K.O.H. Nutton and Law.
		Caspari.	Foerster.	Harkins.	
Mercury	−0·98	0·78	0·43	0·74	—
Zinc	+0·524	0·70	—	0·71	0·70
Lead	−0·095	0·64	0·35	0·62	0·57
Tin	−0·085	0·53	0·43	0·55	0·61
Cadmium	+0·162	0·48	0·48	—	0·52
Arsenic	−0·550	—		0·39	
Bismuth	−0·490		—	0·38	
Iron	+0·093	—	—		0·15
Copper	−0·515	0·23	0·10	0·25	0·41
Cobalt	−0·019	—	—	0·22	
Nickel	−0·022	0·21	0·10	0·15	0·37
Silver	−0·947	0·15		0·13	—
Platinum	−1·140	0·09	0·07	0·07	
Gold	−1·356	0·02	0·055		

On the theory that the protection of iron by a deposit of arsenic is due to the high over-voltage of hydrogen on the latter the action would be as follows: Iron dissolves, and by so doing deposits arsenic upon the surface of the iron. Since the arsenic is deposited simultaneously with the dissolving of the iron, and only as a result of this dissolving, it is hardly possible that the iron should be perfectly covered by arsenic, but here and there holes will exist, allowing the iron to make contact with the electrolyte. Voltaic cells are thus formed. From the single potentials of iron and of arsenic, 0·093 and — 0·550, these cells should have an electromotive force of 0·64 volts, and the corrosion of the iron ought to be very vigorous. It is here that the over-voltage of hydrogen comes into play. The iron is anode and the arsenic cathode, and, just as in any other primary cell with sulphuric acid as electrolyte, hydrogen is deposited on the cathode. But when hydrogen is liberated on arsenic the potential of the latter is raised 0·39 volts higher than — 0·277, the potential at which hydrogen is liberated on platinum-black. This would raise the potential of the arsenic to + 0·113 volts, or higher than the potential of the iron anode. This means that in our iron-arsenic cell there can be no visible evolution of hydrogen on the arsenic, for before this can occur the potential of the cathode has become equal to that of the anode, and corrosion of the iron ceases; in other words, this particular primary cell polarises so badly that after a few seconds of action its electromotive force has fallen to zero.

If the above explanation is correct, protection should be afforded by those metals which plate out on iron by immersion, and whose over-voltage for hydrogen is great enough to raise their potentials to at least equal the single potential of iron. The potentials of the following metals are far enough below that of iron to expect that they will deposit on iron even in moderately strong sulphuric acid: Antimony, arsenic, bismuth, gold, lead, mercury, platinum, silver and tin. Potential measurements made by students in the writer's laboratory indicate that chromium should be included in the list. Omitting lead, on account of the insolubility of its sulphate, mercury, tin, and arsenic show the highest over-voltage; compounds of these metals were therefore used in a preliminary experiment by A. C. Shape.

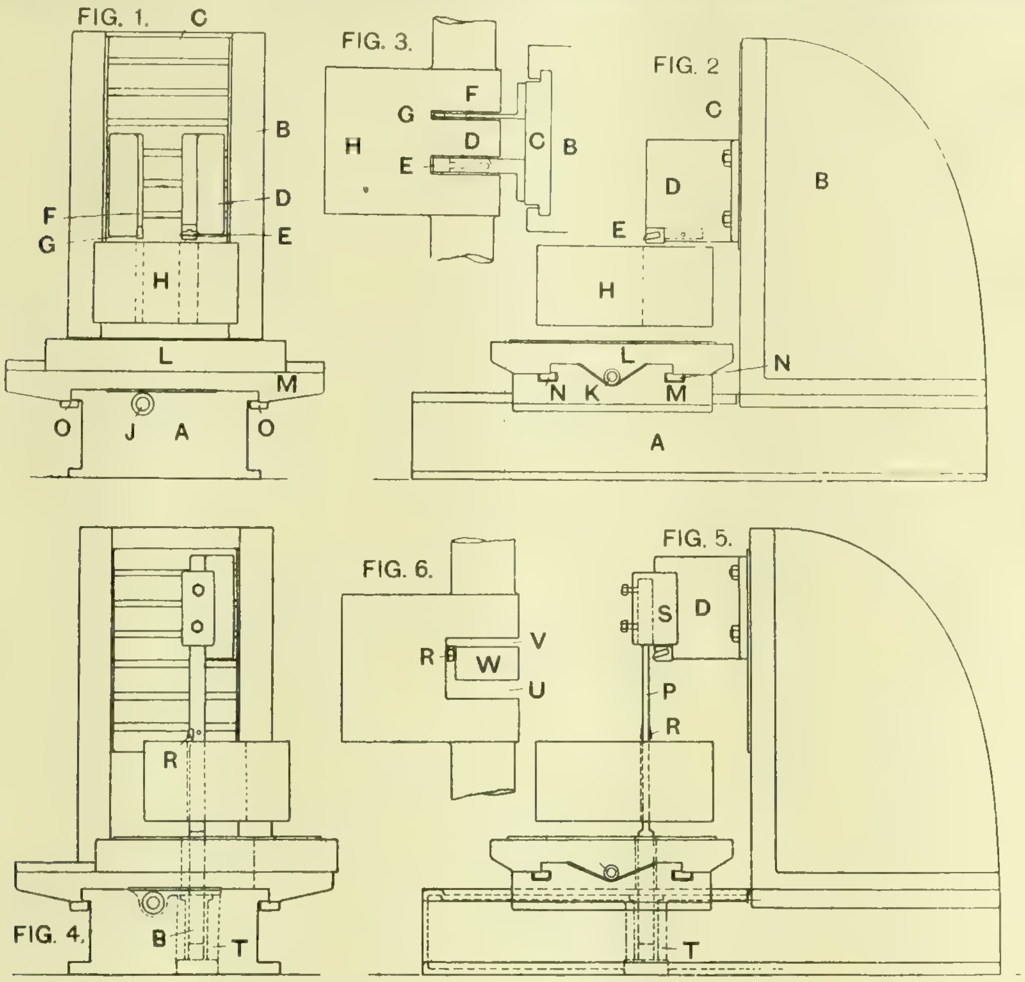
From the experiments made certain definite conclusions can be drawn and other generalisations now appear probable, but may require revision or rejection in the light of future experiments. The writer's hypothesis, that the protective action of arsenic is due to its high over-voltage, has been in a general way confirmed. Other metals of high over-voltage have had a protective influence, while all metals of low over-voltage which deposit on iron are accelerators of its corrosion. So far as over-voltages are known, bismuth alone fails to conform to the hypothesis. Theoretically it should retard corrosion: actually it is an accelerator. Unless re-determinations of the over-voltage of bismuth and the single potential of iron shall reconcile theory with fact, the writer's hypothesis fails. The over-voltage of bismuth was presumably measured on a solid electrode. Bismuth deposited as a powder. If there is the same difference in over-voltage for bismuth as between smooth and spongy platinum, this correction would put bismuth in the list of accelerators.

The statements which follow are intended to apply only to the corrosion of iron by sulphuric acid. Tin, chromium, and mercury retard corrosion; of these, tin alone is as effective as arsenic. The protective action of mercury is very slight. Oxidising agents are in themselves accelerators of corrosion by acids, although in dilute solution this may be masked by a protective action which supervenes when the oxygen has been used up, as might happen with chromates. Reducing agents should show more or less protective action, but this fact remains to be confirmed by further experiment. In general, the whole subject as here presented is but a preliminary study which opens many possibilities for future investigation.

First International Radio Telegraph Conference.—The first international radio telegraph conference in the world's history opened on the 4th inst. in the theatre of the Institution of Electrical Engineers, London. It was attended by representatives of practically every country in the world. The proceedings were strictly private. During the course of an address of welcome to the delegates the Postmaster General (Mr. Herbert Samuel) said the recent disaster to the "Titanic" had given prominence to the need for a fuller use of wireless telegraphy at sea, and for the discovery of fresh methods to enable it to discharge efficiently its important duty of preventing disasters, and of aiding in the work of rescue. Measures necessary or desirable, such as those relating to a compulsory installation of wireless telegraphy on board ships, were perhaps outside the limits of the convention which that conference was summoned to consider, but the British Government, and he did not doubt other Governments also, would welcome the opinions of that great assembly on the subject.

MUIR'S SLOTTING MACHINE.

HITHERTO in the machining of objects from which it is required to remove large pieces from the solid, such as the webs of cranks, it has been customary to remove the same by the combined processes of drilling and slotting or drilling and sawing. In the machining of large cranks and similar classes of work it has hitherto been practically impossible to carry out the operation by slotting alone owing to the considerable projection necessary for the tool from its holder, this projection preventing cross-cutting from slot to slot. In the machine under notice, the invention of Messrs. Wm. Muir & Co., Ltd., Britannia Works, Sherborne Street, Manchester, and James Henry Melloy, the whole operation of cutting into the solid



MUIR'S SLOTTING MACHINE.

and across the web to remove any size of piece required, irrespective of the depth of the object, is performed solely by slotting, and at one setting of the work.

To effect this there is provided in addition to the in-slotting tools, a cross-cutting tool held in a bar or holder, which is supported at both ends, so that when tooling the greatest depths the spring of the tool is reduced to a minimum. For cutting out the web of a crank two relieving tool holders and tools are used, set at the required distance apart, one being narrow and the other of a width sufficient to admit the cross-cutting tool and bar or holder. These relieving tool holders are firmly fixed to the face of the reciprocating ram of the slotting machine to cut two parallel slots at the required distance apart. When the in-cutting operation is finished the cross-cutting relieving tool holder and tool is introduced, and the automatic cross traverse of the table carrying the work is put into gear and the relieving cross-cutting tool then cuts from the broad slot to the narrow slot, and so detaches the surplus piece of metal, a slot being formed in the table to permit this cross traverse. The relieving tool holder or bar is held firmly at the upper end in a bracket attached to the broad tool holder on the reciprocating ram, and also passes through the table into a supporting footstep fixed in the body of the machine, thus giving support to both ends of the cross-cutting tool holder or bar as the tool reciprocates and cuts through the solid web.

Referring to the illustrations, Fig. 1 is a front elevation and Fig. 2 a side elevation of a slotting machine showing the two in-cutting relieving tool holders in position with their tools set the required distance apart for in-cutting and parallel slotting the web of a crank or the like. Fig. 3 is a plan of Fig. 2, showing a crank with the in-cutting tools in the two parallel slots which they have cut in the web of a crank. Figs. 4, 5, and 6 are similar views respectively to Figs. 1, 2, and 3, but show the cross-cutting relieving tool holder and tool in position, and in Fig. 6 just reaching the completion of its cross-cut from the broad to the narrow slot. In these views A denotes the bed of the machine; B the standard or upright; C the reciprocating ram; D the broad relieving tool holder, and E the broad relieving tool; F the narrow relieving tool holder and G the narrow relieving tool; H the crank; L the work table; J the actuating screw for traversing the same longitudinally and K the cross traverse actuating screw; M the bottom slide; N the holding-down plates for the table; O the holding-down plates for the slide. All the foregoing parts operate in the usual way to cut by means of the relieving tools E and G two parallel slots, one broad and one narrow, in the crank H, as clearly shown in Fig. 3, the table L with the work being traversed by means of the operating screw J in the usual manner up to the reciprocating relieving tools E and G which cut the two parallel slots.

In Figs. 4 to 6 the in-cutting relieving tool holder F and relieving tool G have been detached, although this is not essential, and to the broad tool holder D is applied a bracket S, in which is secured a cross-cutting relieving tool holder or bar P by means of pinching screws. The tool holder or bar P passes through a slot in the table, and at its lower end enters a sleeve secured in a cylindrical boss T cast in the bed plate. The tool holder or bar P carries the cross-cutting relieving tool R, which is set at right angles to the slot U of the broad slot T, and facing in the direction of the narrow slot V. By then actuating the cross traverse screw K, table L, carrying the work H, is set in motion, and the cross-cutting tool R cuts from the broad slot U to the narrow slot V, and so completely detaches the surplus piece W of metal from the web of the work. The machine, it will be seen, enables crank webs of any depth to be cut out from the solid at one setting, thus effecting great economy in working, as the cutting tool is simple and inexpensive, and requires very little upkeep as compared with sawing.

ELECTRIC MOTOR TROUBLES.

IN the operation of induction motors trouble is sometimes experienced from the sudden stopping of the machine even though the load does not exceed the rated value. The common cause of this is the rubbing of the rotor against the teeth of the stator. The air gap of the induction motor is usually made very small, for the sake of keeping the power-factor as high as possible. Hence when the motor stops the air gap should be investigated.

Low voltage on the line is another cause of induction-motor trouble. If the motor load is unsteady and the line voltage low, the machine may stop and the fuses be blown as the load quickly swings to some relatively large value. The torque, or turning effort, of a motor of the kind in question is proportional to the square of the applied voltage. Trouble is sometimes experienced in starting an induction motor because attempts are made to start it on too low a voltage. Low voltage on a motor may be caused by an unbalanced voltage on the line.

Vibration in an induction motor may be due to the fact that the shaft is sprung, or it may be that there is an unbalanced magnetic pull on the rotor due to an uneven clearance in the air gap or to the eccentricity of the rotor.

If one phase of the stator on a Y-connected 3-phase motor is open-circuited, the motor will not start; if it is started mechanically, it will run as a single-phase motor and the load it can carry will be materially reduced. An ammeter connected in each phase will give current readings in only two of them. If the motor is delta-connected, current will flow in each lead, but the currents will be unbalanced. In either case, if the machine is not started mechanically, the rotor will remain stationary and simply act as the secondary of a transformer. The whole machine will rise to a high temperature, and the conductors on the rotor may be badly burned in as many places as there are poles in the stator winding.

The faults which may develop in direct-current motors are: Sparking at the brushes; heating of commutator, armature, or bearings; noisy operation; running at wrong speed; and failure of motor to start.

Sparking at the brushes is not usually objectionable, if moderate in duration and amount. If allowed to continue beyond these limits it will burn and roughen the commutator, thus aggravating the difficulty. Sparking may be caused in several ways, among which are: too much current on armature, brushes not set at neutral point, commutator has high bars, or poor brush contact. To decrease the effect of sparking on account of the armature carrying too much current, the driven load should be reduced, the strength of the magnetic field should be increased or the size of driving pulley decreased. If the motor starting-box has too little resistance, it will cause the motor to spark badly at first, owing to a very sudden start. In this case the only remedy is an increase of resistance to cut down the voltage applied to the armature terminals.

To find the correct neutral position for the brushes, carefully shift the brushes backward or forward until sparking is minimised. If the brushes are not exactly opposite in a two-pole machine or 90° apart on a four-pole machine, they should be made so by counting the commutator bars and dividing by either two or four, as the case may be. To remedy high bars on the commutator or flat bars or projecting mica, smooth the commutator with a fine file or fine sandpaper, the latter being applied by a block of wood which exactly fits the commutator. If, however, the commutator is very rough or eccentric, it should be turned down in a lathe. On large machines, a slide-rest attachment is usually provided for either turning off or grinding the commutator without removing the armature from the bearings. To improve the brush contact, draw a strip of sandpaper back and forth beneath the brush with the rough side scraping the carbon. See that the brush holders work freely; lack of this may be the cause of poor brush contact.

Armature heating may be caused by moisture in the armature, unequal strength of magnetic poles, or by excessive current in the armature coils. Excessive eddy currents in the armature core may cause heating, too. Heating from this last cause may be distinguished by the fact that it is not accompanied by any sparking at the brushes. If there are excessive eddy currents in the conductors and not in the iron, this will be shown by the conductors becoming hotter than the iron on no-load running. In this case the conductors should be reduced in thickness, or else they should be split up into a number of strands, which should be twisted together. Beveling off the edges of the pole pieces may also reduce the trouble.

If for any reason a motor armature has become damp, it may, in the case of a small machine, be dried bv being placed in an oven kept at the proper temperature, while a larger armature can usually be dried by holding about three-fourths the normal full-load current on it continuously until it is dry, the armature being turned over occasionally in the meantime by hand.

Unequal strength of magnetic poles will, in the case of motors having multipolar fields and parallel windings in the armature, cause excessive currents to flow in the armature and thus to heat it. The trouble usually is that the armature is closer to some of the poles than to others, and the disorder may be corrected by slightly shifting the bearings, but in some cases, especially when direct-connected, it is preferable to shift the field magnet. When the armature gets out of centre from too much bearing wear, however, the proper procedure is to replace the bearings with new ones.

Heating of the commutator, like sparking, may occur in direct-current machines, and in the commutator types of alternating-current machines. There are various causes for commutator heating, among which are: Heat spread from another part of machine, sparking, carbon brushes heated by current, friction of brushes on commutator or bad connections in the brush holder. If the heat in the commutator comes from another part of the machine, start up the motor with the parts cool and run for a short time. The seat of the trouble is in the part that heats first. Any of the causes of sparking will cause heating, which may be slight or serious.

An overheated commutator will decompose carbon brushes and cover the commutator with a black film which offers resistance to the efficient collection of current. Carbon brushes require less attention than copper, because they do not cut the commutator, and their high specific resistance usually reduces sparking, but it may also cause them to heat more than copper brushes. The friction produced by the brushes will generate heat, which can be detected even when the brushes carry little or no current. Reduce the spring tension and decrease voltage, keeping up speed by weakening field strength.

The cause of bearings heating should be found and removed promptly, but heating may be reduced temporarily by applying cold water or ice to them. This should be resorted to only when it is absolutely necessary to keep running, and great care should be taken not to allow any water to get upon the commutator, armature, or field coils, as it might short-circuit or ground them. If the bearing is very hot, the shaft should be kept revolving slowly, as it might stick to bearing, if stopped. Heating of bearings is due to a lack of oil, shaft rough, grit, or other foreign matter in bearings, shaft and journal too tight, shaft sprung, or bearings out of line, too great a load on belt, or bearings heated by hot armature, commutator, or pulley. A rough shaft should be turned to smoothness in a lathe and the bearing fitted to the new diameter. It is very difficult to straighten a bent shaft; it might be bent back or turned true, however, but usually a new shaft will be necessary. In lining up bearings by either raising or lowering the bearing on its seat, or by moving it sideways, it is well to note that an even air gap must be maintained at all times, to avoid any trouble due to an unequalised magnetic pull on the armature. If there is too great a load or strain on belt, which would cause heating of bearings, reduce the belt tension, or use larger pulleys and lighter belt, so as to relieve the side strain on the shaft. The slipping of the belt on the pulley may heat one or both bearings.

Noisy operation may arise from the pulley or armature being out of balance, a shoulder on the shaft or the shaft collar striking against the bearing, chattering of the brushes, and so on. These causes may be discovered, as a rule, without great difficulty.

Operating at wrong speed is generally a serious matter in an establishment where reliable speeds are essential. The speed may be either too low or too high. A low speed may come from either a low voltage, overload, short-circuit, or ground in armature or shaft tight in bearings. A high speed may result from either a weak magnetic field or voltage too high. Any of these faults can be easily remedied by adjusting the voltage, field, or load to the name-plate rating. A short-circuited armature coil is often caused by a piece of solder or other metal getting between the commutator bars or their connections with the armature. If the short-circuit is within the coil itself, the only effective remedy is to rewind the coil.

When a motor fails to start, the trouble is generally outside the motor itself. The trouble usually is an open circuit somewhere, or else the machine is not properly connected to the line.—" Electrician and Mechanic."

Brighton Railway Electrification.—The new electrified London Bridge to Crystal Palace line of the London, Brighton, and South Coast Railway was formally opened a few days ago. This brings up the total length of suburban lines of this company worked electrically to about 20 miles. The other routes are Victoria to Crystal Palace and Victoria to London Bridge. Unlike almost all other electric railway companies in this country, the single phase alternating current method of working is utilised.

NEW PROCESSES FOR CHILLING AND HARDENING CAST IRON.*

BY THOS. D. WEST.

CONDITIONS are occasionally such that an "inside chill" is produced in castings, by which is meant that a casting with a grey or soft exterior may have the interior, or portions of it, composed of a hard, white, or chilled iron, as shown in Figs. 2, 3, 9, and 10. While inside chilling is claimed to be produced by hydraulic pressure, this is not the inside chill which has puzzled foundrymen, and prior to the mechanical creation of inside chill by the author, no one, as far as he knows, has explained how it could be produced at will. The discovery of how this can be done is due largely to experiments which the author has been conducting during the past two years with a view to overcoming the defects now existing in chilled car wheels, and this investigation led to other lines of research, as will be seen herein.

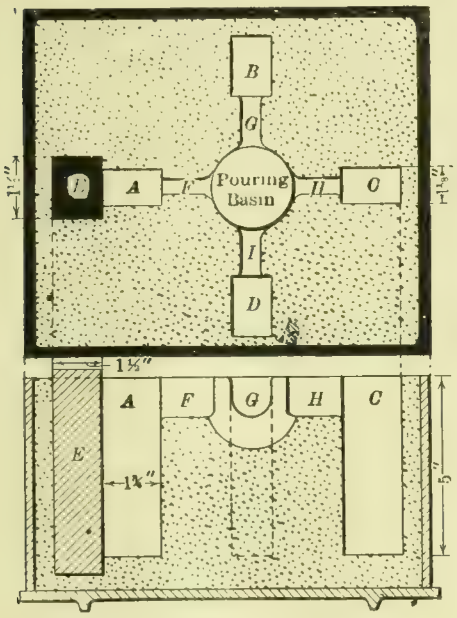


FIG. 1.—MOULD FOR TEST BARS THAT SOLVED INSIDE CHILL PROPERTIES.

Most of the experiments were made at the West Steel Casting Company, Cleveland, Ohio. This company makes castings by the converter and crucible methods, the former requiring a cupola similar to that used in iron founding, and so permitting the casting of chillable metals. The irons used were approximately of the following composition: Carbon, 2·75 to 3·25; silicon, 1·75 to 2·00; sulphur, around 0·06; manganese and phosphor, each about 0·04. In cases where a more chillable metal was desired, small portions of stick or powdered sulphur were dropped on top of the molten metal when in the hand ladle.

In Fig. 1 is illustrated the experiment that created mechanically an inside chill. This gives views of the mould used in casting test specimens in open sand of the size seen in Fig. 5. The bar A was cast against a chiller block as at E, while bars B, C, and D were surrounded with rammed sand. The bars having been poured, the gate connections F, G, H, and I were broken and the sand around C and D removed as soon as their solidification would permit. When it was thought C and D would stand the pressure of tongs, they were lifted quickly, and C was doused into a pail of water, while D was broken by an assistant to display conditions of its interior. The immersed bar C having cooled to a dark colour, it was taken from the water and broken, and displayed an inside chill, such as is seen at E′, Fig. 9. The bar D showed an interior condition bordering on semi-molten metal. The chilled bar A showed that the chiller E had chilled the surface of A about ⅛in. deep, while the bar B had a nice grey fracture. Bars A and B were not removed from their moulds until nearly cold.

The philosophy of mechanically creating an inside chill exists in the outside body of a casting cooling slowly enough to allow the carbon to take a graphitic form, while the inner body, which is not wholly solidified, is cooled so rapidly that the carbon is held in the combined form, similar to the way it is held in the molten metal.

The graphitic state of the carbon in the solidified body causes the iron to be grey and soft, while the combined state causes it to be hard and white, or chilled.

The ability to create an inside chill by strictly physical manipulation led to the belief that it might be practicable to increase the depth of a chill beyond what present chillers can do with like irons. Especially was this thought practicable for such castings as chilled car wheels and rolls. Several methods were devised for testing purposes; these devices admitted of a wide range for experiments, and as a rule led to satisfactory results.

* Paper read before the American Society of Mechanical Engineers.

Variable Conditions Affecting Chilling.— As many who are interested in founding are not cognisant of what is involved in the chilling of cast iron, the following recital is given of actions that take place and of conditions that exist in the process of chilling:—

(*a*) Iron is chilled prior to any formation of graphite. A chill may be made harder by continuing to cool it while the adjoining metal is still in a semi-molten state or very hot; as by this action any backward annealing to soften the chill is more or less retarded.

(*b*) Under like conditions the lower the silicon, and the higher the sulphur and carbon, the deeper the chill.

(*c*) Under like conditions the chill will be deeper the smaller the area of the cross-section to be chilled.

(*d*) Under like conditions the less the thickness in the chiller below what can be utilised the less the chill in the casting.

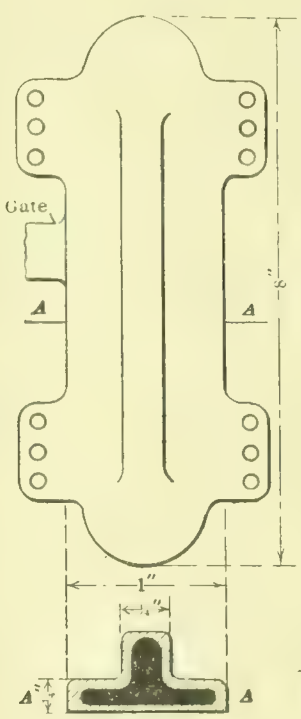
(*e*) The longer the casting remains in close contact with its chiller, while its metal is in a chillable state, the deeper the chill.

(*f*) The more fluid or the hotter the metal used in pouring a chiller mould, all other conditions being the same, the deeper the chill, from ⅛in. to possibly ⅜in.; and the greater the chillable nature of the metal, the more pronounced this effect.

(*g*) Not all grades of cast iron are chillable. It requires as a rule for iron of a general carbon, less than 2 per cent. of silicon and above 0·06 per cent. of sulphur.

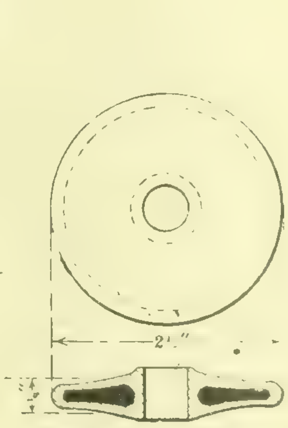
(*h*) On account of the variable percentages of silicon, sulphur, and carbon required to produce chilled castings, ranging from 1·75 down to 0·50 for silicon, from 0·10 down to 0·05 for sulphur, and from 4·00 down to 2·50 for carbon, it can be seen that there must be what are commonly called "grades" in chillable irons.

Mould for Making Comparative Chilling Tests.— In order to make comparative tests, a twin-chiller mould was designed, shown in Figs. 4, 7, and 8. By having the two moulds combined so that they could be poured from the same basin, it was possible to make all the conditions alike in both, except the one which it was desired should vary for the particular test under way. The mould was further designed to produce conditions similar to those existing when casting chilled car wheels and rolls. In making these latter castings the contraction of the chilled crust and the expansion of the chiller create a space between the exterior body of the casting and the interior face of the chiller. The ability to create a space as above in this experimental mould and to apply a heat-



Shaded lines gray or soft iron

FIG. 2.



Black, white or chilled iron

FIG. 3.

CASTINGS WITH GREY EXTERIOR AND CHILLED INTERIOR.

absorbing element to it in connection with other actions or treatment referred to later on, made it possible to conduct a large number of very satisfactory comparative tests.

In order to obtain a variable action so far as the chillers P, Fig. 4, were concerned, the braces M were removed and the wedges N driven down. If it were desired to have the space K in both moulds, two persons were employed to work in unison at their respective ends. The wedges N would not be knocked down until the metal filling the mould showed evidence at the top edge of the bars of having solidified sufficiently to produce a self-sustaining crust. It was rather

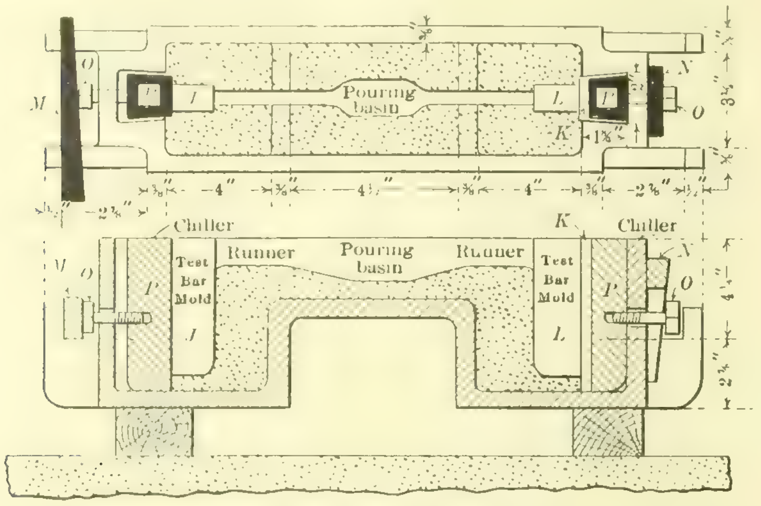


FIG. 4. MOULD FOR MAKING CHILLED TWIN SPECIMENS FOR FRACTURE TESTS.

remarkable in the air-cooling tests, to be described later on, how clearly the rate of cooling and inner solidification could be judged by the changing colour of the hot metal at the top edge of the bars next the chillers.

In casting bars intended to be kept in close contact with their chillers, either the runners connecting the pouring basin with the mould must be broken as soon as the metal in them has solidified sufficiently to permit such action; or care must be taken when pouring the moulds not to fill them any higher than the level of the bottom of the pouring runners. By these means the disturbing influence due to the contraction of the runners and pouring basin is avoided.

Fig. 5 shows the form and size of the pattern used for moulding the bars, while Fig. 6 is that of the manipulative chiller P employed in these tests. Each of these chillers weighs 3lbs. 14oz., and the bars made from the pattern, Fig.

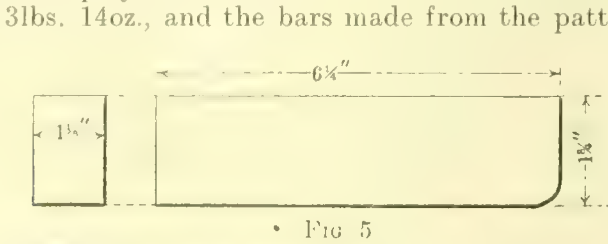


FIG 5

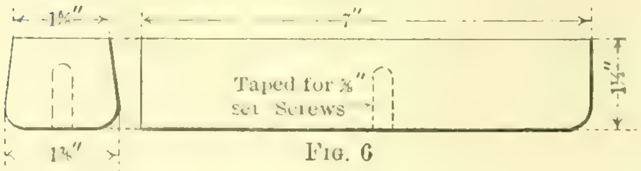


FIG. 6

FIG. 5. FRACTURE TEST BAR PATTERN; FIG 6 MANIPULATIVE CHILLER

5, averaged 3lbs. and 4oz. As Figs. 7 and 8 show devices for other purposes than those displayed in Fig. 4, comments on them are deferred.

First Experiments for Discovering Value of Hardening Materials.

In starting to use the twin chiller moulds shown in Figs. 1, 7, and 8, the first manipulation was to draw back the chiller P of one mould about ¼in. from the face of its bar casting as soon as the latter had solidified sufficiently to have a self-supporting crust facing the chiller, while the companion bar was left in close contact with its chiller until of a dark colour (see Fig. 1).

In various tests a ¼in. space K, Fig. 4, was formed by moving back the chiller, and the effect tried of quickly packing different materials into this space upon the backward movement of the chiller. The materials tried at different times were fine sand, coke dust, charcoal, powdered manganese, bone dust, hardening powder, and poisonous cyanide. These tests were made with a view to determining whether such filling of the space would increase the depth of chilling in a bar, or cause it to be any harder than when the chiller remained in close contact with the bar until the latter was nearly cold.

No noticeable effects were produced by the use of these intended hardeners. The thickness of chill of the bars kept in close contact with their chillers exceeded that of the treated bars by from ¼in. to ⅜in. This was to be expected, as the withdrawal of the chillers P to create a packing space broke the contact of the chillers with their bars at the crucial moment, so far as their effectiveness was concerned in increasing the depth of the chill.

Second Experiment for Discovering Value of Hardening Materials.

In this series of tests, both chillers were pulled back at the same moment to create spaces adjacent to both bars, as at K, Fig. 4. The tests were to discover if any greater depth of chill or hardening was produced by packing one of the spaces quickly with the materials used in the first experiments while the other space was left open. The series showed the chill to be from $\frac{1}{16}$in. to ⅛in. deeper in several of the treated bars than in the non-treated bars.

Tests for hardness, except for the cyanide, showed a gain of 6 to 10 per cent. by the scleroscope. One cyanide test with companion all-chilled bars averaged 68 for the treated and 70 for the non-treated; while with another set of companion bars which were not chilled the non-treated bar gave 58 and the treated bar 50 on an average. This softening action of the cyanide may have been due to the fact that

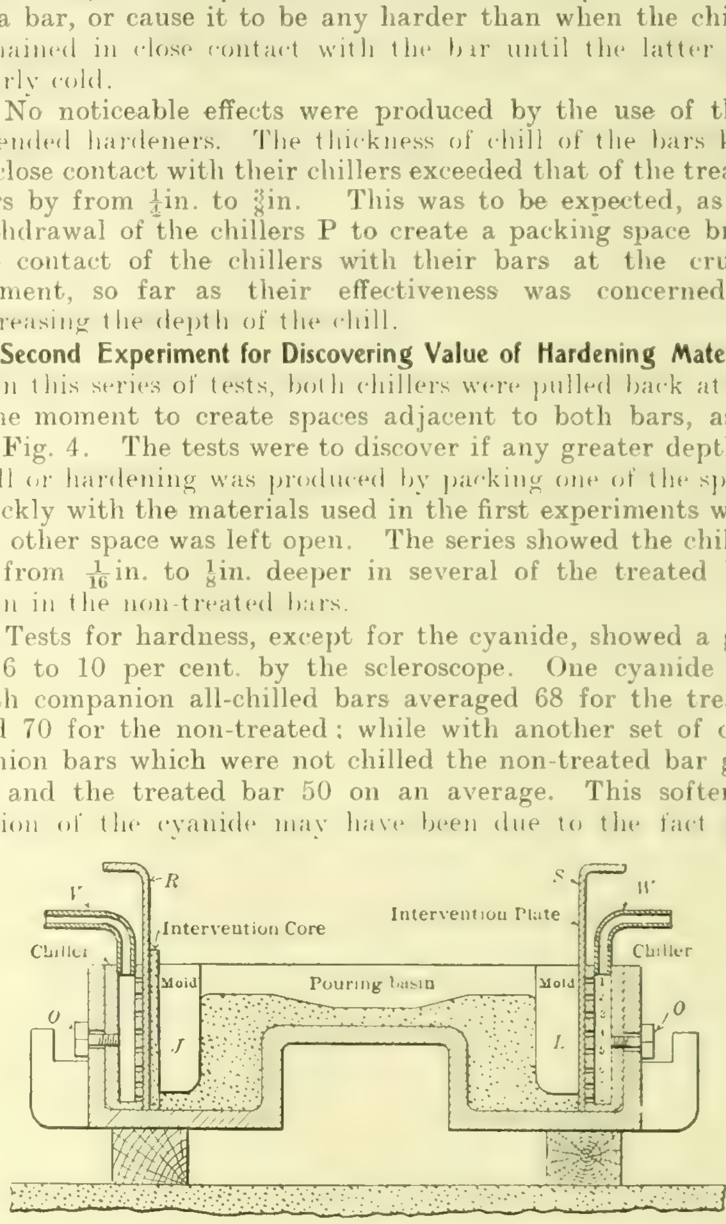


FIG. 7. INTERVENTION PLATE SYSTEM FOR AIR COOLING AND CHILLING OF MOLTEN METAL.

the bars were not cooled in water after treatment, as is necessary when case-hardening steel with cyanide. A peculiar effect of the cyanide is to produce a denser and a finer crystallisation of the treated chilled face about ⅛in. thick.

Immersion Experiments.—For this series, open sand moulds of the plan shown in Fig. 1 were used, and by the aid of an assistant, two of the four bars were removed as soon as the crust solidification permitted. One of these bars was immersed and moved around in a pan of mud, which in some tests had salt mixed with it, while the second bar was simultaneously submerged in a pail of water. These tests were duplicated by having the pan nearly filled with a high firetest oil in place of the mud. Tests made by the second use of the open sand mould, Fig. 1, showed that the mud or oil cooling had little or no effect in chilling, on the average, while the water cooling was radical in its action. A′, B′, C′, and D′, Fig. 9, give a fair illustration of these tests. A′ is the chiller-cooled bar; B′ the all-sand one; C′ the mud-cooled bar, and D′ the one placed in water. Bars A′ and D′ were both left in their moulds to cool naturally. The bar D′ displayed an inside chill, as seen by the white appearance at D′ and the grey corners and surface indicated by M′. The best sample of this effect, which was closely duplicated in several tests, is seen at E′ in connection with the chiller-cooled companion bar F′, which latter was cast against the face of the chiller E, Fig. 1, the same as bar A′ in Fig. 9. The bar F′ showed that a harder grade of iron was used than for A′.

The writer's experience in producing this inside chill mechanically demonstrates it to be a sensitive process partaking of numerous forms, yet all verifying its practicability. It is not improbable that castings, or sections of them, will eventually be produced in a regular manner for commercial

use, having a grey or mottled exterior crust, while the adjoining or interior body of metal will be of a mottled, chilled, or white iron. The writer can conceive of castings in which this combination of hardness might prove useful, but as his ideas might be considered visionary, he refrains from mentioning them.

Hardening a Chilled Body when Hot by Impingement of Air Against its Surface.—Special attention was paid in this series of tests to the hardening effect of air applied directly to the hot chilled face of a bar. For tests of this character it is essential that the depth of chill in the comparative bars be of the same thickness. This condition was obtained by admitting the air to the treated bar only after it was thought the inner metal had all solidified, so that it could not be

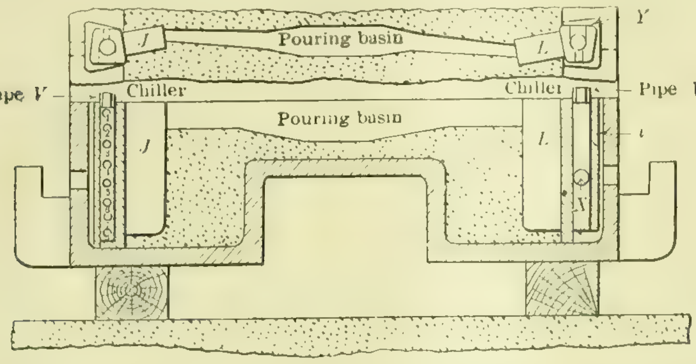


FIG. 8.—CHILLER MOULD FOR TESTING CHILLING EFFECT ON CASTINGS BY COOLING CHILLER.

held responsible for any variation of depth of chill in the treated bars. Only three specimens of this series were tested by the scleroscope, as given in Table I.; but from filing and grinding tests made as a check on the results it is evident that a chill's hardness can be very materially increased by applying air, &c., as herein described.

TABLE I.—*Scleroscope Tests for Hardness.**

Set Number of Tests.	Set 1	Set 2	Set 3
Average of air-cooled chilled bars	56	65	61
Average of natural-cooled chilled bars	48	58	53
Average of increase in hardness effected	8	7	8

* The writer is under obligations to the kindness of Mr. Walter D. Sayle, president of the Cleveland Punch and Shear Works, Cleveland, O., for the scleroscope tests given herein.

Tests of the grey sides of the chilled bars for the second and third sets in Table I. gave 52 and 42 respectively, showing them to average 25·4 softer than the chilled sides which had received the air treatment.

Effect of Air Saturated with Water.—This series was conducted with a view to learning whether air saturated with water might be more effective than air alone in creating a chill, or in hardening. There was some difficulty at the start in obtaining satisfactory saturation, but this was finally secured by the use of a device which made it possible to vary the proportion of air or water as desired. The series was instructive in demonstrating that so far as the chilling was concerned there was little to be gained by the saturated air, or what was gained would be secured by the use of a greater volume of air alone, so that the water could be dispensed with. This is not, however, to belittle the effectiveness of saturated air as a hardening medium, for among the tests in which saturated air was strongly applied, one gave 70 for the treated bar and 52 for the non-treated bar, a gain of 34·6 per cent. due to hardening.

Softening Effect of Annealing Chilled Iron.—Specimens of this series of tests were cast in the twin-chiller mould, as arranged in Fig. 8, without applying any air cooling to either chillers. This gave the same depth of chill in both bars. Several sets were cast and annealed, but only one set was tested by the scleroscope. Other sets showed by filing and grinding that they checked closely with those tested by the scleroscope. The annealing was done as follows: The bars were taken out of their mould together and one left in the open air, of about 70° Fah., while the other was laid on the bottom of a hot crucible furnace, the oil fire having been shut off, and left there about 12 hours. The chilled side of the unannealed bar tested at 68 and the grey side at 45. The chilled side of the annealed bar tested at 47 and the grey side 35. This gave a difference for the chilled sides of 21, and for the grey sides of 10.

Relative Efficiency of Warm and Cold Chillers.—In order to be assured of correctness in his researches, the author undertook to determine the efficiency of different metals, and of different thicknesses of metal, for chillers, and the relative efficiency of warm and cold chillers. To determine the latter two chillers, both alike, were used, one of which was heated to various temperatures, from one bearable to the hand to one that would burn the flesh, while the other chiller was kept at the temperature of the atmosphere. The first three sets of these tests were made on a day when the thermometer registered 62°, and the second set of four tests when it was 55°. The tests showed from $\frac{1}{16}$in. to $\frac{3}{16}$in. greater depth of chill in the bars having the cold chiller than those having the heated ones. Having recently read the claim that a warm chiller would chill deeper than a cold one, it was thought necessary to learn whether such was a fact, as it is unreasonable to expect such a result.

Efficiency of Different Thicknesses for Chillers.—To determine the effect of different thicknesses for chillers, tests were made by the writer at the Cleveland branch of the National Car Wheel Company, as well as at the foundry of the West Steel Casting Company. For this series open sand moulds were used, as seen in Fig. 11. The chillers, as shown, were respectively $\frac{1}{4}$in., $\frac{1}{2}$in., $\frac{3}{4}$in., 1in., 2in., and 3in. thick, and all 2in. wide by 9in. deep.

The test specimens cast against these chillers in the wheel foundry were $1\frac{7}{8}$in. by $2\frac{1}{2}$in., and 8in. long, and at the steel foundry, because of having a less chilling metal, they were of the size shown in Fig. 5. The top row of fracture views, Nos. 1 to 6, Fig. 10, is a fair representation of results obtained. The thickness of chill in the samples shown in

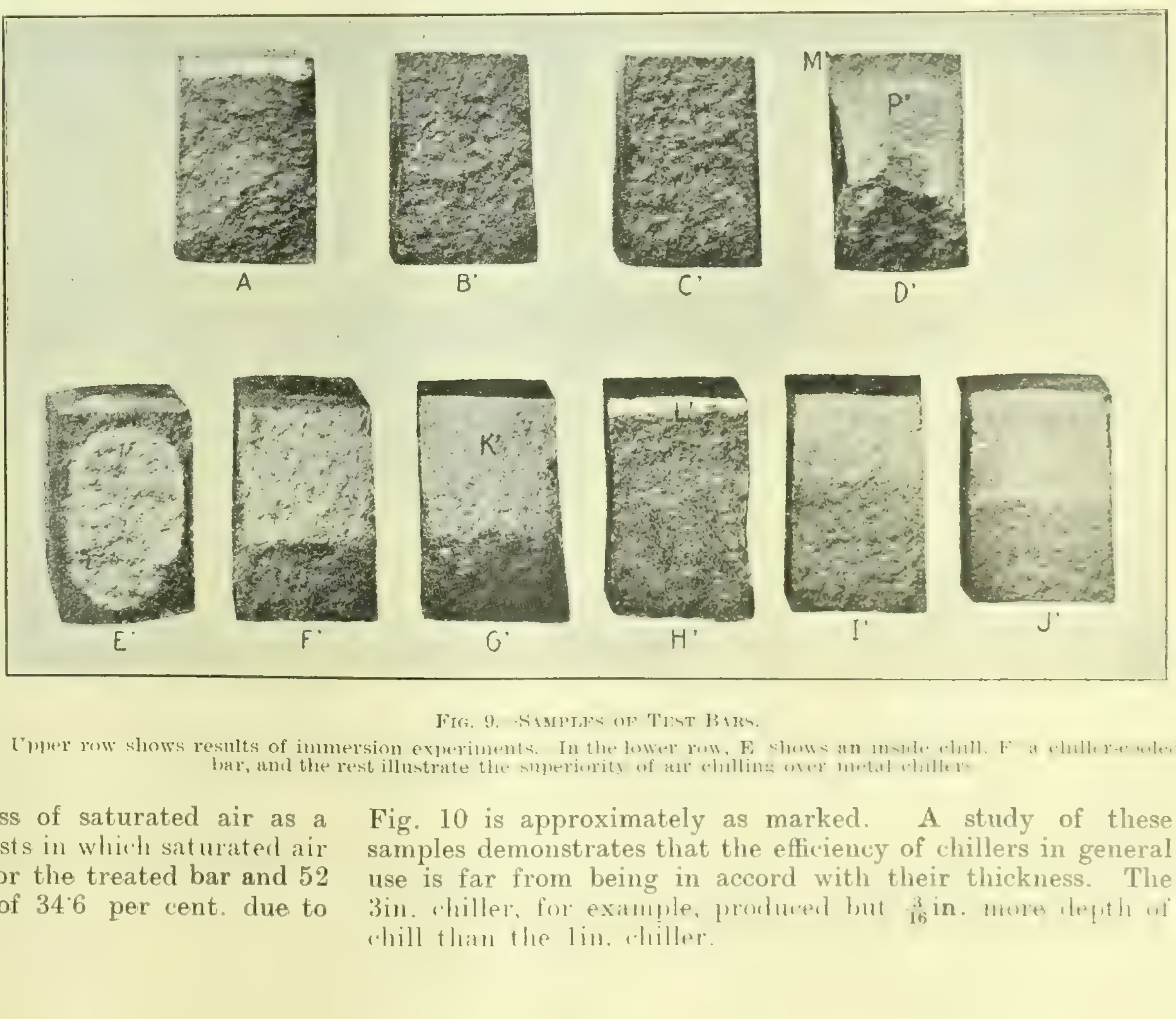


FIG. 9.—SAMPLES OF TEST BARS.
Upper row shows results of immersion experiments. In the lower row, E shows an inside chill, F a chiller-sealed bar, and the rest illustrate the superiority of air chilling over metal chillers.

Fig. 10 is approximately as marked. A study of these samples demonstrates that the efficiency of chillers in general use is far from being in accord with their thickness. The 3in. chiller, for example, produced but $\frac{3}{16}$in. more depth of chill than the 1in. chiller.

Aside from their value in other ways, these tests suggest the advisability of makers of chilled rolls, car wheels, &c., trying steel metal chillers in place of the much heavier cast-iron ones. Steel chillers need be made only of the thickness required for efficiency in cooling, and would still be strong enough to resist the contraction and expansion strains to which chillers are subjected. There is a liability of difficulty being encountered in using steel chillers on account of the steel warping through repeated heating. By using ribs or giving a special form to steel chillers this objection may be greatly reduced, if not wholly overcome.

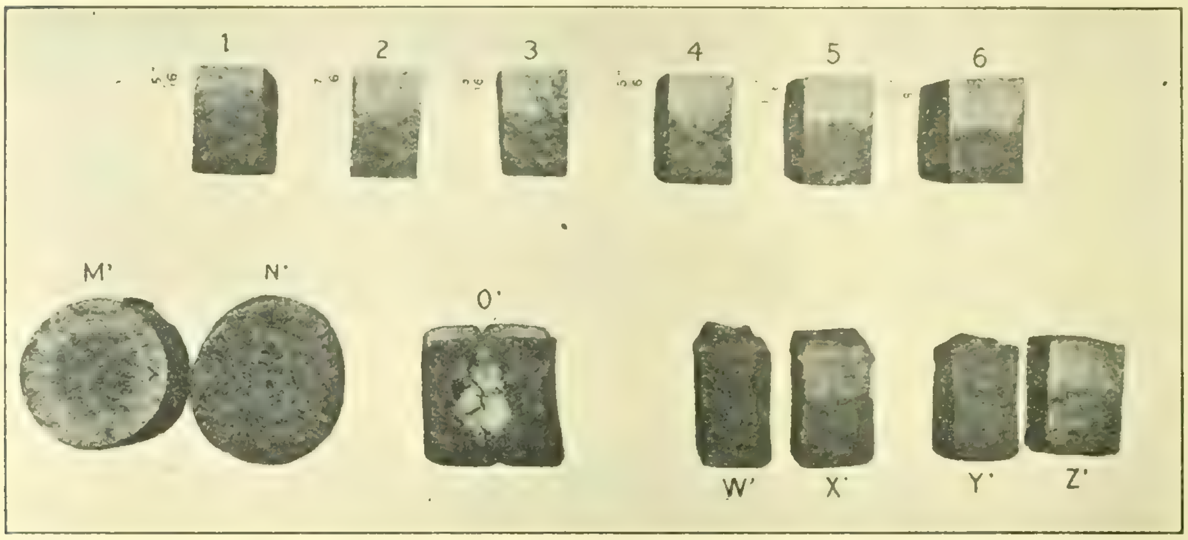


FIG. 10.—SAMPLES OF TEST BARS.
Upper row illustrates efficiency of chillers of different thicknesses; lower row, results with sand-faced mould, and air-cooled bars containing vanadium and titanium.

Efficiency of Different Metals for Chillers.—It was important, at least to the writer, to know whether any difference existed in the efficiency of chillers of grey, white, or all-chilled cast iron or of steel or wrought iron. Tests were made with these different metals at both foundries. Two sets of chillers were used, one 2in. square and the other 1in. by 2in., all close to 9in. long. Aside from grinding one face of these chillers to remove the scale and make them smooth, as with all other chillers used in the experiments of this paper, they were chipped or ground at their lower ends, if needed, to make them all of the same weight. The plan of the open sand mould used is shown in Fig. 12. The test-bar patterns were of the same size as used for the tests of Fig. 11, about four sets being cast from each size pattern. While slight differences in the thicknesses of the chills resulting from chillers of the different materials seemed to indicate that one or another of the materials produced the deepest chill, there was so little practical difference in the results, taking an average of all the tests, that none of the chillers could be rated as being decidedly better than the others.

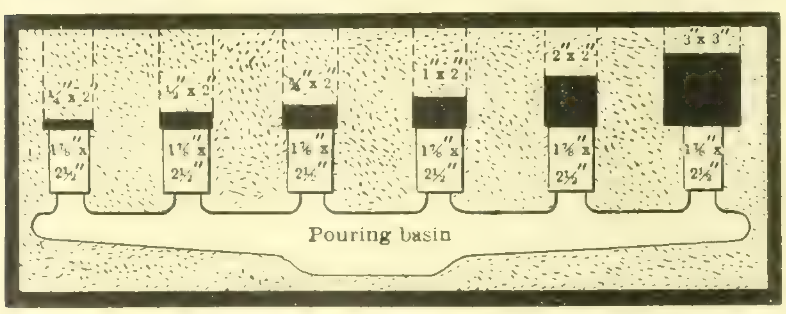


FIG. 11. TESTING EFFICIENCY OF DIFFERENT THICKNESSES OF CHILLERS.

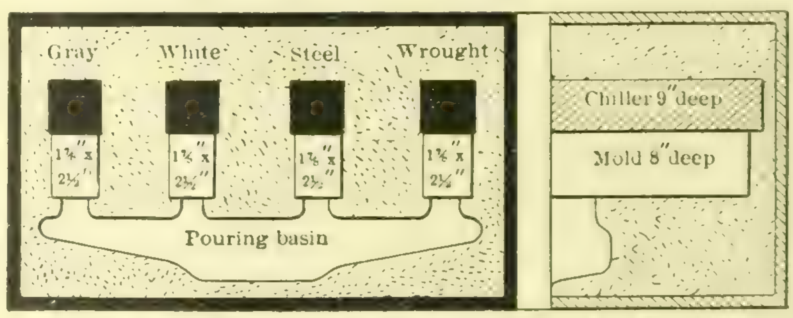


FIG. 12. TESTING EFFICIENCY OF DIFFERENT METALS FOR CHILLERS.

Value of Cooling Chillers.—The chief information sought in this series of tests was whether, when a casting contracts away from a chiller, the depth of chill is increased by cooling the chiller, and at what point the cooling ceases to have this effect. The chillers for these tests were arranged so as to have the orifices 1 to 8, Fig. 7, turned away from the face of the mould as in Fig. 8. This gave a solid surface to the body of the chiller fronting the mould, and prevented the air used to cool the chiller from impinging on the hot face of the bar. For the first tests, intervention plates S were used for fronting each chiller, after the ideas displayed in Fig. 7. As soon as solidification of the metal at the face of these plates would permit, they were pulled out simultaneously to create a space between the bars and their chillers, as seen by the opening at K, Fig. 4. The plates S removed, air of about 50lbs. pressure was admitted to one of the pipes, as at W, Fig. 7, which passed down the bore of its chiller to find exit at X, and at the orifices 1 to 8 to the exterior of the chiller; from whence it passed upward and escaped to the external atmosphere from around the opening Y in the plan view of Fig. 8.

In the use of chillers for car wheels, rolls, &c., the contraction of the casting and expansion of the chiller leave a space between the two, and these tests were therefore well adapted to demonstrate whether internally or externally-cooled chillers used for this class of castings would produce a deeper chill than those not cooled. Half-a-dozen tests were made without finding any practical difference in the depth or character of the chill produced by the air-cooled chiller bars and that of their companions which were not cooled.

Following these tests, fully six more were made with the plates S omitted on both sides, so as to have the bars cast directly against the face of their chillers, as displayed in Fig. 8. Here both bars remained in close contact with their chillers until cooled to a dark colour. In casting these bars air of about 50lbs. pressure was admitted to one side only, passing down the pipe W and escaping at the lower exits seen at X, and thence passing upward to the external atmosphere through the space I. It was a surprise to find that this method proved practically no more effective than that just described. These tests appear to confirm those illustrated in Fig. 11 by demonstrating that there is a limit to which the thickness of a chiller affects its efficiency, and that its efficiency cannot be assisted by artificial means. They forcibly illustrate the fact that if little or nothing is to be gained by holding a casting in close contact with a cooled chiller until it becomes of a dark colour, it would be unreasonable to expect any benefit from a heat-absorbing medium passing rapidly through the internal body of a chiller or over its outer external surface when a space existed between the two.

(To be continued.)

Personal.—Mr. W. J. Guy, of Sheffield, has been appointed manager at Newburn Steelworks in succession to Mr. W. E. Hampton, who has removed to Birmingham. The new official has held several important posts. He has come from the Sheffield works of Messrs. John Brown & Co., Ltd., of Sheffield and Clydebank, and was associated with that well known firm for over 10 years.

Engineer Decapitated at a Mill.—At the River Mill, Dukinfield, on the 4th inst., the decapitated body of the engineer was found on the top platform of the rope race. The platform is only 5ft. square. Two ropes were off the pulley, but how the accident happened is unknown. The ropes, which were only tightened about a fortnight ago, are estimated to travel at a speed of a mile and a half a minute, and it is presumed that in attending to his duty his head became entangled with them.

MACHINE FOR TESTING THE HARDNESS OF METALS.

WE illustrate herewith a machine for testing the hardness of metals, the invention of R. Guillery, 44, Avenue de Ségur, Paris. It depends upon the principle enunciated by Brinell, in which the hardness of a metal is measured by the impression produced by a ball of given diameter loaded with a given number of kilograms. Under the usual conditions the ball is 10 mm. diam. and supports a load of 3,000 kg. The relation between the load and the spherical surface of the impression is called by Brinell the coefficient of hardness of the metal. It is particularly interesting to determine this coefficient since for the carbon steels, that is, for the ordinary steels, it is very nearly proportional to the tensile coefficient in the relation of ·36 to 1.

Fig. 1 is a transverse section of the apparatus. Fig. 2 is a front view with the eccentric lever in section. Figs. 3 and 4 represent sections through the lever for the case when only a single stroke is used in the trial. The apparatus at its lower part carries a nest of Belleville springs (springs consisting of a metallic disc, in which the central portion is provided with an aperture and is raised above the rest of the periphery, two of these springs being placed together, so that their peripheries are in contact), bearing on the one hand against a ball support A internally threaded for the purpose of mounting, and on the other hand against the base by abutment washers and a hollow ring B of elastic metal filled with mercury and communicating with a glass tube C placed outside the frame and indicating at a given temperature the pressure employed. At its upper part the apparatus carries a lever D turning through a limited angle; this lever

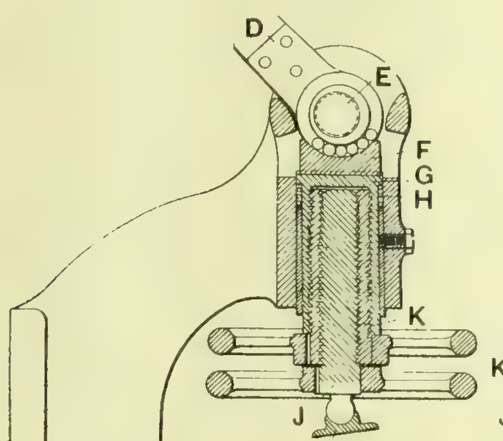


FIG. 1.

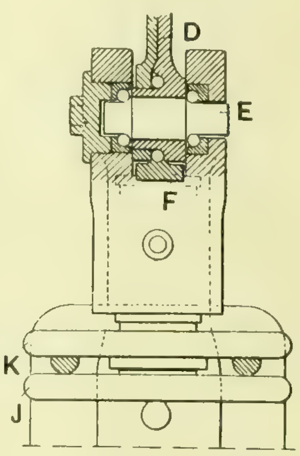


FIG. 2.

MACHINE FOR TESTING HARDNESS OF METALS.

by its eccentric axle E and its ball bearings, imparts to the half bush F a vertical movement which is greater for the full stroke of the lever than the maximum impression of the ball on soft metals. This movement when transmitted to the ball M causes a depression of the Belleville springs equivalent to the load of 3,000 kg. required in the Brinell test. The half bush F rests on the socket G kept in contact with it by the spring H, which tends always to raise it. The socket G is screw threaded and carries two screws J and K, with hand wheels, telescoped in each other, so as to allow any thickness of metal to be tested between the ball M and the universally jointed support N.

Figs. 3 and 4 show a modification suitable for tests performed with a single stroke, for example, in testing heated metals. The eccentric axle S, which turns on rollers, is provided with a hexagonal extension over which the lever R can be slipped; by removing the lever and replacing it on another side of the hexagon, the stroke of the half bush can be in-

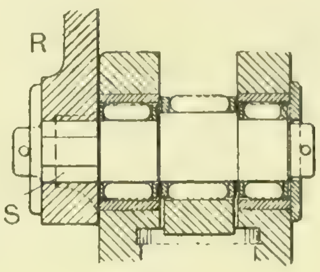


FIG. 3.

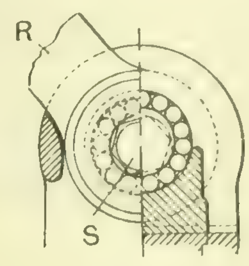


FIG. 4.

creased, so that it is always greater than the impression, together with the depression of the Belleville springs. An electric contact P indicates through a bell when the load of 3,000 kg. has been attained. The test is continued until the bell sounds; the pressure exerted by the ball on the piece tested is then 3,000 kilos. The spherical surface of the impression is then measured, and the quotient of 3,000 kilos by the area in square millimetres is the required coefficient of hardness.

REPORTS ON THE RECENT DUST EXPLOSIONS.

THE report of Mr. H. J. Jackson, H.M. Inspector of Factories, who conducted an enquiry into the explosion at Messrs. J. Bibby & Sons' factory at Liverpool, on November 24th, when 39 persons were killed and 101 injured, has just been issued. During the process of manufacture of the oil-cake, the firm used meal which had been treated with naphtha, and Mr. Jackson reports that in his opinion the explosion was due to the ignition of a dense cloud of dust produced by the breaking of the driving belt of the "street end dressing machine" disintegrator. The disintegrator belts were 8in. wide, they ran at a speed of about 5,000 per minute, and the workmen stated that when they broke they caused a cloud of dust "like a fog" for a minute or two, due to the dislodging of accumulations of dust on the girders, machinery, and plant. Experiments showed that a dense cloud of this dust yielded an explosion with (1) an ordinary lucifer match when ignited in the dust; (2) the flame of an ordinary gas jet; (3) the flash caused by fusing an electric fuse wire; (4) the spark produced by breaking circuit of an electro-magnet. The inspector expresses the opinion that while the striking of a match might have been the cause of the initial flash which brought about the explosion, it may have been due to the breaking of a magnet wire, or to the bursting of the uncovered fuse on the temporary switchboard at the very moment when a dense dust cloud was formed by the breaking of the disintegrator belt. Mr. Jackson makes a number of recommendations applicable where carbonaceous dust is generated, which include provision for the prevention, interception, or removal of dust; the prohibition of matches, smoking, naked gas lights, and electric lamps. He says underground rooms are unsuitable for disintegrators, or for grinding machinery, and suggests that the roof of a room used for that purpose should offer little resistance to an explosive force.

The report has also been issued of Mr. W. S. Smith, H.M. Inspector for Dangerous Trades, on the explosion at the works of Messrs. William Primrose & Sons, Glasgow, on November 10th last, which caused the deaths of two men and three children, and injuries to eight persons. In this case also the cause is attributed to the ignition of carbonaceous dust, probably by a spark, but more probably by a naked light, the direct suggestion being that the explosion followed a fall of dust from an overhead beam on to a Bunsen burner.

THE FUNCTION OF THE LABORATORY IN THE TRAINING OF AN ENGINEER.*

BY PROF. E. W. MARCHANT, D.SC. (LOND.), M.I.E.E.

THE conference recently held by the Institution of Civil Engineers, whatever other effects it may have produced, has aroused a great deal of interest in the subject of engineering training. It is not proposed to deal at length in this paper with the general question of the proper training for an engineer, but it may be of interest to make some attempt to summarise the main conclusions on which there appeared to be agreement at the recent conference.

In the first place it must be recognised that it is impossible to indicate any royal road to becoming an engineer; the path pursued must depend very largely on the individual, and what may be good for one is bad for another. The three essential conditions are:—(1) That the engineer should have a good general education as a foundation for his future knowledge, and that this education should include a good grounding in mathematics; (2) that he should have a good college training which should include a grounding in the general principles underlying all branches of engineering; (3) that he should have a good workshop training or pupilage.

These conclusions appear nowadays to be almost obvious, and it is, perhaps, hardly necessary to state them save to emphasize the fact that hardly a voice was raised which did not recognise that all three things were essential, and that an engineer could not be regarded as fully trained until he had gone through all these phases of his education. Beyond that point it is very difficult to go. The most varied views were expressed as to the most desirable order in which to place the last two stages, whether to put college training first or to have it after a training in works, or whether to have it sandwiched in between. The author's own view is that it is best to have college training first and works afterwards, and for the student to gain the knowledge of practical work, that it is so desirable for him to have, during his college career in the long vacation of his college course. These matters lie, however, beyond the scope of this paper.

It is only with the second stage of the engineer's education that this paper specifically deals. There are laboratories in schools and laboratories in works which serve most useful purposes, but these laboratories are not places where engineering training is given. The college laboratory is the only place designed with a view to giving training suitable for an engineer, and it is not to be expected that either the school or the works will ever succeed, even if they should attempt to do so, in providing instruction which would enable a college laboratory to be dispensed with. Engineering is a profession which deals with three things: materials, machines, and men. Of the last of these things no amount of teaching will ever succeed in giving any real knowledge, the only way to learn being by experience. This is a fact well known and universally recognised, but what holds for the last, holds for the two first also, though not perhaps to the same degree. To know anything about materials and machines it is essential that one should have experience in the use of them. Knowledge gained by experience is real knowledge, and is not soon forgotten and lost, and it is with the object of instilling some of this real knowledge about materials and machines that the laboratory has been created. Although, therefore, it may appear that the function of the laboratory in an engineering training is comparatively small, as forming only one part of the college training, it is really fundamental, the most fundamental part in the training of an engineer, and an engineer trained without laboratory practice has missed the greater part of what a college can teach him.

An engineering laboratory was first established in England, as far as the author is aware, by Prof. Kennedy, and since it was founded at University College, London, many engineering laboratories have been built, some simple, some most elaborate in every detail of equipment. It is one of the objects of this paper to discuss what is the best kind of laboratory for educational purposes. Before discussing this question in greater detail it will be desirable to state as simply as possible what a laboratory training may be expected to do for the average student. The chief functions of any scientific laboratory are: (1) To teach the art of deduction from experiment. (2) To give a practical knowledge of the operation of the machines with which the laboratory is intended to deal.

There can be no doubt that the type of laboratory in which the student does nothing but make observations is of very little value. After the preliminary interest has evaporated, the student will lose interest in his work, his inherent laziness (and the word inherent is not intended to be in any sense in disparagement of the average student) will be encouraged, and what is perhaps the most important result of all, the student will gain no real knowledge of the actual behaviour of the machinery with which he has to deal; he will be unable, for example, to carry out a test on his own responsibility, because he will never have had the experience of making the necessary preparations for the tests he has made.

It is not necessary that the machinery used should be of great size. For most purposes a machine of 10 h.p. to 15 h.p. is sufficient, and there is a further advantage in the use of small machines, in that the student can be given a freer hand in making the necessary connections and arranging the testing appliances. With very large machines the value of the material used means that much greater care must be exercised before a test is started; in many cases it is the custom for all arrangements for the test to be made beforehand by the laboratory staff. The disadvantage of this practice is obvious, and its necessity is in itself a reason why large machines are undesirable. At the same time the use of small machines exclusively for laboratory practice is also undesirable, since the student does not obtain that sense of scale, as Prof. Unwin recently put it, which it should be one of the objects of a laboratory training to give. It is questionable, however, whether the expenditure involved in the provision of large plant is altogether justified, since it is usually possible to arrange for tests to be made on outside plant of large power or for students to participate, as assistants, in tests that are being made elsewhere.

The advantage of carrying out one or two tests outside the laboratory under ordinary practical conditions is very great, and it would be of assistance if engineers would give even greater facilities than they have done in the past for students to gain this very valuable experience. One is aware of the natural objection that may be felt to students being present at official trials, but there are many observations that have to be made in a trial, which the student can make as well as, if not better than, the ordinary assistant, and the practical advantage he gains is very great. The laboratory's main object is to give knowledge of fundamental principles, and for this purpose a series of tests devised with the object of bringing out some fundamental point, or an experiment on a piece of apparatus specially designed to emphasize a particular phenomenon, is the best means for instruction. Besides giving knowledge of machines, it is essential that the laboratory tests should give a knowledge of the qualities of the materials used in engineering construction, of the conductivity of metals, of the insulating qualities of materials, and of their power to resist strain, of the magnetic qualities of iron, and of the laws of temperature rise in simple cases. Besides this, the calibration and testing of instruments (and the accuracy of observation attained by tests of this kind of work is of fundamental value) forms an important part of the training which the laboratory should afford.

Laboratory work appeals especially to the English temperament, which is experimental rather than theoretical, and it may be used with advantage to a greater extent, the author believes, in English institutions than in those of some other countries. In spite of this fact, the laboratory has reached its greatest development in Germany and America, largely because the funds that have been available for educational purposes have been much greater as a rule than they have been here. In Germany, especially, the laboratories in Berlin, Dresden, Carlsruhe, and some other places, can hardly fail, at first sight, to cause a pang of envy in the minds of those who have to work with far fewer facilities. In some cases, which it is not necessary to specify, the equipment does not appear to have been devised in the best way. Too little is left for the student to do. He is appalled by the complexity of the appliances with which he has to deal, and the average student fails to understand exactly what he is doing when he is carrying out a test. In the later stages of his training, it is most desirable that a good deal should be left to the

* Paper read before the Liverpool Engineering Society.

student's initiative. He should be required to carry out a complete series of tests on a given plant, he should make these tests, as far as possible, on his own responsibility, he should connect up his own instruments, and write a report on the test, similar to that which would be required if the test were being made officially.

In some cases the student appears to be set a definite routine in his laboratory course, the organisation of the laboratory work appears to be almost military in its precision, and the inevitable result, as far as the English student is concerned, is to deaden his intelligence and make him a far less useful member of the engineering profession than he would have been had be been given greater freedom and allowed to act on his own initiative.

There has been, and still is, a great tendency in the equipment of laboratories to standardise the arrangements adopted. To a certain extent this is almost a necessity, since the apparatus and machinery required for simple tests is bound to be very similar, and the nature of the tests can hardly vary to any great extent if they are to illustrate the same laws. In the higher branches of training there would seem to be much less reason for any great similarity between laboratories. The field of knowledge which can be covered by the student when his studies are more specialised is necessarily smaller, the total amount of time available for instruction is comparatively short, and even if it were possible for him to spend a longer time at his training it seems very doubtful whether any advantage would be really gained by him. This being so, it would appear that the most desirable course to adopt would be to restrict the provision of machinery and apparatus in any given laboratory to the branches of electrical engineering in which the professor and his staff are most intimately concerned. As a matter of fact this is precisely what has happened and what is bound to happen in laboratory equipment, and it is the course which is most likely to be useful in providing engineering education for all the types of citizen that may require it. It would be most unfortunate if all laboratories outside a central institution were to concern themselves with the training of engineers up to the point at which they begin to do really interesting work, and that they should then be transplanted to a central college where all advanced work and research work was to be undertaken. If such a co-ordination were proposed to be carried out (and it is not in the author's view at all a feasible proposition), it would, from the point of view of the laboratory training, be much better if the preliminary training were all given in a central institution and that, after the first two years of preliminary training had been received, the students should then be drafted off to the laboratories which were best adapted to provide a training in that branch of engineering which they were anxious to follow.

With things as they are, of course, such a proposal is altogether out of the question. All laboratories are now provided more or less completely with the material necessary for giving a good preliminary training; it is to be hoped that unnecessary duplication may be avoided in the further provision that has to be made to meet the requirements which modern developments have rendered necessary. The necessity for this restriction in the scope of work is also desirable from the purely educational standpoint. The modern tendency both in general and engineering education appears to be against specialisation. This may be sound theoretically, and the position is one for which it is very easy to give ample justification, but is seems very doubtful whether a greater degree of specialisation would not give better results in general education, and there is no doubt whatever that a more specialised training is much better for engineers than one which covers a greater range of subjects. Whatever branch of engineering a student may subsequently take up, he will be far better able to cope with new problems and to solve difficulties, if he has had experience in the complete solution of some problem, if he has, for example, carried out an exhaustive series of trials on a given piece of machinery, than if he has been given a very broad general training in all branches of engineering. The great function of the laboratory, as has been already stated, is to teach the art of deduction from experiment, but it would seem in many modern laboratories that this function has been entirely lost sight of and its function perverted into a training in the art of reading instruments correctly and drawing curves.

The chief argument that has been used against specialisation is that the engineer does not know what he will have to do subsequently. A distinguished schoolmaster once said to the author, "If I were in a motor car that was running away down hill, my one prayer would be that the chauffeur should have been taught Latin." I am not prepared to agree with this dictum, but it emphasizes the point that the primary object of engineering education is education, and that good education is a far more important thing than the acquisition of a knowledge of facts.

Although the laboratory is fundamental as far as the training of an engineer is concerned, it may be well to define some of its limitations. The work of an engineer, as distinguished from that of a test-room assistant, is primarily the design of a machine, or a transmission line, or a power station, or of some other engineering structure. That is, his work is constructive and not analytical. The training which the laboratory gives is mainly in methods of analysis, and it is a matter for discussion as to how much of a student's time should be spent in work of this kind, and how much in the constructive design which it will be his main business to achieve in his subsequent career. There is no question that the training now given in laboratories is adequate as far as practical requirements are concerned, for it is the practice of some works to employ college-trained men in their test rooms almost exclusively, and to take them direct from college to do this work. The main object of a college course is not, however, to turn out men of this type, but rather engineers who shall be responsible for new works of construction. It is, of course, impossible for a college (and no college has, with possibly one exception, attempted) to produce a fully-trained and qualified engineer. The practical training under commercial conditions, the knowledge of men, and of the economic possibilities of a works can only be gained by practical experience in works, and it is one of the drawbacks of design work undertaken at colleges that the student has not, as a rule, got the kind of knowledge it is essential for him to have if he is to make a successful design. The student works under direction, he has comparatively small opportunity of using his own powers of initiative, and his work tends to become very largely the copying of drawings which have been made in former years by other students. It is not, of course, necessary that the work done should be of this character, but it is very difficult to avoid the kind of result that has been indicated. The student is bound to be governed in his design by empirical formulæ, and in most cases it is not possible to test the design, after it has been made, by running the machine or station that may have been under consideration. It is a notable fact that, at Cornell University, where design classes were part of the college course some years ago, these courses have now been replaced by analytical courses, in which actual machines, the operation of which is known, are analysed and their performance predicted from the figures available for the material of which they are made. At the same time, a well-supervised drawing office, under the direction of a thoroughly-qualified teacher, is one of the most successful means of educating an engineer that can be devised, and the difficulties met with in practice in obtaining the desired results, are difficulties which are not inherent in the system, but are difficulties which could easily be overcome under proper conditions.

One of the most valuable uses to which a laboratory can be put is for research. This work should be regarded as one of the most important parts of the training of an engineer, because it teaches him better than anything else the art of deduction from experiment and the art of observation. The precision and accuracy necessary to investigate a new phenomenon is far greater than is required in the case of tests which are being repeated and of which the main results are known. It is difficult, in most laboratories, to carry on research work on a very large scale, but there is no reason why work done with small machines and small apparatus should not prove as valuable as that which has been carried out with larger plant.

In most cases it is the carrying out of the work that is of the greatest value, and not the result. A great many papers are published not, mainly, in engineering subjects, of very problematical value, but in so far as these represent an honest attempt at investigation in some subject they are good, though some question may, perhaps, be raised as to the advisability of publishing the result in extenso.

NOTE ON THE INVESTIGATION OF FRACTURES.*

BY F. ROGERS, D.ENG.

It is rarely possible to investigate systematically the cause of an unexpected fracture by known methods without rather long and laborious research. The consequence is that, more or less pardonably, this is made the excuse in the majority of cases of tests to destruction for not investigating at all. Since a large class of failures, including principally all faults which may be broadly classed as some form of segregation, and usually excluding heat treatment, is due to more or less localised fault, it is highly desirable that the fracture itself should be studied if possible. The general appearance and so-called "grain" of the fracture, and possibly any non-metallic inclusion, if not too minute, can easily be noted, but it is notorious that every attempt to obtain information about structure by applying the microscope directly to the fractured surface has failed.

A few methods have been suggested for obtaining a cross-section through the fracture, and examining this by means of the microscope. In Rosenhain's method,† copper is heavily deposited upon the fracture during about eight days. I have obtained good results without this delay by gently pressing a number of leaves of Dutch metal (imitation gold leaf) into contact with the fracture, and binding by means of a small steep clamp. Doubtless quite perfect results could be obtained by a combination of the two methods—*i.e.*, after depositing copper for a short time, perhaps three or four hours, in order to form a more perfect mechanical protection for the fracture, leaves of Dutch metal could be clamped against the copper.

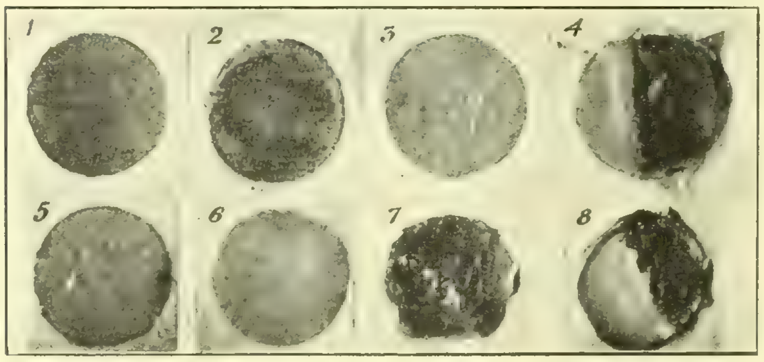


FIG. 1. BROMIDE PRINTS FROM CUT SECTIONS AND FRACTURES

Another useful method is to cast a fusible alloy, melting at about 100° C., against the fracture. This also usually requires the use of the clamp.

The drawback to such methods is that they are very laborious, giving little more than a mathematical line upon the actual fracture for each section taken, and there is always the possibility that the ultimate cause of weakness may not lie in one of the sections taken. Consequently, it occurred to me that, if even a comparatively rough chemical examination of the fractured surface could be made, as, for example, by a method of contact printing, it might be quite as valuable on the whole as the more elaborate microscopic methods; and whilst giving sufficient indication for many practical purposes as to the cause of failure, it might also in other cases be useful as a preliminary to the examination by the elaborate methods, thus indefinitely minimising labour spent upon trying to find the position of the fault which had caused the trouble.

After experiments in several directions, I have adopted a method which is virtually a modification of the well known method of obtaining a "sulphur print" from a cut surface. A piece of a specially prepared tissue, which consists of a gelatine emulsion of silver bromide, coated upon a very stiff tease clay, is soaked in a dilute acid solution containing also a toughening agent, and immediately pressed into contact with the clean fracture for a few seconds and withdrawn. The entire process occupies no more than a minute. Precise details are given in the Appendix.

In order to find whether it would be possible to interpret with certainty the meaning of such a print, it was desirable to determine what relation exists between a print from a fracture, and a print obtained by the ordinary method from a neighbouring cut section, and also to establish what nature of contrast was to be expected between an actually segregated region and an unsegregated region in the same fracture. On this account some prints are shown (see Fig. 1) for mutual comparison, which have been made upon cut sections and fractures by the special tissue, and upon cut sections and fractures by means of a standard make of bromide paper, which is frequently used in sulphur printing. Bromide paper was, in fact, one of the first means tried for printing from a fracture, and it was found necessary to press or hammer it into contact with the aid of the same stiff clay subsequently used for making the tissue. The effect of different durations of contact of the print with the metal is also shown. The reproductions are accompanied by an explanatory legend.

The first and most striking fact that was established was that the printing of a fracture proceeds at an astonishingly greater speed than the printing of a neighbouring cut surface. This is shown by a comparison of No. 4 (fracture) with No. 3 (cut), Fig. 1. In these the depth of printing has been restricted by using very dilute acid and brief duration of contact. A print from a fracture made with the same concentration of acid and duration of contact as either Nos. 1, 2, or 5 (Fig. 1), which approximate to the ordinary method of sulphur printing from cut surfaces, would show only an unrecognisable black smudge. If one may, for argument's sake, assume—what is not necessarily strictly accurate—that the proportion of sulphur indicated is inversely proportional to the duration of contact and concentration of acid necessary to give a print of a definite depth of colour, then it appears that the percentage of sulphur indicated by a print from a fracture is of the order of one hundred times as great as that indicated by a print from a neighbouring cut section. This cannot mean anything else, I think, than that the fracture has picked its way through the minute sulphide specks with correspondingly great preference. This would not be surprising if we were dealing with an alloy containing, say, 0·4 per cent. of sulphur, in which the manganese sulphide would be expected to form a network. In steels containing less than 0·04 per cent. of sulphur, we are well aware that the sulphide rarely exists as a partial network, but almost solely as minute isolated lens-shaped particles, lying in the direction of the length of the forging or of rolling.

It is interesting in this connection to recall that at a meeting of the Sheffield Society of Metallurgists and Engineers in January last, Dr. Stead showed a photomicrograph of a sulphide area in a piece of steel which, after polishing, had been bent in a plane at right angles to the surface photographed. An incipient crack was seen to have travelled through the little area of manganese sulphide, and to be making its way into the metal at each of its ends.

It may conceivably be argued that the relatively rough preparation of the cut samples for printing has, by causing a certain amount of "flow" of the surface of the metal to cover and so protect the sulphide, been in part responsible for the great difference between cut surfaces and fractures respectively. This is not so, however, for a piece of steel gives much the same depth of colour, whether printed as roughly cut off, or after smooth filing, or after polishing on emery papers, or after polishing as for careful microscopic examination. Further, much protection is hardly to be expected, as the acid would probably soon dissolve away any possible thin film of metal; and in any event, unless a sulphide speck were thoroughly covered, it would not be effectually protected from the action of the acid. The great difference between a print from a fracture and a print from a neighbouring cut surface seems to be independent of the mode of fracture; it is found to be of the same kind, whether the fracture was caused by tensile stress, slow bending, repeated severe bending, or shock. It is also of the same sort in steels ranging from dead mild up to 1·3 per cent. carbon tool steel.

It seems to me that the extraordinary degree of selection of a path through the specks of manganese sulphide as the line of least resistance to fracture strongly confirms the desirability of keeping sulphur low, if any confirmation be needed. No known method of treatment will bring the sulphur into a less harmful form than the usual little longitudinally

* Abstract of paper read before the Iron and Steel Institute, May 1912.
† Journal of the Iron and Steel Institute, 1906, No. II, p. 189.

arranged rods of manganese sulphide. Hence the inherent unsoundness of the remark one sometimes hears, to the effect that "0·05 per cent. of sulphur would be equally safe" in steels which now usually contain under, say, 0·035 per cent., apart from the absence of any margin of safety for local variations from the analysis taken in the usual position.

It is quite probable that the path of least resistance also follows, in a similar manner, the minute high phosphorus regions, so far as is compatible with the difference in the

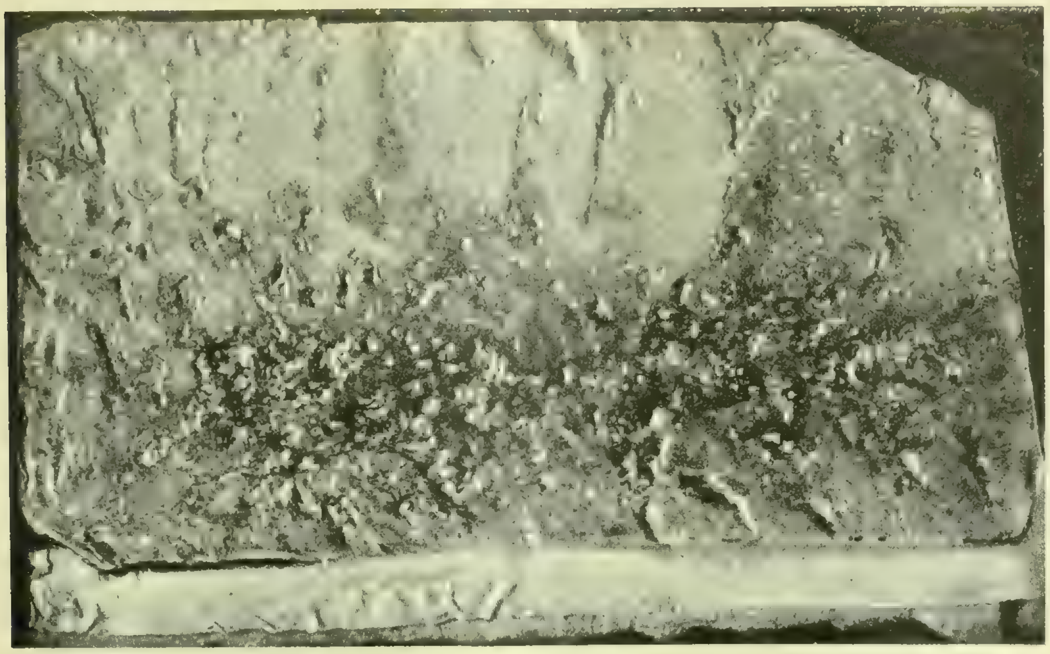


FIG. 2. PRINT FROM PART OF FRACTURE OF A STEEL TYRE.

forms in which phosphorus and sulphur are known to occur in steel. Perhaps a printing method could be devised to establish this, but it was considered that a sulphur method would be quite sufficient for most practical applications, and on the whole preferable to a phosphorus method as an index of segregation.

The present expression of opinion that the selection of the path of fracture is largely biased to the actual sulphur and phosphorus bearing areas, is by no means inconsistent with the view that fracture in low to medium carbon steels, under repeated alternations of stress, tends to prefer a path through ferrite, which has been confirmed by others for different kinds of stress. Not only has pure, well crystallised ferrite a peculiar weakness of its own under dynamic stress, but in steels which contain ferrite, the tendency for the sulphur and phosphorus to be associated geographically with the ferrite is well understood.

There seems to be no doubt that the method of printing from a fracture here described, although, as may be expected, rather a rough-and-ready than a pretty test, can, with a little care and practice in its use, be relied upon to indicate a segregated area in a fracture. There are slight variations in the depth of colour in the print, due to the differences in contact pressure over the various irregularities of the surface. One soon learns how to allow for these by observing the shape of the surface, which is also shown in its impression in the tissue.

Some examples of prints from fractures are given in Figs. 2 and 3, and the position of the segregation, if any, is indicated. It should be borne in mind that part of the variation of depth of colour in the reproductions at places where no segregation is indicated is due to the light and shade effect, caused by the fact that the print is also an impression of the fracture.

Fig. 2 shows a print on the special tissue taken from a part of the fracture of a high-class steel tyre. The position of the bore is shown, and it is seen that a satisfactory print has been obtained along the full length of the bore, and extending about an inch and a half inwards from the bore. This is more than is ordinarily likely to be necessary for this class of tyre. This fracture, which was deliberately made for the purpose of printing, shows no signs of segregation.

Fig. 3 represents a print upon the special tissue taken from a rail in a position as near as was convenient to the topmost portion of the ingot used. In spite of this, no marked segregation is shown. The print is merely a trifle darker, generally towards the web of the rail. In this case, the head, web, and base were printed on three separate portions of tissue, and subsequently pieced together. The lighter areas in the base were caused by allowing some splashes of the acid solution to fall on this portion whilst printing from the web.

In conclusion, it is hoped that the rough-and-ready method of printing from a fracture here brought forward, will be found useful whenever unexpected results are obtained in tests to destruction, such as in falling weight tests of rails, tyres, or axles, in tensile tests of all kinds of material, and bending tests of plates. It is probably the simplest and quickest method of investigating a fracture at present available, and should show instantly whether breakage has been assisted by segration or not. With obviously necessary precautions, there is no reason why the method might not be applied to a fracture which has occurred in service.

APPENDIX.

DETAILS OF PREPARATION AND USE OF THE TISSUE.

It is hoped that it will soon be possible to purchase the tissue prepared ready for use. In the meantime, the following details will enable any one to prepare a supply which can be stocked for use as required.

Clay.—Melt together 1lb. of vaseline and one ordinary wax candle. The minimum possible quantity of the mixture that will give a stiff cohering clay is incorporated with finely

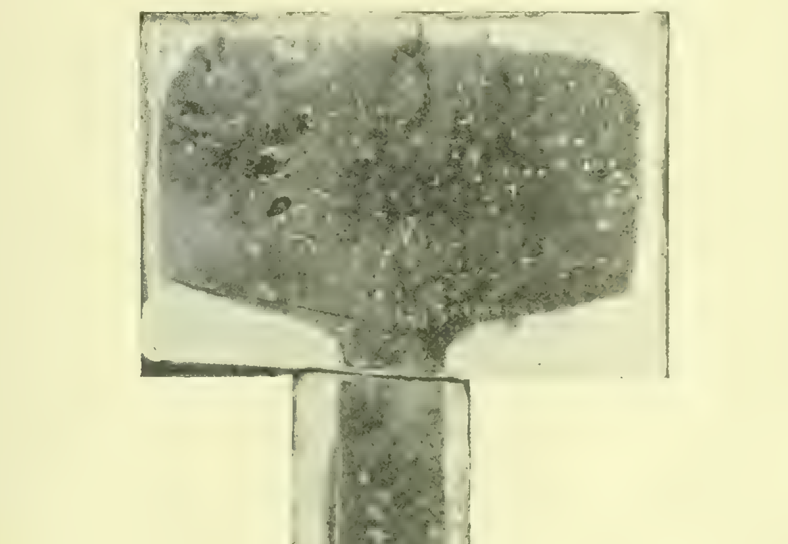


FIG. 3. PRINT FROM FRACTURE OF A STEEL RAIL.

ground and dried whiting. This is rolled into sheets about $\frac{1}{16}$in. thick. Plasticene is too soft for the purpose, and its colour is against it, but it will answer if stiffened by the addition of whiting.

Silver Bromide Emulsion.—Digest the following together at about 43° C.: —

Water	150 cubic centimetres.
Gelatine	15 grammes.
10 per cent. hydrochloric acid ...	3 cubic centimetres.
Potassium bromide	8·4 grammes.

Then add the following solution, also heated to 43° C.: —

Water	50 cubic centimetres.
Silver nitrate	10 grammes.

The whole is digested at about 43° C. for about a quarter of an hour. Chill rapidly to set, cut up, wash in a jelly-bag for two hours, re-melt, add a further 15 grammes of gelatine, and the emulsion is ready to be coated upon its support. It can be stored by allowing it to set, and putting a little carbolic acid in alcohol upon the surface.

Coating.—Warm a sheet of the clay, sprinkle finely powdered calcium sulphate upon it, rub lightly until greasiness is removed, dust off the excess of calcium sulphate. Immediately pour a little of the melted emulsion on, and spread with a glass rod and by tilting the sheet about. Leave in a horizontal position to dry.

To take a Print from a Fracture. Soak the tissue for 20 to 30 seconds in—

Water	100 cubic centimetres.
Sulphuric acid	1 cubic centimetre.
Alum	5 grammes.

See that the surface of the gelatine is well wetted by the solution, which is assisted by gently stroking with the finger, then instantly apply and press into contact by means of the fingers. Withdraw the print in about twelve seconds, or rather longer in the case of exceptionally pure steels. Chiefly on account of the difficulty of keeping the whole of the tissue satisfactorily wetted, it is on the whole best, in the case of large and very irregular fractures, to print the surface in several overlapping portions. It is quite easy to print a very irregular fracture in pieces about 3in. by 2in., whilst with a fairly regular surface, 5in. by 3in. gives no trouble.

Fixing.—This can be done as usual for a print, in hypo., but, owing to the risk of stripping the gelatine from the clay, is best omitted. It is sufficient to rinse the print gently, and allow to dry at once.

Description of Fig. 1.

Number	Printed upon.	Sulphuric Acid, per cent	Duration of Contact, Minutes.	Surface.
1	Bromide paper	1	5	Cut.
2	..	5	1	Cut.
3	..	1	½	Cut.
4	..	1	½	Fractured.
5	Tissue	1	5	Cut.
6	..	1	½	Cut.
7	..	1	½	Fractured.
8	..	1	½	Half fractured, half cut.

Much depends on keeping both the solution and the steel cool; the temperatures should not exceed about 20° C. A little practice is necessary in order to know how much pressure to use. It is worth remembering that there are usually two fractured surfaces to each fracture.

THE GENERATION OF ELECTRICITY BY CARBON AT HIGH TEMPERATURES.

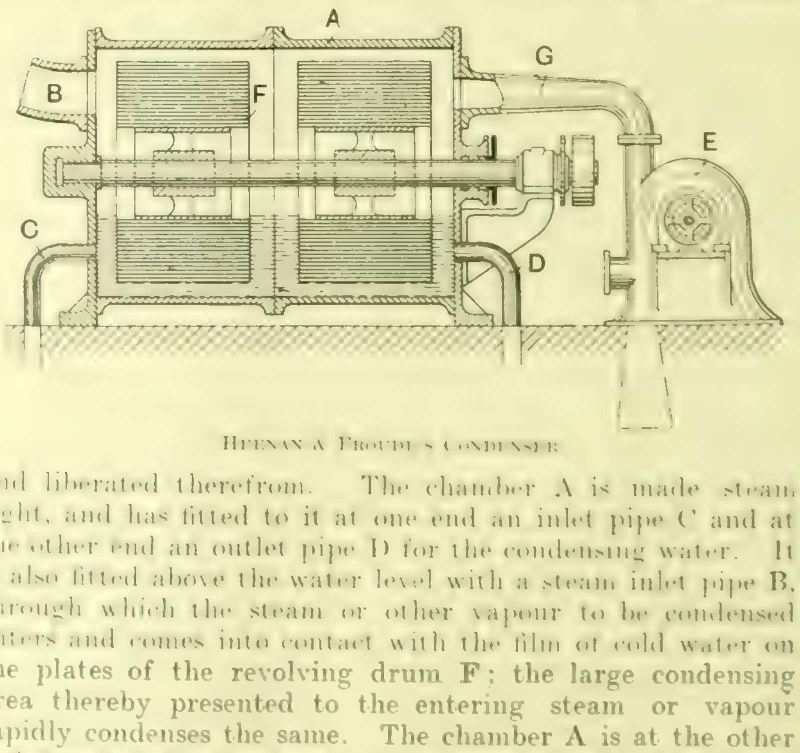
At a recent meeting of the Physical Society of London, a paper on "The Generation of Electricity by Carbon at High Temperatures," by Dr. J. A. Harker, F.R.S., and Dr. G. W. C. Kaye, was read by Dr. Harker. The experiments described owe their origin to some contamination phenomena which were encountered when tubes of refractory rare earths were baked in carbon-tube resistance furnaces at temperatures from 1,500° C. upwards. It was found that the tubes often had their outer surfaces carbonised to an appreciable depth, while the inner surfaces, though freely exposed, were much less attacked. The blackening was presumably caused by particles shot from the carbon walls of the furnace with velocity high enough to penetrate the refractory material after crossing a few millimetres of air at atmospheric pressure.

The preliminary experiments on the nature of these particles were carried out by the use of two insulated exploring electrodes of carbon inserted into an alternating-current furnace. They were connected externally to a battery of cells and the potential-current curves were determined for the electrode gap in the furnace at a number of temperatures. No appreciable current could be detected at temperatures below about 1,400° C., but as the temperature rose it was found that quite small electromotive forces gave rise to steady currents of relatively enormous magnitude. For example, with 8 volts, currents up to 10 amperes have been obtained at a temperature of about 2,500° C. The relation between current and temperature was found to be of an exponential character. The magnitude of the currents made it evident that the atmosphere of the furnace was ionised to an unusual degree at high temperatures, and the authors were led to try the effect of temperature alone in the absence of any applied potential. Accordingly the battery was cut out, and while one of the electrodes remained stationary within the furnace the other could be suddenly displaced to a colder or hotter part of the furnace. The resulting difference of temperature manifested itself as a transient current in the circuit, which in some cases amounted to 2 amperes. The current died away when the two electrodes attained the same temperature.

In the apparatus shown the movable electrode was moved in and out of the hot region of the furnace by means of a clockwork mechanism. The pulsating electric current thus produced was large enough at high furnace temperatures to light up a nest of small glow lamps, the illumination waxing and waning as the movable electrode moved in and out. The experiment has been modified in later work by keeping both electrodes stationary and water cooling one of them. The cold electrode was made up of a brass tube, which in some cases was provided with a carbon sleeve. A continuous current can thus be generated. Its direction is such as would be produced by a discharge of negative particles from the hot electrode. As before, no potential is applied. At the lower temperatures small positive currents have also been detected; at high temperatures negative currents up to nearly an ampere have been measured. The whole of the experiments were conducted at atmospheric pressure and almost entirely with low-voltage alternating-current furnaces.

HEENAN & FROUDE'S CONDENSER.

The accompanying sectional view shows a design of condenser for steam or other vapour, the invention of Messrs. Heenan and Froude, Ltd., 4, Chapel Walks, Manchester, Mr. James Bliss, and Mr. A. B. Cleworth. The condenser comprises a rotary apparatus with spiral or concentric plate in combination with a suction pump to form a partial vacuum in the drum casing and draw off any air introduced by the steam



HEENAN & FROUDE'S CONDENSER.

and liberated therefrom. The chamber A is made steam tight, and has fitted to it at one end an inlet pipe C and at the other end an outlet pipe D for the condensing water. It is also fitted above the water level with a steam inlet pipe B, through which the steam or other vapour to be condensed enters and comes into contact with the film of cold water on the plates of the revolving drum F; the large condensing area thereby presented to the entering steam or vapour rapidly condenses the same. The chamber A is at the other end fitted with an exhaust pipe G connected as shown with a suction pump E, which is capable of maintaining a considerable degree of vacuum, for example, up to 6lbs. or 7lbs., in the chamber, and draws off any air introduced by the steam or liberated therefrom.

BITUMINOUS COAL PRODUCERS FOR POWER.*

BY C. M. GARLAND.

IN the development of the power producer for the gasification of fuels containing above 12 per cent. volatile matter, the manufacturers at an early date divided themselves on the question of the method of handling this troublesome constituent, and proceeded with their developments along two diverging lines. In one they sought to convert the condensible combustible constituent of the volatile matter into fixed combustible gases by drawing this product through either the whole or part of the incandescent fuel remaining after volatilisation; in the other to separate the condensible portion from the permanent gases after these had left the generating chamber. The former group accordingly turned their energies to the development of down-draught and double-zone arrangements, while the latter bent their efforts towards the production of efficient up-draught generators and tar-handling apparatus. It has been the fortune of the writer to observe the operation of a number of plants of the latter type, and to analyse the results of the operation of others. It is the object of this paper to present some of the data accumulated, which are necessarily more or less fragmentary in character.

Description of Apparatus.—The plants are all of two general types, suction and pressure, while the apparatus is essentially similar in each, varying principally in size and general arrangement. Fig. 1 shows a vertical section through the producer, scrubber, and the water-sealed gas main which is characteristic of the arrangement of all later plants up to about 1,000 h.p. capacity. The pressure plant differs from the suction plant by the addition of a fan-type blower, frequently installed in duplicate, and a regulating holder. This latter in the earlier plants served as a large storage reservoir, with capacity sufficient to keep the engines operating from 3 to 10 minutes in cases of emergency. It was also thought that this large capacity tended to ensure greater uniformity in the composition of the gas supplied to the engines, so that the holders were placed in series with the engine and scrubbers. In more recent plants the size of the holder has been greatly reduced, and in most cases floats on the line so that the gases do not pass through this piece of apparatus. This change has been brought about partly by the fact that a large storage capacity is not required and in many places is undesirable. Also the mixing effect of the gases in the holder has proved a fallacy. From Fig. 1 it will be noted that the producer A is of the water-sealed type, with central blast B, and superimposed vaporiser C. The gases pass direct from the producer to the scrubber D, which is provided with a vertical baffle E from the scrubber to the water-sealed main F, and from this to the tar extractor G. This latter piece of apparatus is of the centrifugal type, and is illustrated in Fig. 2. The extractor has been in use a number of years, and was brought out by Mr. F. V. Matton, of the Camden Ironworks.

Referring to Fig. 2, the gas enters at A and meets a stream of water at B. The mixture flows upon the rotating vanes C, and is discharged into the stationary vanes D. The water and a portion of the tar is thrown out against the casing E, and follows this around to the drain F, which discharges into the seal pit G. The gas leaving the stationary vanes D re-enters the rotating vanes H on the opposite side of the disc I. The gas here meets a stream of water from the nozzle J, moving in the direction opposite to the gas which removes the remaining tar. The gas leaves at K. The extractors are usually designed to deliver the gas under a low pressure, and are built in more than one stage for the larger powers.

A portion of the steam generated in the superimposed vaporiser C in Fig. 1 is used to saturate the blast. The amount supplied is indicated by the temperature shown on the thermometer H, which extends into the blast pipe I. The steam pressure on the vaporiser is maintained constant by the back pressure valve J, while the air pressure on the main K is also constant. The valve L is therefore used to vary the amount of steam delivered to the blast. The butterfly valve M connects with the holder, and regulates the amount of blast delivered to the producer. Changes in the position of this valve do not affect the relative proportions of air and steam. In more recent plants a thermostat located in the blast pipe operates a throttle valve in the steam line from the vaporiser in order to maintain a constant temperature of the blast.

The fuel is fed to the producer by the hand-operated centrifugal charging device N, which ensures a very even distribution of fuel. This consists of the hopper provided with the ribbed charging bell O, which is rigidly mounted on the shaft P and held against its seat by the counterweight Q. When the fuel is charged the bell is lowered by the arm R, and at the same time rotated by the arm S. Both arms are hand operated. After the fuel is charged, the counterweight Q causes the bell O to seat. A sliding cover closes the top of the hopper, which prevents the escape of gas while dropping a charge of fuel.

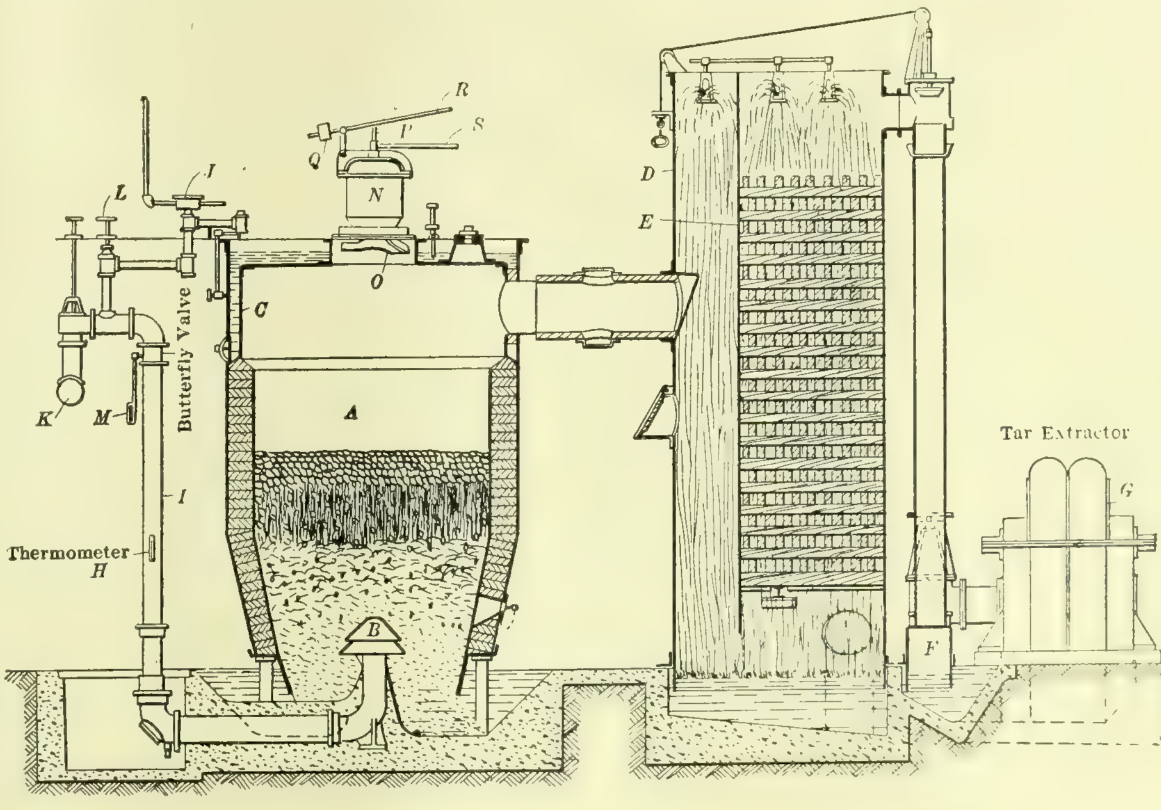


FIG. 1.—SECTION OF GAS PRODUCER PLANT.

With this brief general description it will not be necessary to describe a number of individual plants. In order, however, to indicate the extent and variety of the work, Table I. giving the equipment, service, load conditions, &c., has been prepared from a number of representative plants operating on different fuels.

Thermal Efficiency of the Producer.—The efficiency depends to a certain extent upon the amount of volatile matter contained in the fuel. For fuels containing as high as 30 to 50 per cent. of volatile matter, the thermal efficiency based on the higher heating value of the gas is about 66 per cent., while the efficiency based on the effective heating value of the gas is ordinarily 5 per cent. lower than this, or 62·7 per cent. Where the volatile matter does not exceed 20 per cent. the efficiency is somewhat higher, and 70 per cent. based on the higher heating value of the gas is an average figure. The lower value is approximately 66·5 per cent. In plants of the

* Abstract of paper read before the American Society of Mechanical Engineers.

present type, however, thermal efficiency is not necessarily of paramount importance, for more often it is a question of the adaptability of the producer to a given fuel or to several fuels, and of continuity and reliability of operation.

Composition of the Gas.—The composition of the gas and the heating value are comparatively uniform where proper attention is given to the operation of the producers. Table II. shows the gas analyses taken on a seven day test, which was made on the plant marked C in Table I. The calorific values by the calorimeter, taken every two hours, are plotted in Fig. 3. The average higher heating value of the gas was 144·1 B.T.U. per cubic foot at 62° Fah. and 30in. mercury pressure. The average lower heating value was approximately 136 B.T.U. under the same conditions of pressure and temperature. For fuels containing greater percentages of volatile matter there is a tendency towards an increase in the calorific value of the gas due to the increase in hydrocarbons. With the lignites, for example, the higher heating value of the gas may average as much as 155 B.T.U. per cubic foot.

TABLE I.—*Bituminous Coal and Lignite Plants.*

Plant	A	B	C	D	E	F	G
Type of plant	Suction	Suction	Pressure	Pressure	Suction	Suction	Pressure
No. of producers	1	1	3	2	2	1	2
No. of tar extractors	1	1	2	2	1	1	2
Inside diameter of producers, ft.	7	6	8	6	7	5	7
Spare producers	0	0	1	1	0	0	0
Spare tar extractors	0	0	1	1	0	0	1
Size of holder, cu. ft.	—	–	5,000	5,000		–	15,000
Rated capacity of plant, b.h.p.	225	140	900	190	500	125	500
Character of service	Light and power	Light and power	Light and power	Light and power	Mill	Pumping	Light and power gas for heating
Years plant in operation	2	2½	1½	6½	3	2	5
Hours per day in operation	11	18–24	24		10–24	10–24	24
Days per week in operation	6	6½	6½		6½	6½–7	6
Load factor, per cent.	About 100	–	Variable	–	Variable	About 100	About 100
Character of load	Uniform	Variable	Variable	Variable	Variable	Uniform	Uniform
Fuel used	Illinois coal	*Various	Pocahontas	Pocahontas	Lignite	Lignite	Pocahontas New River.
Proximate analysis fuel:							
Fixed carbon, per cent.	55·30	32·10	73·70	71·40	16·4	29·39	
Volatile, per cent.	35·47	47·00	17·7	21·70	51·2	39·84	
Moisture, per cent.	3·00	3·90	1·6	2·20	25·7	23·11	—
Ash, per cent.	6·23	17·00	7·0	4·70	6·7	6·78	
B.T.U. per lb.	13,500	11,000	14,700	14,700	8,500	—	14,700

* Texas bituminous coal used when determining solid matter in the gas.

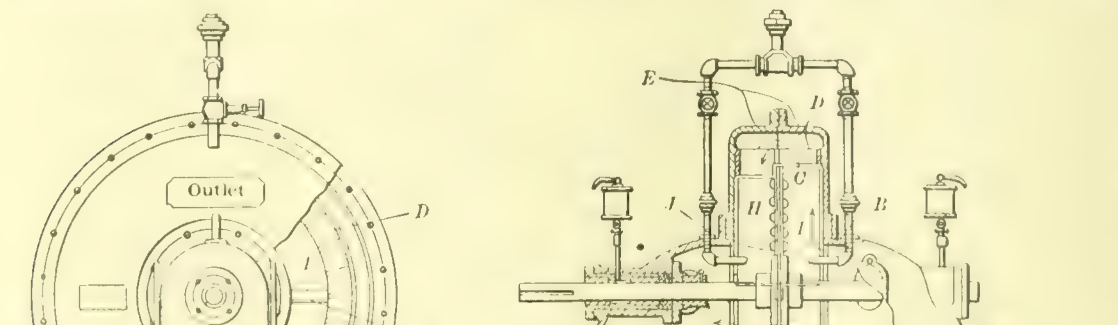


FIG. 2.—175 H.P. TAR EXTRACTOR.

Volume of Gas Generated.—The volume of gas generated per pound of coal depends upon the composition of the coal and the condition of the fuel bed. In the seven-day test (Table II.), the volume of the standard gas generated per pound of run of mine Pocahontas coal was approximately 71·5 cub. ft. For lignite the volume of standard gas varies between 36 and 40 cub. ft. per pound.

Cleanliness of the Gas.—A large number of tests have been made on the cleanliness of the gas delivered by the tar extractors in the above plants. The results of these determinations are given in Table III. From these it will be seen that the amount of solid matter in the gas has been reduced to a very small quantity, and averages 0·0206 grains per cubic foot of standard gas. The efficiency of the tar extractor is given also in several cases. This was taken as the ratio of the weight of solid matter in the gas leaving the extractor, to the weight of solid matter in the gas entering the extractor, multiplied by 100. The determinations were made by drawing samples of the gas through three thicknesses of filter paper, on which the solid matter was deposited. In most cases simultaneous samples were taken from the entering and exit sides of the extractor. These samples were measured by calibrated meters.

It will be seen from the results of Table III. that the average weight of solid matter per cubic foot of standard gas is not sufficient to cause trouble in engines of ordinarily good design. Experience seems to indicate that with 0·03 grains of solid matter per cubic foot in the gas, the engine valves require cleaning once in two or three weeks. There is no trouble from this source in plants that are properly operated, and the cleaning of the valves would not be considered a hardship.

In making the above determinations, no attempt was made to separate the tar from the dust, as this was not deemed of sufficient importance.

Handling of the Tar.—In the earlier plants considerable difficulty was experienced by the tar accumulating in the scrubbers and pipe lines, which caused frequent shutdowns. In almost every case this trouble was due to lack of experience on the part of the builders in designing these parts, and to the operators who failed to take proper precautions and profit by their first troubles. At the present time and for the more modern plants it can be safely said that trouble from this cause has almost entirely ceased. The water sealed gas main has solved the piping difficulty, while refinement in the design of the other parts and close attention to detail has accomplished the same effect for these.

In so far as the yield of tar is concerned, there are but three objections that can be urged against this (1) Loss in

efficiency of the plant due to the removal of a combustible constituent from the fuel; (2) the expenditure of power in the driving of the tar extractor for the removal of this constituent; (3) difficulties in the disposal of the constituent.

Taking it for granted that the tar in every instance can be disposed of satisfactorily, as it can be, the answer to these objections is that it is entirely a question of economy, and if it does not pay to handle this element then bituminous coal is either not the fuel to use, or a producer plant is not the kind suitable to the conditions.

TABLE II.—*Gas Analyses, Seven-day Test. Plant C.*

Day	CO_2	O_2	CO	H_2	CH_4	Day	CO_2	O_2	CO	H_2	CH_4
1st*	5·6	0·2	24·1	7·65	4·5	4th	5·0	0·4	23·6	10·80	2·3
	4·0	0·2	27·6	9·83	3·3		4·0	0·2	25·4	10·52	3·3
	6·8	0·4	22·6	10·36	2·0		4·6	0·2	24·2	9·60	3·3
	5·8	0·2	23·6	13·80	2·4		4·2	0·4	25·1	11·70	2·6
							4·7	0·0	25·8	12·00	2·6
							6·0	0·3	20·8	10·53	2·1
2nd	8·2	0·3	17·5	11·30	3·4	5th	3·5	0·2	25·5	9·50	2·6
	5·2	1·2	21·8	14·00	2·5						
	4·5	0·2	25·9	13·40	2·2	6th	4·2	0·2	24·7	9·15	3·5
	4·8	0·2	25·5	11·60	2·4		5·0	0·3	24·7	9·40	3·8
	4·6	0·4	26·3	10·60	2·4						
	7·9	0·7	18·7	12·43	3·0	7th	5·0	0·2	24·2	9·15	3·4
	5·4	0·3	24·5	8·50	2·2		4·9	0·3	24·8	11·03	2·0
	7·2	0·2	19·6	10·53	3·6		4·4	0·3	25·7	12·00	2·6
	7·3	0·1	20·1	10·30	2·9		4·9	0·3	25·0	12·00	2·0
							5·3	0·4	25·3	10·80	2·0
3rd	7·8	0·4	18·8	10·90	3·8		4·5	0·3	25·6	9·80	2·2
	5·2	0·4	24·0	11·40	2·6						
	5·5	0·2	22·5	8·93	3·4	8th*	4·0	0·2	26·0	9·25	2·4
	5·5	0·2	22·5	8·93	3·4		5·5	0·3	24·3	11·45	2·0
	5·2	0·4	23·6	9·50	2·9		5·0	0·3	24·3	11·53	2·0

* One-half day only.

The magnitude of the above items is fairly well known. The loss in thermal efficiency (1) varies from 12 per cent. for fuels containing from 15 to 20 per cent. volatile matter to 17 per cent. for fuels containing above or near 30 per cent. of volatile matter. The amount of power (2) required to drive the tar extractor depends upon the nature of the tar produced. With lignites, for example, which produce a thin yellowish tar resembling very nearly a heavy oil, the power required is at least 25 per cent. less than the amount required for bituminous coals. For bituminous coals this power varies from 5 per cent. of the power of the plant in a plant of 100 b.h.p. to about 3·5 per cent. for a plant of 1,000 b.h.p., and it is believed that this figure will be reduced almost one-half in the near future. As to the difficulties in the disposal of the tar (3), there is in some instances a ready market for the tar product, so that this may be disposed of to advantage. In other cases where boilers are in service, it can be burned without difficulty under these boilers.

TABLE III.—*Tests on Cleanliness of Gas delivered by Tar Extractors.*

Plant	No. of Determinations	Fuel.	Per cent. Volatile.	Grains, solid matter cu. ft.	Efficiency Extractor per cent.
A	1	Illinois coal	31·0	0·0150	96·0
B	2	Texas Bituminous ..	47·0	0·0062	99·5
C	11	Pocahontas	17·7	0·0163	98·5
D	1	Pocahontas	21·7	0·0585	93·5*
E	2	Texas Lignite	51·2	0·0050	99·5
F	2	Pocahontas	22·8	0·0227	—

* Tar extractors operated at 1,000 r.p.m., instead of 1,500 r.p.m. rated speed Dry scrubber used beyond tar extractors in this plant; solid matter in gas leaving dry scrubber 0·0421 grains per cubic foot.

The usual method of handling the tar is to place the extractor over a pit containing water into which the mixture of tar and water from the extractor is discharged. The pit is arranged so that the tar may be skimmed from this into a barrel or receiver. Where a receiver is used it is provided with an airtight cover, and when the receiver is filled the cover is put in place and either steam or air under pressure placed above the tar, which forces it through piping to the point of disposal. Where the tar is thick and heavy, it is necessary to provide the receiver with a steam coil to keep the tar in a fluid condition.

The Fuel Required.—It can almost be safely said that any fuel can be used in any well-designed producer of the up draught type. If the fuel cannot be used the probabilities are that the fault is either in the operation or in the design of the producer. The reason for this is that there are but three fundamental requirements for the successful gasification of a fuel. These are, uniform distribution of the blast, uniform distribution of the green fuel, and uniform removal of ash. These three are essentially one, as they are so closely related and interdependent that they reduce to uniform distribution of the blast. When these requirements have been met in the design of the producer, the writer has never found a fuel that could not be gasified, at much higher rates and with much less labour than is considered possible by the majority of engineers.

An example in which the difficulty lies in the operation of the producer is illustrated in the case of the Texas bituminous coal, Plant B, Table I. This was a highly caking coal, and the operators of the producer stated that it was impossible to use this fuel in the producer. After observing the operation for a few hours it was found that the difficulty

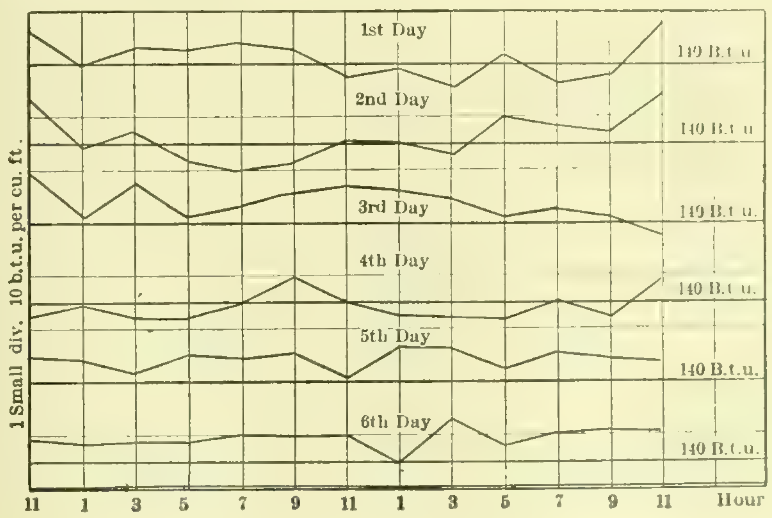


FIG. 3.—HEATING VALUE (HIGHER) OF GAS FOR 144 HOURS CONTINUOUS RUN. PLANT C.

was due to the caking properties. When full hoppers of fuel were dropped upon the hot bed the fuel fused into a solid mass through which the blast could not penetrate. By charging a half hopper of fuel every 15 minutes in place of a full hopper every 30 minutes, there was no further difficulty. The analyses of Table I. indicate the variety of fuels that are being used successfully.

Reliability.—Referring to Table I., from the last reports obtained about one year ago, Plant D had been in successful operation for over five years without a shutdown and without having the fire drawn from the producers. The last reports from Plant A indicated highly satisfactory results and no shutdowns, the engine pulling full load and a large portion of the time as much as 15 per cent. overload. Fig. 3 shows the heating value of the gas taken every second hour for 144 hours continuous running, while Table II. shows the analyses of the gases taken over the same period from Plant C, Table I. Two 8ft. producers were in operation for the full period. The engines pulled an average load of 568 kw. with a maximum of 640 kw. for one hour, and a minimum of 405 kw. for one hour. The coal consumption was 1·78lbs. per kilowatt hour at the generator terminals, including a 24-hour stand-by, and the rate of gasification was about 10lbs. of coal per square foot of fuel bed per hour. The fuel used was Pocahontas run of mine.

Plant F is used for irrigation work where the load is intermittent. At times it operated at full load 24 hours per day, and at other times only 10 hours per day. Results have been entirely satisfactory. The same is true of E, which operates a cotton meal mill. This is one of the most successful

lignite plants. The latest reports state that lignite screenings, costing less than 50 cents per ton, are being used successfully.

Plant G showed a fuel consumption of 1·65lbs. of coal at full load per kilowatt-hour at the generator terminals, 1·89lbs. at three-quarter load, and 2·2lbs. at one-half load, when operating on Pocahontas coal. On New River slack the coal per kilowatt-hour is approximately 1·6lbs. at about full load.

Plant B was reported unsatisfactory. It was found on investigation that for two years the plant had been operated from 18 to 24 hours per day, and the station logs showed that the engine had pulled a 25 per cent. overload for about two hours during the peak every evening. Any fuel that could be picked up in the open market was used, and the man that operated the producers also fired two boilers for running about 400 h.p. in high-speed steam engines.

Producer Plant Costs.—The cost of producer plants and of operating are by no means fixed quantities, so that it is very difficult to give figures that are general and that can be safely applied to any and every case. Each plant requires individual consideration in order that no mistakes or misunderstandings may arise. The first cost depends upon (*a*) the service or load conditions, that is, continuous, intermittent, or variable load, and the magnitude of the load. These determine the necessity for duplicate or spare apparatus, and the number of units into which the plant should be divided. (*b*) Upon the design of the producer. With a given fuel one type of producer may gasify 50 per cent. more fuel than another type, or one type may be capable of continuous operation, while still another may require a light load during the period of the removal of ash. (*c*) Upon the method of generating steam for the blast. That is, whether or not the producer generates its own steam supply or requires that this should be generated in separately-fired boilers, either direct fired or exhaust fired. Where the producer generates its own steam supply the first cost of the producer plant is, as a rule, much less expensive than the installation of either direct or exhaust-fired boilers. (*d*) Upon the characteristics of the fuel. One fuel may be gasified at a much higher rate than another, thus reducing the size of the producers required. (*e*) Upon the percentage of ash. With low percentage a plain water-sealed producer is satisfactory. With percentages above 12 or 15 per cent. a rotating table and cone bottom become desirable in order to reduce the labour costs. (*f*) Upon the scrubbing apparatus required. This depends upon the amount of volatile matter in the coal, and the characteristic of the products resulting from the volatile matter which appear in the gas. (*g*) Upon the method of handling the coal. (*h*) Upon local conditions.

The operating costs are very intimately connected with the first cost, and depend upon (*a*) the character of the fuel. Some fuels require a greater amount of labour than others. (*b*) The design of the producer. A properly-designed producer will require much less labour than a poorly-designed producer when operating on a given fuel at a given rate of gasification. In some instances small changes in the arrangement of the admission of the blast to the producer have reduced the labour required to operate at least 50 per cent. (*c*) The amount of ash contained in the fuel. (*d*) The coal-handling machinery. (*e*) Facilities for handling the tar. (*f*) Supervision. In every instance where the plant is under the direction of a man that understands the apparatus, and has given his thought to the operation, the operating costs are greatly reduced. (*g*) Local conditions.

Each producer should be of the water-sealed type for continuous operation since the fuel is a bituminous coal of medium grade containing a fair amount of ash. The steam for the blast may be obtained by the use of a superimposed vaporiser, a vaporiser placed between the producer and the scrubber, an exhaust boiler or an independently fired boiler. The latter is very uneconomical and has a high initial cost, so that it is not used in power work at the present time. The exhaust boiler is economical provided there is no other use for the steam that may be thus generated. The first cost is, however, high, and as in many cases it must be located at a distance from the producers and requires more or less attention, its use in plants of this size and for this purpose is hardly justifiable.

The vaporiser or boiler between the producer and scrubber, while an excellent arrangement for anthracite plants, is unsuitable for bituminous coal plants on account of the solid matter that is carried in the gas. The superimposed vaporiser therefore remains as the last choice. This is low in first cost, and while it absorbs a certain amount of radiant heat from the fuel bed, which could otherwise be utilised, it is convenient, requires little or no attention and essentially no repairs, so that for small and medium-sized bituminous plants it is the most economical method of generating steam for the producers, and will therefore be selected.

To each producer a static scrubber will be connected, as shown in Fig. 1. These scrubbers will in turn connect to a water-sealed gas main. Since the plant is to operate continuously, two tar extractors and two fan blowers will be required, one of each for a spare. The tar extractors and fan blowers should be driven by electric motors direct connected: 35 h.p. or 40 h.p. motors will be required by the former, while 5 h.p. or 7½ h.p. motors will be required for the latter. The coal-handling apparatus will consist of a 30-ton coal bin located above the second producer with spouts to the coal hoppers of each producer. A track bin will be located near the producer house, and an elevator used for delivering the coal from the track bin to the 30-ton coal bin above the producers.

The ash removed from the water seals of the producer will be loaded into a small car, which may be hoisted into either a railroad car or ash wagon by means of a block and tackle or an air lift. The building will be of steel frame construction with corrugated iron sides. A charging platform will be built around the producers.

Future Developments.—Plants of the type described have proved reliable and economical in practically every case. Particularly is this true for plants operating on poor fuels, like the lignites, and plants operating on high priced fuels. The economy obtained depends, however, to a large extent upon the intelligence displayed in the operation and in the design of the plant.

The future for these plants is also promising, as more economical results are now recognised as attainable, through the following improvements which reduce the first cost of the plant and also the operating costs: (*a*) Increase in the rate of gasification; (*b*) decrease in the power required to drive the cleaning apparatus; (*c*) utilisation of waste heat. Increase in the rate of gasification has been made possible by a careful study of the effect of the distribution of the blast on the operation of the producer.

A number of years ago the writer demonstrated on a small anthracite producer in the mechanical engineering laboratory of the University of Illinois that certain fuels could be gasified at rates as high as 40lbs. per square foot of fuel bed per hour without difficulty. The results of one of these tests were presented to the Society at the annual meeting in 1909.* Later, while operating on lignite in Texas which produced a very fine ash and caused considerable trouble in the ordinary central blast producer, the prime reason for the satisfactory gasification of one fuel at a very high rate of gasification and the failure in the gasification of another fuel at the same rate, was most clearly and forcibly demonstrated.

These two experiences, with a study of the operation of a large number of producers on bituminous, semi-bituminous, lignites, anthracites, and semi anthracites, have led to the complete realisation of the three fundamental requirements that must be met in the successful gasification of all fuels as previously set forth, viz.: (*a*) Uniform distribution of the green fuel; (*b*) uniform removal of ash; (*c*) uniform distribution of the blast.

A study of the producers on the market to-day will reveal the fact that there are few if any that meet all of these comparatively simple requirements. A few have partially done so and have proved successful at low rates of gasification, or at high rates on certain fuels. The Mond producer illustrates the latter, although this fails entirely to meet the first and second requirements, but very nearly meets the third, which is the most important and the end desired.

The Taylor producer illustrates the former, for as it was designed it failed to meet requirements *b* and *c*, and, while

*Tests on Suction Gas Producers with a Korting Ejector, Trans. Vol. 31, p. 831.

successful for gasification of 10lbs. and under, was never capable of higher rates on average fuels. A change in accordance with the above requirements demonstrated that a gasification of 15lbs. was accomplished with the same ease as 10lbs. had been accomplished in the past, when operating on a poor grade of anthracite.

From this study and investigation it has become apparent that average fuels can be gasified at rates from 50 to 150 per cent. greater than the present rating of producers (9lbs. to 10lbs. per square foot of fuel bed per hour), and with no increase in labour. This means a great reduction in the first cost of producer plants and also in the operating costs. Furthermore, the same principles produce the same results in large producers as in small producers, so that it is just as practicable to build a producer of large as of small diameter, while the labour per square foot of fuel bed required in the operation of the producer, the first cost, and operating costs are greatly reduced. A producer 9ft. diam. inside the lining, having an area of 63·6 sq. ft., requires less labour to operate than two producers 6ft. diam. (area 56·5 sq. ft.), while the quality of the gas is more uniform than that obtained from one of the smaller units. The same is true of the producer 10½ft. diam., which is easier to operate than two producers 7ft. diam. It is, however, true that the gas from two smaller producers will probably be more uniform in quality than the gas from one large producer. In any case where continuous operation and uniform condition are essential, at least two units should be installed. The writer's experience would indicate that producers up to 15ft. inside diameter are practical. The power required to drive the cleaning apparatus has previously been referred to.

Utilisation of the waste heat is an item that has received some attention in the past, but not as much as it warrants. As a rule, the average gas plant is extremely wasteful of heat. About 12 per cent. of the heat in the fuel is thrown away in the scrubber water, while about 60 per cent. is thrown away in the cooling water to the engine cylinders and in the exhaust. These last two quantities are available for steam raising in the bituminous coal plant. Approximately 2½lbs. of steam can be generated per brake horse-power of the engine. Where there is a fairly uniform load and a demand for this steam, it can be obtained at a comparatively small cost, and when credited against the cost of gas at the same rate as the cost of steam by direct firing, reduces the cost of gas from the plant from 12 to 20 per cent. If there is no demand for steam for heating or other purposes it may be used for the generation of power either in engines or turbines.

In the case of a 1,240 b.h.p. plant, 3,100lbs. of steam can be obtained from the engine exhaust and jackets per hour. For good economy the exhaust boilers should be of the low-pressure self-contained type, generating steam under about 5lbs. or 10lbs. pressure. The heating surface should be approximately twice the amount per brake horse-power as that used in direct-fired boilers. It should not, however, be sufficient to reduce the temperature of the leaving gases below 220° Fah., unless a cast-iron boiler is used. Boilers for this purpose can be made practically automatic in operation, and as a rule can be attended by the engine-room operators, so that there is essentially no additional operating cost involved.

METALLURGICAL DEVELOPMENTS IN IRON AND STEEL.*

BY JOHN S. UNGER.

THE increased demand for steel and the many new purposes to which iron or steel is being applied is shown by the fact that in 1880 the United States produced 54lbs. annually per unit of population; in 1890, 153lbs.; in 1900, 398lbs.; in 1910, 640lbs., or about 12 times as much as 30 years ago. During the last decade the production and consumption of the metal iron has increased about 60 per cent. As the consumption per unit increases and the demand extends to those nations not now large users of iron, the following conditions will result: New fields of raw material will be found; inferior raw materials must be employed; new processes of manufacture will be developed, capable of dealing with material of poorer quality; and substitutes, either metallic or otherwise, will be offered for iron.

* Paper read at the New York meeting of the American Iron and Steel Institute, May, 1912.

The gradual exhaustion of lump ores has forced the employment of from 80 to 100 per cent. of fine ores in the blastfurnace. Such ores are usually inferior physically or metallurgically to lump ores, and require some preliminary preparation. Washing, magnetic separation, pneumatic or other forms of concentration, followed by some form of agglomeration, such as sintering, nodulising, or briquetting, are growing very rapidly and extending to other fine materials, which were practically waste products in the past. The success attained in treating flue dust, pyritic residues, and even iron or steel turnings, has caused metallurgists to demand that these artificial products be made the equal of the better grades of lump ore, in order that their use may be extended beyond the blastfurnace to the steel furnace, in which a lump ore is almost a necessity.

Coal capable of producing high-grade coke by the older methods is only found in certain localities. In the manufacture of by-product coke it has been shown that coke of high quality can be made by the proper admixture of coals, some of which alone are unfit for coking purposes. This coke is the equal of the older coke, thus opening up a new source of supply, and in addition the by-products of the process are conserved.

It may be said that it requires about 2lbs. ore, 1lb. coke, ½lb. limestone, and 4½lbs. of air, or a total of 8lbs. material to make 1lb. of iron and ½lb. of slag, while 6½lbs. of gaseous products are given off. Fifty-six per cent. of the material going into a furnace is air. The average variation between winter and summer season in temperature, pressure and moisture, and moisture content will be as much as 15 to 20 per cent., while the variation in a single day may be 8 per cent. Refrigeration of the air or desiccation of the blast has been tried as a remedy, resulting in more regular working of the furnace, more uniform quality of product, and a saving of about 2s. per ton of pig iron produced.

Thin-lined, water-cooled furnaces have been used in Europe for some years. In the United States, four or more furnaces have been in blast for some time with promising results. It appears that the blastfurnace of the future may be likened to a cylindrical furnace set in a tank of water reaching from the ground to the top of the furnace. This preservation of constant lines in the interior of a furnace and the use of a lining of the proper thickness to maintain an economical heat balance have shown a reduction in fuel, greater regularity of working, and less variation in product.

The use of the waste gases with their attendant savings, for gas engine purposes, is more nearly a mechanical problem and not properly within the scope of this paper. It is sufficient to say that the majority of future installations will be of this kind. Where steam engines are installed, they will be connected with low-pressure turbines in order to conserve as much of the available energy as possible.

Within a few years the use of the Bessemer process has declined very rapidly, being supplanted by the basic open hearth. This was mainly brought about by the scarcity of Bessemer ores and the fact that open-hearth steel is slightly more ductile than Bessemer steel of the same strength. A combination of the two processes, known as the duplex process, is used with success at several plants. All steel-making processes of a purifying character are necessarily oxidising at some stage of the operation. The making of crucible steel is not one of purification, but depends for its superiority on the use of pure materials and their fusion out of direct contact with the fuel.

The electric furnace for the manufacture of ferro alloys is indispensable and has come to stay, while the profitable use of the moderate-sized electric furnace as a substitute for the production of steels of similar qualities to crucible steels, will likely revolutionise the crucible steel industry within a few years. The electric production of pig iron need not be considered at this time. In localities where fuel is scarce and expensive and ore and power are cheap, it will probably be of importance.

Several steel processes have been brought out, mostly combinations of older methods. In one it is proposed to tap the metal from the blastfurnace into a rolling open-hearth furnace, arranged with tuyeres on one side, in which the metal is blown, the slag removed, the furnace moved back to

a normal position, where the operation is finished by the open-hearth process.

Open-hearth furnaces with removable ends and roofs are frequently employed. One of the latest modifications is a removable body, which can be used as container or ladle and which is picked up by a crane and carried to the point of casting, thus retaining the heat in the steel and avoiding the use of a ladle. Water-cooled ports, frames, and doors are common. The success attending the water-cooling of blast-furnaces indicates that within a few years an open-hearth furnace equipped with water-cooled ports, sides, and roof will be the regular practice.

The use of natural gas as a fuel in favoured localities is of great importance to the steel industry. This fuel is free from injurious impurities and of high calorific value. As the fields from which this gas is drawn become exhausted, it is constantly necessary to develop new territory to keep up the supply. Since the supply does not equal the demand, the cost becomes prohibitive and substitutes must be used. The results obtained with fuel oil and tar are very encouraging. At some plants where they are so situated in regard to blast-furnaces, open-hearth furnaces, and by-product coke ovens, the excess blastfurnace gas is used to coke the coal, while the higher quality by-product gas is used either alone or with producer gas in the open-hearth or heating furnaces.

Deep cementation and that of lesser degree, called case-hardening, were formerly performed by means of solid carbon or compounds carrying a large percentage of carbonaceous matter. The increased use of superficially hardened material in gears, roller bearings, cutters, tools, projectiles, &c., has brought out solid compounds of great activity, and promoted the use of a number of gases, vapours, and mixtures of the same which act very rapidly and at much lower temperature than formerly required in cementation by gases or solids.

Piping and segregation, which are of widely different character, are usually classed together, as they come under the general heading of ingot defects. As a rule they exist together, but in many cases either one or the other will exist in such a limited degree as to be negligible.

Piping may be caused by the shrinkage of the metal during solidification, or it may be due to cavities formed by gases imprisoned in the steel, or to a combination of both causes. For more than 50 years attempts have been made to reduce piping. These embrace covering the top of the ingot with molten slag or steel, liquid compression, cooling the top of the ingot slowly by a mould in which the top is made up of material which absorbs heat slowly, keeping the metal liquid by gaseous or solid fuel, or the electric arc, casting in a vacuum, the addition of some substance which creates a high temperature at the top, or the addition of elements which absorb the gases. New schemes are brought forward constantly, but an analysis shows them to be modifications of older principles. None have been universally adopted. All fail to accomplish completely the result intended. A few improve the conditions, others are impracticable, while in practically all the cost is prohibitive, except for the more expensive steels. Some alloy steels pipe very much more than ordinary steels, and even in ordinary steels it may be said that the shrinkage cavity extends to a greater depth in the ingot of a high-carbon steel than in one of low carbon.

Segregation is the separation of the more fusible compounds of the steel, as the carbides, phosphides, and sulphides of iron, to that part of the ingot which is the last to solidify. Elements having the characteristics of true metals, which alloy with iron in all proportions, as nickel or manganese, segregate very little or none at all, while the non-metals, such as carbon, phosphorus, and sulphur, are the worst offenders. The only real cure for segregation must be one of these three remedies: Instantaneous solidification of the liquid steel, the use of steel containing elements which do not segregate under ordinary conditions of cooling, or the use of pure iron. None of these remedies is practical, but the nearer these conditions are approached the less the segregation.

When all is considered, probably the cheapest and safest method of dealing with piping and segregation in the ordinary ingot of 3 to 4 tons weight is to allow the steel to cool in the regular way, discard 30 per cent. from the top and use the remainder. This discard may not always remove all pipe and segregation, but the pipe which remains will close up in working, and the segregation be of such slight extent as not to be injurious.

Those alloys in which iron predominates will now be considered. Of the 80 known elements, about one-half have been combined with iron in greater or less proportions. Ordinary commercial steel is an alloy commonly made up of about 10 elements. Some of these elements, such as sulphur and phosphorus, have always been considered injurious. Nearly all purifying processes have had the reduction of these two elements as their primary object. Sulphur is sometimes added to low-sulphur steel to confer the property of rapid machining, while a certain percentage of phosphorus is of great value in preventing the sticking together of a pack of sheets or to ensure a firmly adhering coat of spelter in galvanising.

All the elements present or added produce certain beneficial or injurious effects, depending on the amount. Manganese up to 1·25 per cent. is a necessity; from this point up to 6 per cent. it produces hardness and brittleness, rendering the material unfit for service. When the steel carries about 12 per cent., a slightly magnetic, hard, ductile alloy of great value in the arts is obtained.

Silicon produces soundness, but renders the steel harder. In steel castings rarely more than 0·50 per cent. is used, as higher percentages yield a hard casting difficult to machine. A steel containing 1 per cent. manganese, 1·75 per cent. silicon, and 0·50 per cent. carbon will show after proper heat treatment an elastic limit of 200,000lbs. and an elongation of 10 per cent. Steel containing about 3 per cent. of silicon is difficult to forge or roll, but when finished and properly heat treated will show very valuable magnetic properties, which are indispensable to the electrical engineer. This steel is one of the newer alloy steels.

Carbon varying from traces to 1·50 per cent. produces marked physical changes, and seems to show the most pronounced effect of any element. Until the advent of alloy steel, and even since then, its proportions largely govern the various properties of the entire range of steels.

Nickel alone or with other elements, as chromium or vanadium, improves the strength of steel without materially decreasing the ductility. At least five classes of nickel steels, ranging from 3 to 36 per cent. nickel, are important iron alloys. The 36 per cent. alloy, called invar, is remarkable in possessing the least expansion or contraction per unit of temperature of any metallic substance.

Vanadium is one of the newer elements to be added to iron. It seems to rank next to carbon in intensity of effect, and is used in small percentages, usually from 0·25 to 0·50 per cent. It aids in raising the elastic limit of the steel to within 70 to 90 per cent. of the ultimate strength, and improves its resistance to failure under repeatedly applied dynamic stresses.

Tungsten was used by Mushet in the development of self-hardening tool steel, contributing the property of hardening while cooling in the air. This discovery was the beginning of the great developments made in the tungsten, molybdenum, chromium, high-speed tool steels of the present day.

Of the newer elements alloyed with iron might be mentioned boron, titanium, arsenic, antimony, bismuth, copper, and magnesium. Some of these alloys look very promising.

The use of alloy steels containing other than the regular elements is growing very rapidly. One factor that has contributed to their growth is the great advance made in the automobile industry. Statistics show that over 600,000 tons of alloy steel was made during 1910, or more than three times as much as in 1909.

Heat treatment may be defined as the careful heating of steel to a predetermined temperature, followed by a slow or rapid cooling, usually followed by a second heating to a lower temperature than the first, then by rapid or slow cooling. The temperatures used and the method of cooling employed vary as the composition of the steel or its uses vary.

Treatment affects the mechanical, chemical, electrical, and physical qualities of the metal. High temperatures are not always essential to these changes. Certain steels will become three times stronger at -180 C. and show very little change in ductility. Other steels non-magnetic at ordinary temperatures become highly magnetic at the temperature of

liquid air. Prolonged heating in boiling water will destroy the hardness of a carefully tempered edge tool. Heating a soft steel, not ordinarily sensitive to heat treatment, to between 300° and 400° C. and then quenching will show a marked reduction in ductility and a decided difference in solubility when acted upon by chemical agents.

Steels may be separated into three classes: Soft steels up to 0·25 per cent. carbon, medium steels from 0·26 to 0·75 per cent. carbon, and hard steels, or those above 0·75 per cent. carbon.

Soft steels, such as sheets, wire, or tubes, are but slightly changed by heat treatment, unless the action be continued over a very long period. In some cases this may prove detrimental. Very few attempts have been made to treat steel of this grade beyond an annealing or normalising to ensure uniform heating and cooling throughout.

Medium steels furnish by far the largest portion of the tonnage of all steel produced. In this class is found all the harder and stronger varieties of boiler and ship plates, machinery steel, rails, axles, steel castings, car wheels, shafting, woodworking implements, most of the structural and bridge material, and a large quantity of the steel used in automobiles and agricultural machinery. The medium steels have not always been treated, except for such special cases as armour, guns, crank shafts, connecting and piston rods, or any material in which great strength, durability, and security are required. Almost all alloy steels belong to this class. On account of their thermal susceptibility they are usually heat treated to develop their best properties.

The annealing of steel castings in important work is essential. Very little strength is sacrificed, while the toughness as indicated by bending or twisting has been increased from two or four times that of the untreated casting.

Railroad axles, shafts, and forgings were not heat treated in the past. As the alloy steels with their accompanying heat treatments were brought out, attention was immediately given to the treatment of ordinary steels. Most forgings are being heat treated at the present time. It is believed that the treatment now being given to gears, shafting, rails, wheels, plates, bars, and machinery parts will grow until practically all such material will be used in a heat treated condition.

Hard steels, known as tool steels, are not often used in an untreated state. These steels were the first steels made and were valuable, as they could be made intensely hard by heating and quenching in water. It was found that this hardness could be modified by subsequent heating or tempering, yielding a tool or implement of great value. A temperature of 400° C. removes this hardness and makes the tool too soft to cut hard metals.

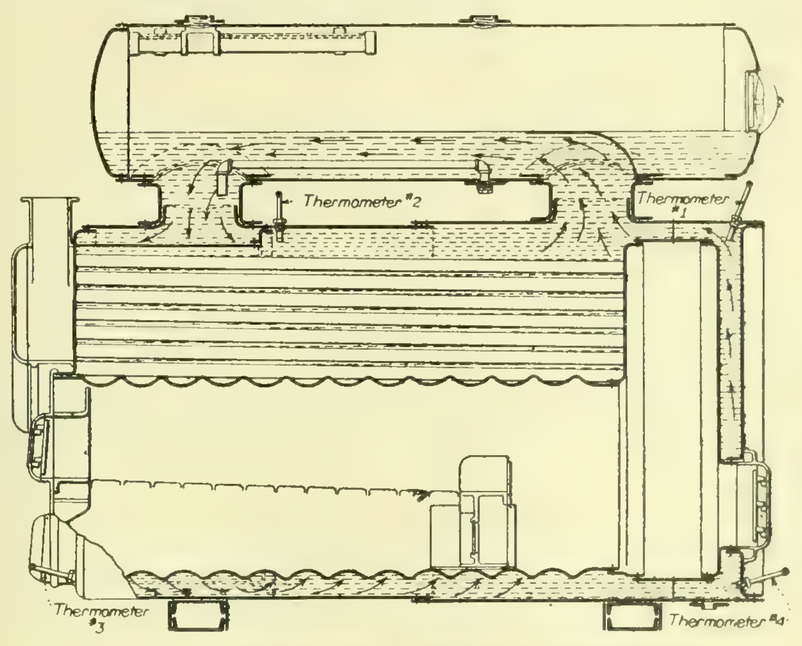
The classic researches of Taylor and White, the inventors of the treatment of high speed chromium-tungsten tool steels at such elevated temperatures as were supposed to destroy such alloys, are an important point in the metallurgical history of tool steels. This discovery completely changed a part of the hard or tool steel industry and revolutionised machine tool operations. This treatment yielded a steel of such wonderful cutting properties that machine tools all over the world had to be built much stronger, of greater power, and capable of being driven at much higher speeds than formerly.

When the great changes in railroad material in the last quarter of a century are considered it is reasonable to believe that the freight car of the future will regularly carry a load of 100 tons. Its size will only be limited by bridge, tunnel, or other clearances. A reinforced concrete roadbed, carrying a track of 150lbs. to 200lbs. rails on steel supports, or perhaps duplicate rails laid a few inches apart on each side of the track, will probably be the standard practice a few years hence. As the elastic limit of the axle wheel and rail are approached, a higher limit will be required, limited only by what the steel maker can produce and by the point to which this may be carried, and still retain sufficient traction under engine wheels to move the load. To distribute the load, four wheels may be mounted on the same axle, or additional wheels and axles put under the future car. The effort to secure a strong material of the least weight, in order to reduce the dead load carried, will always exist. Similar progress will be made in the machinery and building world.

The demand for a stronger, lighter, less corrodible metal will continue, and its use will be governed by its extra cost in comparison with regular material. Iron rusts more rapidly when exposed than almost any of the other common metals. The attempts to protect it by coatings or metallic coverings have done much to increase its durability. It is not an exaggerated statement to say that future researches will develop a method of treating iron which will greatly retard or wholly prevent corrosion. How this is to be accomplished is left to the future. Exposure to a gas or vapour, aided by heat, pressure, or the electric current, may render the iron entirely passive, or diminish the effect of atmospheric conditions. It may be that more than such a simple treatment will be necessary, and that after such a passive condition has been produced it must be fixed or made permanent by additional treatments, as quenching, exposure to other gases or vapours, or to chemical solutions to obtain the desired result.

CIRCULATION TEST OF A STEAM BOILER.

THE "Iron Age," in its issue for May 30th, gives the results of a test for water circulation of a Robb-Brady Scotch boiler at the Sewerage Pumping Station, Framingham, Mass. The boiler was equipped with thermometer oil wells at the four points indicated in the accompanying illustration. With



SECTION OF BOILER SHOWING LOCATION OF THERMOMETERS.

water in the boiler at about 80° the fires were started and readings of the thermometers taken every 5 mins. The following table shows the results of the tests:—

Tests of Water Temperatures in a 50 h.p. Robb-Brady Scotch Boiler.

Time p.m.	Thermometer No. 1.	Thermometer No. 2.	Thermometer No. 3.	Thermometer No. 4.
	Deg. Fah.	Deg. Fah.	Deg. Fah.	Deg. Fah.
3-40	114	112	80	82
3-45	126	124	80	82
3-50	138	140	80	83
3-55	150	150	81	84
4-0	170	170	82	86
4-5	194	190	84	87
4-10	210	210	98	90
4-15	226	224	210	136
4-20	231	230	226	180
4-25	244	242	234	230
4-30	258	260	252	248
4-35	276	278	268	270
4-40	292	292	292	290
4-45	310	308	306	310
4-50*	328	330	328	328
4-55	330	330	328	330
5-0	327	328	327	327

* Safety valve blowing off.

A New Alloy for Tubes and Armour Plate.—Prof. G. Jacquier has discovered a new alloy named "Argilite." It is intended for the manufacture of pipes, tubes, and armour-plate, and consists of 90 per cent. aluminium, 6 per cent. copper, 2 per cent. silicon, and 2 per cent. bismuth. The advantages claimed for it are lightness, hardness, and resistance to pressure and corrosive action.

INDUSTRIAL AND TRADE NOTES.

Light Railway.—The Board of Trade has recently confirmed the undermentioned Order made by the Light Railway Commissioners: Clayton le Moors Light Railway Order, 1912, authorising the construction of a light railway at Clayton le-Moors.

Amalgamation of Locomotive Engineers and the A.S.R.S. Rejected. The Associated Society of Locomotive Engineers and Firemen, at their triennial conference at Leeds on the 7th inst., discussed the question of amalgamation with the Amalgamated Society of Railway Servants, with the view of forming one powerful union. By 135 votes to seven the proposal to amalgamate was rejected. It was contended that, if amalgamation took place, the locomotive engineers and firemen would be in the minority compared with other grades in the railway service.

The Demarcation Dispute at Cammell, Laird's.—An important shipbuilding conference was held on the 4th inst. at Carlisle, and, after sitting from noon till 6.30, the following official statement was made to the Press: The Shipbuilding Employers' Federation met the Executive of the Boilermakers' Society, together with the local representatives from the Birkenhead district, to discuss the question of demarcation which had arisen at Messrs. Cammell, Laird, & Co.'s works. Mr. James H. Boolds, president of the Shipbuilding Federation, was in the chair, and after considerable discussion, the question was thereafter remitted to a local conference for further consideration, with a view to settlement.

Electric Light and Power for Japanese Mines.—The British Acting Consul General at Seoul reports that a Tokio company, acting as agents for a well-known German firm, have prepared a scheme for supplying electric power to the gold and other mining companies in North Pyeng an Province, and will devote a capital of about £102,000 to the purpose. The German firm will supply all the necessary plant and machinery, which will be similar to that installed at the Fushun coal mines. The new power plant will be erected at Reibi, and power and light will be supplied to neighbouring towns. According to the local Press, the Tokio company has also obtained the option to build an electric railway from a point on the Seoul Wiju Railway near Shinanju to the Yalu river, traversing the mining districts of Unsan and Yengben, but details of the scheme are not yet forthcoming.

Oil-engineering Exhibition.—A meeting of manufacturers and others interested in the oil engineering industry was recently held in London in connection with the forthcoming Oil-engineering Exhibition, which is to form an important part of the Hardware and Ironmongery Exhibition to be held at Olympia from September 7th to 17th. This will be the first exhibition directly concerned with the engineering side of the oil industry. The exhibition will be divided into sections dealing with (1) oil-field equipment; (2) transport, including tank steamers, wagons, &c.; (3) oil fuel systems; (4) oil engines; (5) oil refining; (6) oil lighting and heating; (7) oils for fuel, lighting, lubricating, &c.; (8) the world's oil fields; (9) geological photographs, &c. The organisation of the general exhibition is under the direction of Mr. G. D. Smith, while the oil engineering section is in the hands of Mr. S. H. North. Particulars may be obtained from the offices of the Exhibition, 119, Finsbury Pavement, E.C.

The Cambrian Combine's Co-partnery Scheme.—Mr. D. A. Thomas, of the Cambrian Combine, recently gave some details of the co-partnery scheme which his directors are contemplating in connection with the Combine's new pits at Gilfach Goch. I quite realise, he says, that the coal mining industry does not lend itself to co-partnership by reason of its speculative character and widely varying amount of profit from year to year. Moreover, while I believe that the proposal we shall make will be of substantial value to the workmen, it will be really only a small contribution towards settling the unrest so prevalent about the country at the present time, and I fear also that the miners' leaders in South Wales, or at any rate the Socialistic section, will not encourage the men to take advantage of the offer. What I should really like to see would be the Miners' Federation acquiring a controlling interest in a colliery and working it themselves. To suggest that vested interests would combine to prevent the success of such an enterprise is childish.

A Board of Trade Exhibition.—The Board of Trade, on the recommendation of their Advisory Committee on Commercial Intelligence, have arranged for the formation, by H.M. Trade Commissioners in the Self Governing Dominions, of extensive collections of samples of hardware, hollow ware, and tools, of foreign manufacture which compete on a large scale in those Dominions with similar goods of United Kingdom origin. The samples will be accompanied in all cases by detailed information as to country of manufacture, price, rates of customs duty, and other matters affecting the trade. A large number of samples of this kind have now been received from H.M. Trade Commissioner for South Africa. Arrangements have been made with the Chambers of Commerce at Birmingham and Sheffield for their exhibition in those cities at an early date. The samples will subsequently be exhibited in London, and the Board of Trade will also be glad to arrange, so far as practicable, for their exhibition, wholly or in part, at other industrial or commercial centres where such a course seems likely to be of practical utility. The samples from the other self-governing Dominions will be dealt with in a similar manner as soon as they are received.

Mining Certificates.—The Home Secretary has given notice that he has approved a large number of mining schools, institutions, and authorities for the purpose of granting certificates to firemen, examiners, and deputies under the provisions of Section 15 of the Coal Mines Act, 1911. No person will after January 1st, 1913, be eligible to be appointed or to act as a fireman, examiner, or deputy unless he possesses a certificate from an approved school, institution, or authority. This requirement will apply to existing firemen, &c., as well as to firemen hereafter appointed. All applications for information as to the examinations to be held for the purpose of the grant of certificates should be addressed to the approved mining schools, institutions, and authorities, and not to the Home Office. The Secretary of State hopes to be able to issue a supplementary list of approved schools, institutions, and authorities shortly.

Rubber Manufacture for Electrical Purposes in Japan.—H.M. Commercial Attaché at Yokohama, in a recent report on the trade of Japan in 1911, states that in the electrical department of the rubber industry considerable progress has been made in Japan. The one difficulty with which the mills have to contend is the lack of experienced technical men. They have up to date machinery, but the industry is so young in Japan that there are no native trained rubber chemists. Several mills have experimented with foreign instructors, but the result has not been satisfactory in most cases, owing to the inability of the instructors to make themselves understood and the inadequacy of interpreters for this purpose. The difficulty is one which will doubtless disappear as time enables the technical men to acquire their experience, but many costly mistakes have been made. The manufacture of insulated wire has already had its influence in checking the import of European rubber-covered wire, and, in addition to this manufacture, three of the largest mills have installed plants for making lead covered telephone and high tension cables. Although this is hardly directly connected with the rubber industry, the fact that mills have branched out in this direction merits attention, as having a bearing on the future importation of high tension cables from abroad.

Co-operative Production in France.—The June number of "Co-partnership" contains an interesting article on the growth of workmen's productive organisations in France. These associations are much more numerous in France than in this country. The last official report describes them as "associations formed by workmen for carrying on their trade in common," and states that in the beginning of last year they numbered 498. In 1886 there were only 10. The trades carried on are of the most diverse kinds. They perform work for co-operative distributive stores, for municipalities and the Central Government on contract, and for the general public. One association, called "The Workers in Instruments of Precision," consists of highly skilled mechanics, whose sole work is making telephone instruments. It employs about 130 men, all of whom are paid at the same rate, irrespective of output, viz., 10½d. per hour. The manager gets the same pay as the mechanic, with certain allowances for extra expenses. This society began 16 years ago with two men. In 1911 the 498 societies had from 20,000 to 25,000 members. Membership is generally confined to the members of one particular trade union. The profits are divided in dividends on wages and on capital invested by the workmen.

Hydraulic Cranes at Plymouth.—At the Great Western Docks, Plymouth, there have been recently installed five quick acting hydraulic cranes, in substitution for steam cranes. The new cranes will raise three tons to a height of 85ft. at a radius of 50ft. and run on a 14ft. 7in. track, the pedestal arch on which they are mounted permitting railway rolling stock to pass under them. The load is lifted by three rams, working on a single cross-head, and the cranes can turn "round and round," this operation being effected by four direct acting rams, which thrust in turn against a steel forged crank bolted to the central pivot of the crane. Lifting or lowering, derricking, and slewing are performed by hydraulic power, either simultaneously or inde-

pendently, the cranes being capable of derricking with the full load from 50ft. to 20ft. radius. In tests of the lifting and slewing the former operation was performed at the rate of 300ft. a minute and the latter at 600ft. a minute at 50ft. radius, these speeds being 50 per cent. better than were specified. The jib is pushed out by a direct-acting hydraulic ram, and in the event of anything breaking the predominating balance weight pulls the jib up to a state of rest and thus prevents risk of accident through the jib dropping. The cranes were supplied by Messrs. Tannett, Walker, & Co., of Leeds.

Ironmoulders' Lock-out Settled. — A settlement was come to on Monday last in the Falkirk moulders' dispute, as a result of which the men resumed work on Thursday. The dispute arose as the result of the strike of 400 moulders employed at the Carron Company's Mungal Foundry, Bainsford, on a question of the working conditions, the men asserting that owing to the inadequate supply of material from the furnaces they were not kept continually employed during the working hours. This resulted in the men's wages being considerably reduced and in their requiring to work very long hours in order to make casts when they could obtain the material. The dispute, after being the subject of negotiations, culminated in a lock-out of about 4,300 members of the Central Ironmoulders' Association in the Falkirk district. Last week the Board of Trade intervened, and a conference was arranged between the executive of the Central Ironmoulders' Association and the light castings section of the Scottish Federation of Iron and Steel Founders. This conference was held on Monday at Glasgow, and at the close the following communication was made: "On the invitation of the Board of Trade a conference took place between the executive of the Light Castings Founders' Section of the Scottish Employers' Federation of Iron and Steel Founders and the executive of the Central Ironmoulders' Association, Mr. Isaac Mitchell, of the Board of Trade, being present. After prolonged negotiations a settlement was arrived at, and it was agreed that all the men should resume work on Thursday morning."

Standardisation of Engineering Catalogues. — A lecture on this subject was delivered by Mr. Arthur Bourne at a recent meeting of the Junior Institution of Engineers, in the course of which he pointed out that, although the initiation of the movement for the standardisation of trade literature had its birth several years ago, manufacturers both in this and other countries seemed slow to move definitely in the matter. Manufacturers had not, he observed, been slow to realise the very great benefit accruing from scientific and systematic advertising in the technical and daily Press; why, then, should not a little more care, science, and system be brought to bear on the extremely important question of catalogue production, upon which so much money was spent? Under existing conditions it was really difficult to know how to file catalogues, and of the many systems in vogue he doubted if any was really satisfactory. He advocated not only the adoption of a standard size, but also the confining of one article to one catalogue. Manufacturers seemed at the present time to be devoting a considerable amount of attention to export trade, but, in his opinion, the large amounts spent annually in the dispatch of elaborate and costly catalogues abroad was for all practical purposes wasted. What buyers abroad welcomed was literature that gave not only detailed illustrations, but also full and complete information, such as net and gross weights, shipping measurements, code words, and approximate prices, so that, if necessary a quotation could be given without having to refer home. It was really surprising what a large percentage of catalogues failed in this respect.

Coal and Iron in Derby and Notts.—A paper on "The Coal and Iron Industries of Derbyshire and Nottinghamshire" was contributed by Mr. George S. Bragge at the recent meeting of the Surveyors' Institution held at Buckingham. He stated that in their final report, issued in 1905, the Royal Commission appointed in 1901 estimated the net available tonnage of coal remaining unworked in the proved coalfields of Derbyshire and Nottinghamshire at a depth not exceeding 4,000ft. to be 7,360 million tons. The Geological Committee of the same Commission, in estimating the resources of the concealed and unproved coalfields at depths of less than 4,000ft., considered there were 23,000 million tons in the eastward extension of the Yorkshire and Notts coalfield into Lincolnshire. Speaking roughly, one-half of this extension might be reckoned as belonging to the Nottinghamshire coalfield. Associated with these coal seams, and formerly worked with them to a large extent for pig-iron making, were seams of clay ironstone, either in beds or nodules. The discovery of the more cheaply worked iron ores of Lincolnshire, Northamptonshire, and Leicestershire had almostly entirely done away with the working of the clay ironstone. In the northern part of Derbyshire were extensive quarries of mountain limestone, a large portion of the produce of which was used in the manufacture of pig iron as a flux. The output of limestone from this county was the next largest to that from Durham, amounting in the year 1899 to over 1¾ million tons. The pig-iron industry was of the greatest importance, and in Derby and Notts there were 33 furnaces in blast at the end of January last.

Compulsory Working of Patents.—At the 16th annual congress of the International Association for the Protection of Industrial Property, recently held in London, various delegates spoke on the question of compulsory working of patents. Mr. T. F. Iselin said there appeared to be an almost unanimous opinion among the delegates that the omission to work a patented invention should not result in the revocation of the patent but to the granting of compulsory licenses and that each State should make rules for the execution of this provision by means of its internal legislation. Mr. Henri Allart (Paris) remarked that the agitation in favour of the abolition of forfeiture for non working made great headway until the passing of the Patent Act in 1907, which was followed by a proposal in France to strengthen the system of compulsory forfeiture by way of reprisal for measures taken in this country. It was very unsatisfactory to leave to the courts, whose opinions might vary, the duty of deciding whether an inventor who failed to work his patent was justified. He urged the congress to maintain, as they had done on previous occasions, that the system of forfeiture for non-working of patents should be replaced by compulsory licenses. Mr. S. W. Gillet, representing the Manchester Chamber of Commerce, urged the British delegates to remember that compulsory working which benefited the consumer in this country was the only weapon that they had here against the foreign patentee. He agreed that compulsory working should be supplemented by compulsory licensing, but the licensing alone had been tried in this country and it failed, and, as there was no tariff in this country, the power of revocation was the only power they had to enforce the introduction of new manufacture, which was the principle on which the patent laws were based. The Manchester Chamber held that the consumer benefited by compulsory working. The congress passed a resolution that the failure to work a patented invention should not lead to the revocation of the patent but to the granting of compulsory licences, each State making rules for the execution of this provision.

British Trade with Switzerland.— According to the report of H.M. Consul at Zurich on the trade of Switzerland during 1911, the total value of imports from the United Kingdom during the past year was £3,994,300, as compared with £4,507,000 in 1910. The value of exports from Switzerland into this country was £8,516,800 in 1911, as compared with £8,014,000, showing a decrease in imports from the United Kingdom of £512,700, and an increase of Swiss exports to the United Kingdom of £502,800. The report goes on to state that the year 1911 was, on the whole, a satisfactory one for trade and industry in Switzerland, although in some branches progress was slower as compared with the previous year. As a proof that Swiss trade is becoming year by year more prosperous, it may be stated that the total foreign trade of the country has steadily increased from £75,463,000 in 1901 to £122,246,000 in 1911, or 62 per cent. Swiss industry, however, is beginning to feel the growing foreign competition, as well as the prohibitive protective tariffs of many countries, which affect the more costly products of Swiss manufacture, and many of the larger firms have been compelled to establish branch factories in France, Germany, and the United States. This enforced removal of home industries is regarded as a serious national danger. The report makes some suggestions for improving our trade with Switzerland. It states that there are many firms who send their representatives to Germany, France, Austria-Hungary, and Italy, and a visit to the principal centres of trade in Switzerland (Zurich, Berne, Basle, and Geneva) might well be included at little extra expenditure of time and money. If, however, it is not convenient to send travellers, the appointment of Swiss agents, who are generally able to correspond in English, would be the most likely way of securing a better share of trade. The necessity of catalogues being printed in the French or German language, also of weights and measures being given in the metric system and prices quoted in francs, has previously been emphasized. One of the principal Swiss trade organs stated that British exporters would undoubtedly gain a considerable advantage by adopting such a reform, which has long been earnestly desired by the leading Swiss firms interested in the importation of British goods. The total value of German and French imports into Switzerland during 1910 was £22,628,800 and £13,863,600 respectively, as compared with our £4,507,100. The greater volume of business done by these two countries is no doubt due to some extent to the larger number of travellers employed. Germany has 4,797 travellers and France 1,395, while the United Kingdom has only 67.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1910.

Supply of heated air to boiler furnaces. Housley. 28206.

1911.

Milling cutters and method of manufacturing same. Lawton and Lawton. 1034.
Method of and apparatus for recovering heat in furnaces. Von Forell. 4161.
Rotary explosion engines. Ruppe. 4200.
Raising or forcing liquids and compressing elastic fluids. Humphrey. 11817.
Ships' steering gear. Harrison. 12000.
Brake mechanism of colliery winding engines. Shrigley. 12065.
Composition for laying of coal dust in mines. Bowman. 12078.
Process for the solidification of petroleum. Gerard. 12158.
Apparatus for the transmission of power. Stettiner Maschinenbau Akt.-Ges. "Vulcan." 12231.
Carburetters for internal combustion engines. White, and D. Napier & Son, Ltd. 12244.
Automatic train stops and recorders. McCollum. 12422.
Alloys of zinc. Bayliss & Clark. 12457.
Operating of railway points and switches. Thomson. 12539.
Lubricant pump, especially applicable to internal combustion engines. Daimler-Motoren Gesellschaft. 12570.
Rotary engines. Van Deventer and Buffalo Forge Company. 12623.
Fluid-pressure braking apparatus. Cloud. 12661.
Manufacture of weldless steel tubes. Talbot, and Talbot-Stead Tube Company. 12724.
Sand moulding machines. Phillips. 12802.
Machines for pressing or stamping sheet metal. Crabtree and Crabtree. 12815.
Mine ventilation. Tubben. 12855.
Feed water heaters. Clarke. 13075.
Steam turbines. Baumann. 13308.
Lifts or hoists. Mallot & Mallott. 14282.
Cutters for finishing gear teeth. David Brown & Sons (Huddersfield), Ltd., and Brown. 14645.
Machine for measuring the centrifugal force of a weight. Robinson. 14789.
Vices and clamps. Venables. 15119.
Apparatus for purifying water by heating. Savary Carlier. 15229.
Tramway track points. Bellve & Potts. 15551.
Hand-steering gear for ships. Absalom & Willis. 17234.
Lubricant feed arrangements, for engines of motor cars. Thompson. 17856.
Regulating devices for elastic fluid turbines. Warwick Machinery Company (1908). 18156.
Combined crane locomotives. R. & W. Hawthorn, Leslie, & Co., and Straker. 18527.
Feeding and distributing oil under pressure to internal combustion engines. Executors of W. J. Renshaw. 19141.
Centrifugal governors. Amphlett. 19299.
Igniting device for miners' safety lamps. Pasierbski. 19785.
Rust-proofing iron and steel. Johnson. 19868.
Instruments for indicating variations in thickness. Spinney. 20095.
Heater attachment for explosion engines. McCormick. 20684.
Delivery pipe for casting apparatus. De Bugne. 21166.
Nut lock. Delamere. 21655.
Steam boilers. Grille. 21908.
Superheaters. Mestre. 22213.
Apparatus for filtering lubricating oils. Reggio. 22734.
Boiler cleaning apparatus. Pontani. 22933.
Driving belts. Webb. 23842.
Lubricators. D'Oultremont. 25070.
Spring packing rings for pistons. Hansen & Plesner. 26031
Fluid pressure pump governing mechanism. Turner. 26156
Means for returning unconsumed products of combustion to the furnaces of steam boilers. Wait. 26491.
Valve gear for internal-combustion engines. Rieseler & Derry. 26641.
Percussion tools. Battison. 27460.
Pistons. Soc. Metallurgique de Montbard Aulnoye. 28593
Valve gear for the air pumps of internal combustion engines. Geb. Sulzer. 28967.

1912.

Setting of the rolls in universal rolling mills. Sellge, and Deutsch Luxemburgische Bergwerks und Hutten Akt Ges. 109.
Carburetters for internal-combustion engines. Bailey, Bailey, and Dale. 307.
Step-by-step rolling mills. Ackermann. 1183.
Exhaust silencers. Larkins & Shaw. 1402.
Pulleys. Bowen & Walker. 1467.
Pulleys. Brinley. 1468.
Internal combustion engines. Von Handorff. 1981.
Travelling cranes. Slutman & Carbrae. 2557.
Exhaust valves for two stroke cycle internal combustion engines. Cloudsley. 3025.
Chucks for boring machines and lathes. Barnes. 3817.
Apparatus for starting internal combustion engines. Bloxam. 3963.
Gas producer plants. Fuwa. 4895.
Centrifugal fans. London. 5683.
Propellers and fans. Brierley. 6468.
Apparatus for compressing air or gas. Lieblich. 6553.
Vaporising chambers for internal combustion engines. Roberts and Young. 6809.
Reversible screw propellers. Price. 7517.
Transmission mechanism of automobiles. Oesterreichische Daimler Motoren Akt. Ges. 8068.
Floating dock for raising sunken vessels. Le Sauvage. 8101.

ELECTRICAL, 1911.

Operating electric railway track points and switches. Justice. 4385.
Trolley bases for electrically propelled vehicles. Munro, and Railless Electric Traction Company. 12102.
Automatic telephone instrument. Bhisey. 12135.
Cord-grip electric lamp holder. Walter. 12177.
Compound or mixture for preserving the electric properties of metals. Vigneault & Hebert. 13483.
Portable electric battery lamps. Pordes. 14866.
Arrangement for automatic voltage regulation of alternators, decreasing the current in case of short circuit. Lehmann. 18280.
Protective devices for electrical apparatus. British Thomson Houston Company. 19583.
Arc rupturing devices for electrical apparatus. Allgemeine Elektricitats Ges. 20409.
Electric controllers. Canfield. 20531.
Dynamos for mine exploding. Sterling Telephone and Electric Company. 21913.
Connection for lighting metallic vapour electric lamps. Quarzlampen Ges. 23284.
Arc lamps. Weiss. 25899.
Commutation of direct current dynamos. Siemens Bros. Dynamo Works. 27212.

1912.

Electrical selective connecting apparatus operated from a distance. Betulander. 410.
Winding methods for rotating magnet coils. "Vulkan" Maschinenfabriks Akt. Ges. 3919.
Circuit arrangements for polyphase series motors. Siemens Schuckertwerke Ges. 4165.
Telephones. Tattersall. 4773.
Fuse boards and panels for electric distribution. Siemens Schuckertwerke Ges. 5322.
Controlling arrangements for electric cranes. Siemens-Schuckertwerke Ges. 8158.

METAL QUOTATIONS.

TUESDAY, JUNE 11TH.

Aluminium ingot	70/-	per cwt.
„ wire, according to sizes, &c. ......from	102/-	„
„ sheets „ „ ...... „	120/-	„
Antimony ... £27/-/- to	£28/-/-	per ton
Brass, rolled	9d.	per lb.
„ tubes (brazed)	11¼d.	„
„ „ (solid drawn)	9⅝d.	„
„ „ wire	9d.	„
Copper, Standard	£78/10/-	per ton.
Iron, Cleveland	54/-	„
„ Scotch	60/-	„
Lead, English	£18/-/-	„
„ Foreign (soft)	£17/8/6	„
Mica (in original cases), small	6d. to 3/-	per lb.
„ „ „ medium	3/6 to 6/-	„
„ „ „ large	7/6 to 11/-	„
Quicksilver	£8/5/-	per bottle
Silver	28¼d.	per oz.
Spelter	£25/17/6	per ton.
Tin, block	£207/10/-	„
Tin plates	14/9	„
Zinc sheets (Silesian)	£29/-/-	„
„ (Stettin; Vieille Montagne)	£29/7/6	„

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Possibilities of the Oil Engine in Britain.

THE oil engine is very much to the fore at present. This we owe largely to the success of the Diesel oil engine, and hence it is not to be wondered at if many people assume that the Diesel oil engine is the only one of any importance. We may admit at once that the Diesel engine possesses an advantage over all others in the matter of fuel economy, and that where fuel economy is the most important factor to be considered the selection of a Diesel engine in preference to all others can generally be justified. At the same time it is important to recognise that fuel economy is never the only factor to be considered, and is by no means always the most important or a controlling factor. First cost, reliability, simplicity, flexibility of control, ease of starting, and local conditions must all be taken into account. For instance, we are apt to overlook the fact that the petrol engine is a true oil engine, although differing radically from the Diesel. For all but the heaviest motor-car work the petrol engine is almost without a rival in present-day practice, and certainly the Diesel engine, and even the simple paraffin engine, are conspicuous by their absence. Yet petrol costs about six or more times as much per gallon as the crude oil consumed by the Diesel engine, in addition to which the petrol engine is thermally not much more than two-thirds as efficient as the Diesel engine, so that its fuel cost is about ten times that of the latter.

Attention is drawn to the motor-car engine, because it illustrates in a striking manner how unsafe it is to rely upon any one factor as the sole one influencing the choice of an engine. No doubt one of the factors accounting for the supremacy of the petrol engine is the important one that it was established before its rival had become really formidable, and it may be that in time the Diesel will develop along lines sufficient, taken in conjunction with its lower fuel cost, to justify its widespread adoption for motor-car work. At present, however, the petrol engine possesses qualities which more than counter-balance the serious disadvantage of high

fuel cost. It is easy to start and independent of a supply of compressed air. It is comparatively simple in construction, and its adjustments are such as can be entrusted under usual conditions to the average amateur. Also, it is light in weight, low in first cost, and more reliable in small sizes and under road conditions than one would expect the Diesel to be. Again, there are many situations in agriculture and industry where a simple oil engine is valuable, and at present the petrol or the paraffin engine can generally justify themselves against the Diesel. In agricultural work especially, simplicity and robustness are essentials of success, although at the same time fuel is an item not to be despised. Hence the paraffin engine, which comes intermediate between the Diesel and the petrol engine, both in first cost and fuel cost, has here a strong hold.

On the other hand, the Diesel engine is doing a work beyond the powers of the other two. It is extending the field of the oil engine enormously, and opening up possibilities which were scarcely dreamed of two or three years ago. In this country the oil engine is not so advantageously situated as in India, parts of China and the United States, Russia, and other European countries. Oil prices have fluctuated a good deal this last few years, and coal prices naturally vary from point to point, but a fairly common ratio between fuel oil and steam coal prices in England is 4·5 to 1. In some important districts in India the ratio is nearer 2·5 to 1, and other countries can show ratios even more favourable to the oil engine. The ratio of the fuel consumptions of steam and Diesel engines varies widely. It depends upon the engines themselves, their duties, and the quality of the coal. For instance, under steady load conditions a high-class steam turbine installation will develop a kilowatt-hour on about 2lbs. of coal, and a Diesel engine on ¾lb. of oil, so that the ratio of fuel costs in this country under these conditions is about 1·75 to 1 in favour of steam. In inland colliery districts the ratio is more like two to one, and for very large installations is even more favourable to steam. On the other hand, conditions are not always favourable to steam. Thus, under central station conditions 3lbs. of coal per kilowatt-hour is a first-class figure. This is accounted for by the fact that the average load is less than the full-load, and also by the banking, leakage, and radiation losses. Provided the load variations are not extreme, the oil engine scarcely suffers by a fall in load, and in general scores on this point. It also has no stand-by losses worth mentioning. Hence, so far as fuel costs are concerned, central station conditions favour the oil engine. In small stations with heavy peak loads the stand-by losses are usually heavy, and in many such cases the oil engine very decidedly beats the steam plant on the matter of fuel costs. For factory driving the oil engine is less favourably situated. Its starting effort is somewhat defective where the engine is belted or roped direct to the shafting, and a clutch or an electric drive is an obvious mechanical improvement. Both are in use, but the electric drive, unless there are some counterbalancing advantages, imposes a somewhat serious handicap due to the electrical transmission losses.

Fuel cost is not the only factor to be considered. Capital outlay is important. For large units in electric power stations the capital charges are in favour of steam, but the advantage is not so marked in the case of small stations. Lubricating oil is a somewhat costly item for Diesel engines, but water is cheap. Labour in the engine room when running is important, and especially so in large stations, but there is no equivalent to boiler house labour. Reliability has to be considered, especially in factories dependent on one engine, and it would be surprising indeed if a comparatively new engine like the Diesel were as reliable as its older and more completely developed rivals. The Diesel engine is also less flexible than most of its rivals, except perhaps the gas engine; and in some instances, as where the load is liable to wide fluctuations or the speed may have to be much reduced, this is a serious drawback. For factory driving the reciprocating steam engine possesses an advantage over all forms of internal-combustion engine on account of its great flexibility. Thus, if, as very often happens, the load is increased after the engine is installed, or, as also not infrequently happens, the load has been underestimated, the steam engine will comfortably carry the extra load up to 30 or 50 per cent., but the Diesel engine has almost no margin of surplus power. Several failures have resulted from such overloading, and the possibility of such failure is a factor to be allowed for.

The above discussion is necessarily somewhat general, but is sufficient for our present purpose, which is to indicate broadly the fields in which at present the Diesel engine shows a fair prospect of success and in which it is therefore deserving of careful consideration by those who may be considering the installation of a power plant. One serious criticism to the discussion may be offered, and that is the comparative absence of mention of the gas engine. This has been done to avoid undue complexity in the comparisons and not from any desire to slight the strong claims of this form of engine. The discussion shows that the Diesel engine is at its best where it drives an electric generator and not when coupled directly to a heavy load like that imposed by extensive shafting. Its chief merit is high thermal efficiency, and its second the way in which this is maintained under stand-by conditions. As a result the extra cost of oil fuel is often more than neutralised in electric power stations, and for small stations the advantage lies with the Diesel engine. For such work there is a promising future before the Diesel.

TESTS OF JACOBS-SHUPERT LOCOMOTIVE FIREBOX.

A FEW months ago we briefly intimated that a series of tests were to be conducted by Dr. W. F. M. Goss at Coatesville, Pa., for the Jacobs-Shupert United States Firebox Company, of New York, on a boiler fitted with a firebox of the Jacobs-Shupert type in comparison with one of similar size fitted with the usual type of firebox. Three distinct series of tests were to be made, viz.: Series "A" to determine the evaporative efficiencies of the two fireboxes independently of the remaining portions of the boilers; series "B" to determine the evaporative capacities of the boilers as a whole; and series "C" to determine the behaviour of the two boilers under low water conditions. A report covering the tests scheduled under series "A" has been submitted by Dr. Goss and is reproduced below:—

I beg to submit the following report of progress, covering the work done in testing boilers at the testing plant in Coatesville. The tests of series "A" of the outline approved have been entirely completed, with results which in general terms are set forth below.

The Boilers. Two boilers have been employed in the tests, one having a firebox of the radial-stay type, hereinafter referred to as the radial-stay boiler, and the other having a firebox of the Jacobs-Shupert boiler. Both boilers are identical in their general dimensions, which are as follows:—

Outside diameter of shell of boiler at front end	70in.
Diameter of shell at throat	83[illegible]in.
Number of 2[illegible]in. tubes	290
Length of tubes	18ft.
Inside length of firebox	109[illegible]in.
Inside width of firebox	70[illegible]in.

The purpose of the tests of series "A" was to determine for each boiler the evaporation from the firebox and from the tubes separately. To make such a determination possible, the back tube-sheet was extended in all directions to the outside of the boiler, thus forming a diaphragm completely separating the water space on the two sides of this tube-sheet. By this device each boiler was made in effect two boilers, the heating surface of one being all portions of the firebox, excepting the front tube-sheet, and the heating surface of the other being the tubes and tube-sheets.

In carrying out the tests, each compartment was supplied with weighed water, as though it were a separate boiler. The quality of the steam delivered from the firebox end and from the barrel end was determined independently, the purpose being to determine with the highest possible accuracy the heat delivered through the walls of the firebox and the heat delivered through the flues. The general dimensions of interest in this connection are as follows:—

Heating Surface, square feet.

	Radial Stay Boiler.	Jacobs-Shupert Boiler.
In the firebox	179·2	201·9
In the barrel	2805·1	2806·5
Total for both parts of the boiler	2984·3	3008·4

Tests with Oil.—A series of oil-fired tests have been run on each boiler. Three different rates of power have been employed in each series, the rate of fuel consumption ranging from 800lbs. of oil per hour to 2,100lbs. of oil per hour. The total water evaporated from both the firebox end and the tube end of the boilers has ranged from 10,000lbs. per hour to 14,000lbs. per hour, the evaporation per pound of oil being approximately 16lbs. in the tests of lowest power and approximately 14lbs. in those of highest power. In all these tests a surprisingly large percentage of the total work is done by the firebox. This percentage is greatest when the rate of power is lowest. Speaking in general terms, at low rates of power from 45 to 50 per cent. of the total heat transmitted by the boiler is absorbed by the firebox. With increase of power the percentage falls, but the lowest value thus far obtained is approximately 34 per cent.

As the heating surface of the firebox is a comparatively small fraction of the total heating surface of the boiler, it is evident that heat is transmitted from the firebox at rates which are extremely high. For example, results of a number of tests show the evaporation of more than 50lbs. of water per foot of firebox heating surface per hour, which rate of evaporation is equivalent to the development of more than 300 h.p. by the firebox alone. In estimating the significance of these results, it should be remembered that in the experiments the firebox virtually constitutes a boiler by itself, that it had no more water about it than the normal locomotive firebox, and that it could not benefit by the circulation of water from the forward end of the boiler backward into the water legs. The fact that fireboxes subjected to such conditions could be worked at the rate of power stated, is suggestive of new possibilities in boiler design. The full development of these data will make a record of facts with reference to the distribution of work between the firebox and tubes of a modern locomotive boiler which have never before been determined.

The experimental results have not yet been sufficiently studied to permit a final statement to be made concerning the relative performance of the radial-stay boiler and the Jacobs-Shupert boiler. It appears, however, that the absorption of heat by the Jacobs-Shupert firebox is somewhat in excess of that absorbed by the radial-stay firebox, and that taking the boilers as a whole, the Jacobs-Shupert boiler is slightly more efficient.

Tests with Coal.—The oil-fired tests already described have been duplicated by a series of coal-fired tests. The results obtained, so far as they refer to the distribution of work between the firebox and the tubes and to the relative performance of the radial-stay boiler and the Jacobs-Shupert boiler, are in entire agreement with those obtained from oil.

THE TRANSMISSION OF ELECTRICAL ENERGY BY DIRECT CURRENT ON THE SERIES SYSTEM.*

BY J. S. HIGHFIELD.

In his paper of March 7th, 1907, bearing the above title, the author had the privilege of putting before this Institution some facts and theories in regard to this very interesting system. He endeavoured to show that it possessed certain advantages over the alternate-current parallel system which rendered its adoption under some circumstances advisable, and that for certain specified applications the constant-current series motor possesses peculiar advantages. He also dealt with general considerations governing the design under varying conditions.

Since writing that paper matters have progressed. After the most careful consideration, the Metropolitan Electric Supply Company decided to use the series system for supplying their western area, and the plant was put to work in March of last year, and has been running steadily ever since; two sets of winding gear have been constructed, and the Moutier-Lyon System (the largest series transmission yet erected by M. Thury) has been largely extended.

The western area system of the Metropolitan Company is designed ultimately to feed an area containing 300 square miles, the extreme distance by road to the remote points from the power-station at Willesden being about 28 miles. The company hold, and are now working, the Orders in Southall, Hanwell, Brentford, and Acton, and possess bulk-supply powers in the remaining districts to which it is not certain when the opportunity will arise for giving supplies.

Owing to the small load existing in a great part of the district, the important matter was to design a system which

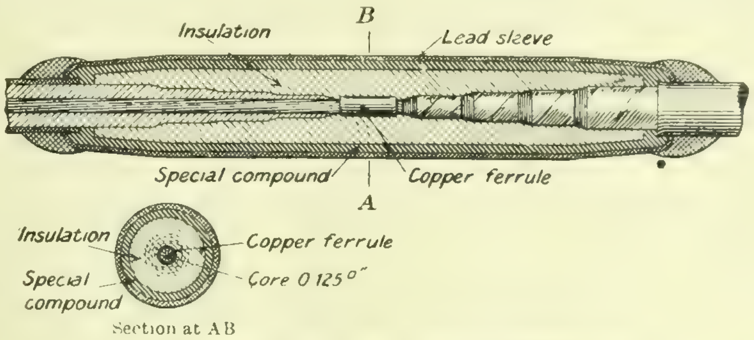


FIG. 1.—JOINT FOR 100,000 VOLT LEAD COVERED CABLE.

would involve the least possible cost in mains and at the same time admit of ready and inexpensive expansion to meet the requirements of a rapidly increasing population. It was also necessary to use a system which, while being inexpensive for short distances, could be readily extended to very long distances. Another consideration to be kept in view was that at some future date it might be advisable to carry the supply to still greater distances. In short, it was realised that a system having these particular advantages might be of great commercial value, and in view of the fact that the immediate cost for the present short distance was not greater than that of other systems, it was decided that the possible future commercial value was sufficiently great to warrant a departure from existing methods.

Portions of the area are already supplied by existing companies and local authorities, some by alternating and some by direct-current systems, and it is contemplated that in time some, or all, of these may think it wise to supplement their present plants with a bulk supply. In such cases it is usually found that it is for a time economical to use the bulk supply for part of the load and to employ the existing plant to supply the peak load. In order to utilise the bulk supply to the best advantage, it is necessary to work it in parallel with the existing plant. In the case of an alternating-current plant it is very difficult to take a supply at a different frequency, and to work the necessary phase-changing motor generator in parallel with the local plant. With the series system parallel running in such cases presents no difficulty.

It was decided to lay mains having a capacity of 10,000 kw. with sufficient reserve in the case of breakdown, and after much

* Paper read before the Institution of Electrical Engineers, at Glasgow, June 12th, 1912.

research it was found that two single-conductor cables, having a core of 0·125 sq. in. section with ½in. of paper insulation sufficient for 100,000 volts direct current, could be laid in iron pipe at less cost than any other system of similar capacity. To provide for continuity of supply in case of breakdown of one of the mains, it was desirable to use the earth as the spare conductor. Further research having shown that this was possible without risk of interference with other electrical circuits, this method, with the consent of the Board of Trade, was decided upon: thus the cost of a third or stand-by cable was avoided.

For the secondary supply the mains are of much less capacity, and can be tapped at frequent intervals to supply small sub-stations for town and village lighting and fairly large power consumers. A somewhat high pressure being necessary for this purpose, it was decided to use 3-phase alternate-current mains at 3,000 volts pressure, and for the low-tension system supplying small consumers a 3-phase 4-wire system at 115 volts pressure between phases. This network showed lower costs and greater convenience than any other. The comparatively high secondary pressure enables an area of about 10 square miles to be worked from each sub-station. Thus in spite of the scattered nature of the demand each sub-station will grow to considerable dimensions, enabling larger plant to be used.

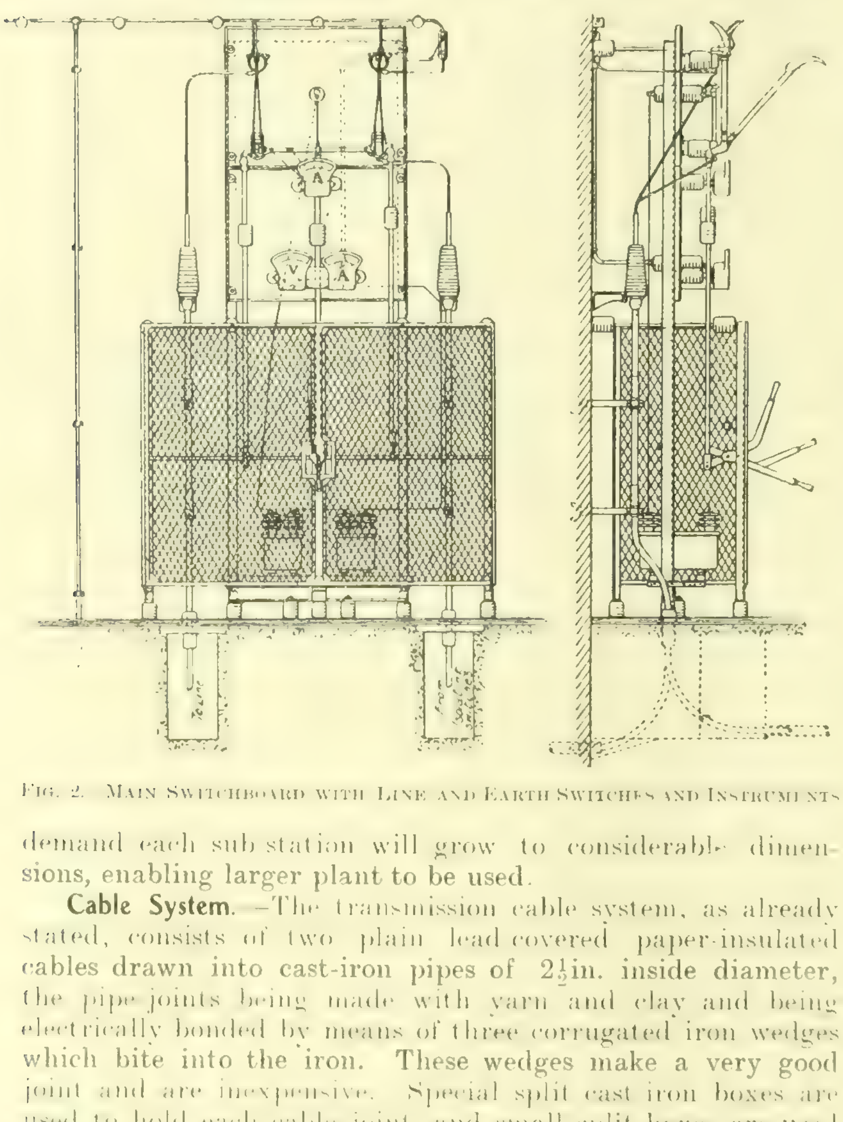


FIG. 2. MAIN SWITCHBOARD WITH LINE AND EARTH SWITCHES AND INSTRUMENTS.

Cable System.—The transmission cable system, as already stated, consists of two plain lead-covered paper-insulated cables drawn into cast-iron pipes of 2½in. inside diameter, the pipe joints being made with yarn and clay and being electrically bonded by means of three corrugated iron wedges which bite into the iron. These wedges make a very good joint and are inexpensive. Special split cast iron boxes are used to hold each cable joint, and small split boxes are used at bends. There are no brick pits or surface covers; the cable is surrounded throughout its length by cast iron; thus the cable is admirably protected. The present system supplies from the power-station to Southall, a distance of about 7 miles.

The joints in the cables are made with paper on a method developed and used by the Metropolitan Company for some years on the 10,000 volt concentric cables, and described by the author in the discussion on a paper by C. Vernier on "The Laying and Maintenance of Transmission Cables."*

These joints are shown in section in Fig. 1. They are made in the following way. The lead is first carefully removed. Steps are made in the paper insulation by carefully unrolling each layer and tearing, not cutting, it off, so as to form four steps. The conductors are joined by a sweated sleeve, and the whole is covered by a paper ribbon, 1in. wide, wound on to the joint off a reel. In this way the paper is never handled, and consequently moisture is not left in the joint. A lead sleeve is then drawn over the joint, and plumbed to the lead sheath of the cable. It is then filled with compound. They are inexpensive, and have proved themselves most reliable.

Each cable length of 220 yards was tested in the factory to 75,000 volts alternating current at 60 cycles, the pressure being applied for 10 minutes; a 6ft. piece of each length manufactured was tested to 130,000 volts alternating current at 60 cycles, which pressure was resisted for about five minutes; the type of joint used was tested up to 150,000 volts 60 cycles without breaking down. After laying the whole length of cable was tested to an alternate current pressure of 20,000 volts 60 cycles for 35 minutes.

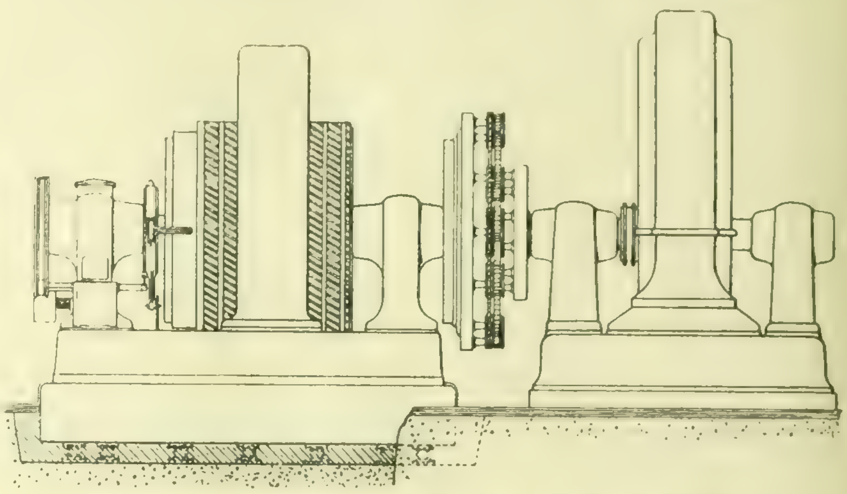


FIG. 3. MOTOR GENERATOR SHOWING INSULATED FOUNDATIONS.

Cable-testing by alternate current is not satisfactory unless a low frequency is employed, and a low frequency necessitates the use of very large transformers in order to supply the charging current: this is particularly difficult where very high pressures are required. Consequently it was decided to test the cables with direct current at a pressure of not less than 150,000 volts. In order to obtain this pressure a special machine was constructed of a similar type to that used by Mr. Watson in the experiments he has described to this Institution, but having a greater capacity. The machine consists of a generator of the Voss type, direct driven by a motor at about 1,000 revs. per minute. The generator and motor are completely enclosed in a cast iron case, the high-tension terminals for the supply to the motor being brought through the case by large ebonite insulators. The case is then filled with nitrogen at a pressure of 200lbs. per square inch. The motor is supplied with current from the small generator, which, of course, owing to its direct connection with the motor, is charged at the full pressure; it is therefore necessary to insulate this generator from earth in the same way as the whole machine is insulated. This generator is in its turn driven by a motor by means of two wooden pulleys and a cotton rope, which provides ample insulation for the maximum pressure given by the machine. Small mechanical defects occurred in the machine and caused delay in carrying out the tests, which, in fact, have not yet been completed. When connected to one cable with its switch gear the machine maintained for periods of about 30 minutes a pressure of 150,000 volts, and for short periods a

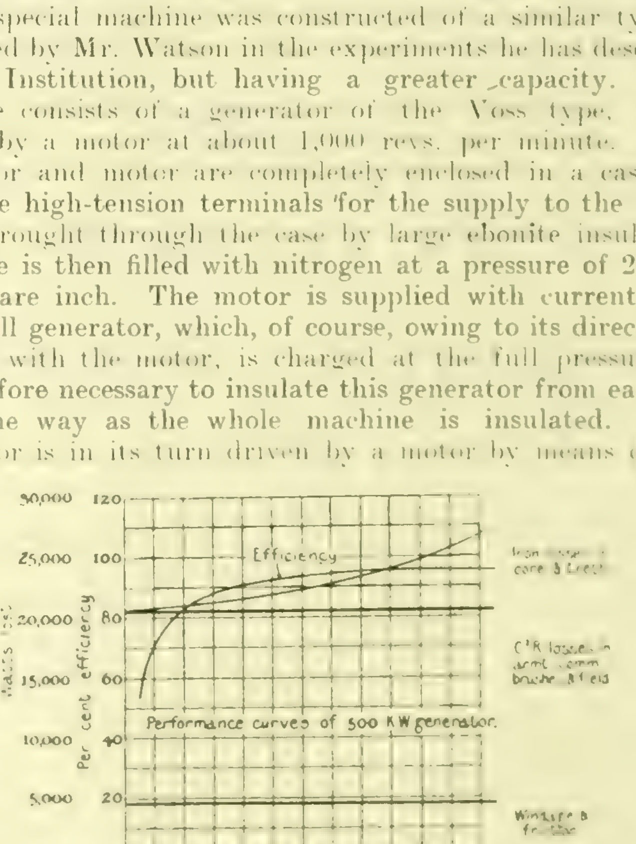


FIG. 4. PERFORMANCE CURVES OF 500 KW. GENERATOR.

* Journal of Institution of Electrical Engineers, Vol. XLVII, page 39, 1911.

pressure of 150,000 volts, the total energy put into the cable and switch gear being approximately 500 watts, this leakage being due to small discharges at various points. The pressures were measured by a single-cell Kelvin-type voltmeter working in compressed air at a pressure of 200lbs. per square inch.

The author regards the construction of this machine as a notable achievement, and thinks that Mr. Watson and the makers are greatly to be congratulated.

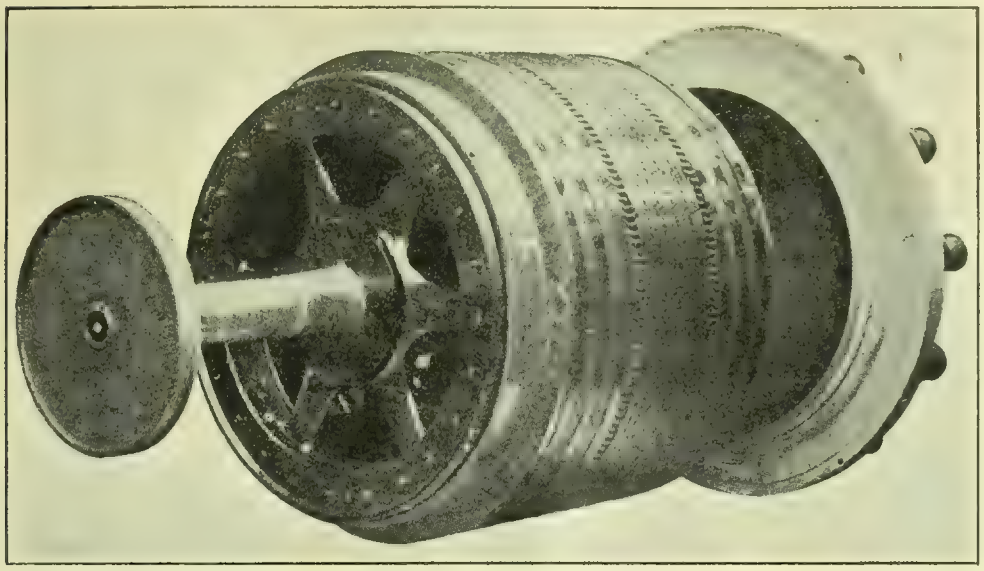


Fig. 5. Armature of 5,000 Volt Continuous-current Generator.

It is proposed to continue these tests with an improved apparatus, as much information is required not only in regard to the insulation of the cables, but also in connection with the machines and foundations. The tests already carried out, together with the experience of the Moutier-Lyon plant, are, the author thinks, quite sufficient to prove that the cable system can be successfully worked at a pressure of 100,000 volts.

Switch Gear.—Each end of each cable is connected to its own switching panel, shown in Fig. 2. The panel contains two switches, one for coupling the cable to the power station or sub-station circuit, and the other for coupling the station circuit to earth. The two switches are interlocked, so that it is impossible to draw one until the other has been closed. The instruments consist of an ammeter in the line, an ammeter in the earth circuit, and a voltmeter to show the pressure between the line and earth; the latter is provided with a switch, so that it can be conveniently disconnected from the circuit. The panels provide for double insulation, the various instruments and switches being carefully insulated with large porcelain insulators from the panels; the frames carrying the panels are again insulated from earth. It is a special advantage of the series system that, with the exception of the cable, it is possible to provide double insulation at all points.

Power Station Plant.—It was decided to drive the first machines by means of synchronous motors supplied with energy from the alternate-current generators already installed in the power station. Later on, when steam-driven direct-current sets are installed, these machines will form a convenient link between the direct and alternate-current systems. There is nothing special about the synchronous motors, which were machines already in the possession of the company. It was for this reason that so low a speed of 200 revs. per minute was chosen for the direct-current generators.

The direct-current generators shown in Fig. 3 have six poles. The commutators are 60in. diam. and 6¾in. long, and contain 1,439 segments. Since the maximum current to be collected is 120 amperes, only two sets of brushes are required. Consequently, not only does the communicator run almost without noise, but the wear is inappreciable. The machines are designed to run sparklessly at any load, but will allow the current to be varied from 70 to 120 amperes. The normal pressure is 5,000 volts: this is the highest pressure for which a machine of this type has, so far, been designed. Therefore the output of the machine at 100 amperes is 500 kw., and at 120 amperes 600 kw. The performance curves of these machines are shown in Fig. 4, and the armature in Fig. 5.

The current is maintained constant by a regulator which serves to regulate the working field by moving the brushes from full to no-load position, and at the same time shunting a part of the field current by means of a diverter. The regulator, shown in the photograph, Fig 6, and in the diagram, Fig. 7, is driven by a small belt from the end of the generator shaft. It consists of a small turbine wholly submerged in oil. The turbine serves to maintain a pressure of about 25lbs. per square inch. In the case containing the turbine is a vertical cylinder in which moves a gate on a vertical shaft through a segment of the cylinder. This gate is immersed in oil, and the supply under pressure from the turbine can be directed to either side, so as to rotate with great force the shaft to which it is attached. This shaft is geared by means of bevel wheels to a horizontal shaft, which acts directly on the brush-rocker. The supply of oil from the turbine is taken through a small piston valve, which serves to distribute it to either side of the gate above mentioned. The position of the main valve is controlled by a solenoid, through which the main current passes, pulling against a spring and controlling a relief valve. It will be seen that the governor is of the relay type, and that any variation in the current through the solenoid changing the direction of the flow of oil brings a very large force into action to move the brush rocker and diverter switch. The rocker is mounted on roller bearings, so that it will move with great ease, and, owing to this and the great force exerted by the regulator, there is very little possibility of failure. In addition to the main spring, there are additional springs to prevent hunting and to provide for the even distribution of load between the machines. The changes in load on the system are not very rapid, and consequently the regulators are not adjusted for regulating at very great speed, but the type of regulator is capable of being adjusted for handling variations from no load to full load taking place in less than one second.

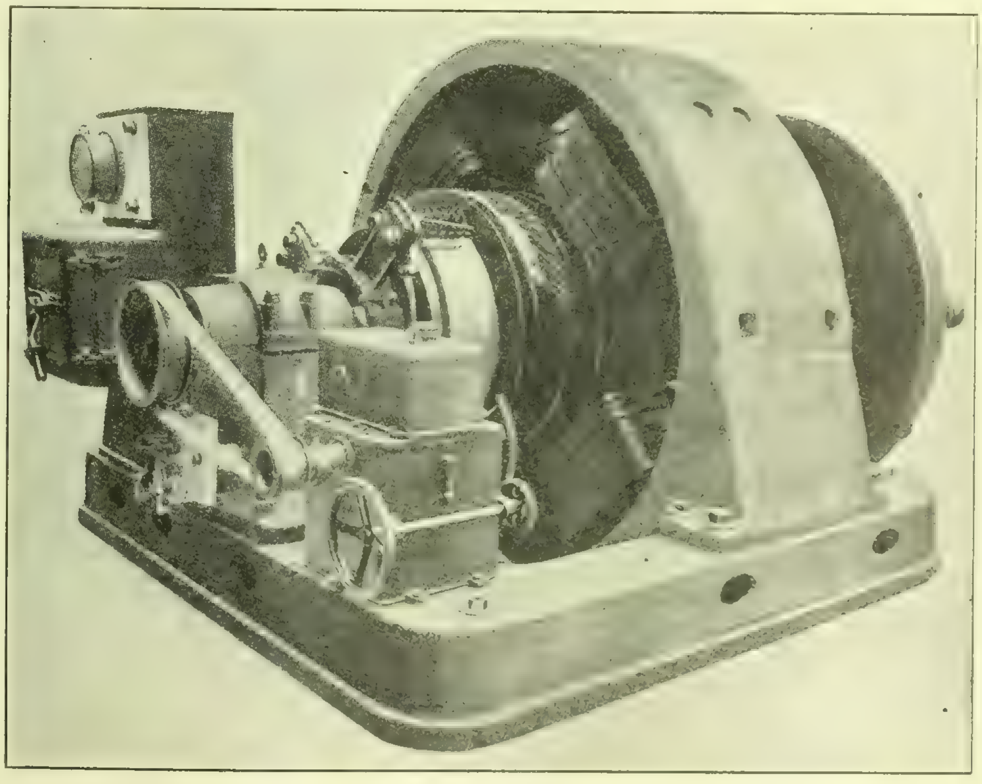


Fig. 6.—The Generator and Regulator.

The generators are driven through an insulating coupling

of the Zodal type, consisting, as shown in Fig. 3, of two discs fitted with pins and rollers for carrying the main forward driving belt and reverse belt, which is necessary to enable the set to be started from the direct-current end and to keep the whole coupling rigid. This coupling has also a slipping member which is essentially a disc form of clutch. This is set to slip when the load on the generator exceeds 25 per cent. overload. If the action of the governor could be made instantaneous this slipping coupling would not be required; but it is a useful device to prevent damage to the generator, and, by slipping, it gives time for the regulator to bring the brushes to the right position to meet sudden changed conditions of load on the system.

The regulators used on these machines are naturally a great improvement on those employed on some of M. Thury's earlier systems, and, although this plant has been running only some nine months, further improvements have been made in the regulators and safety devices, and it is probable that, in consequence of improvements in the generator and regulator design, it will be possible to dispense with the slipping coupling in future sets.

In addition to the regulator each generator is fitted with a short-circuiting switch and operating mechanism, which short-circuits the machine in the event of reversal of direction. This could happen under certain conditions; for instance, if the coupling belt broke on one generator out of several in series, this machine would pull up and reverse its direction; as soon as this occurred the switch would short-circuit the machine and cut it out of circuit. The operating switch shown in Fig. 8 for putting the generator into circuit consists of a four-point rotary switch. This is mounted on a pillar, which also carries a carbon break-switch, which works in parallel with the rotating switch in such a way as to prevent damage to the latter by the arc formed when the inductive circuit of the generator is opened. In addition, the pillar carries an ammeter to show the current given by the machine, and a voltmeter for measuring the volts across the terminals. It was decided to mount the switch pillar on the frame of the machine. This method is a great improvement on the old one of using a separate pillar; it makes a neater job, is less expensive, and is more secure.

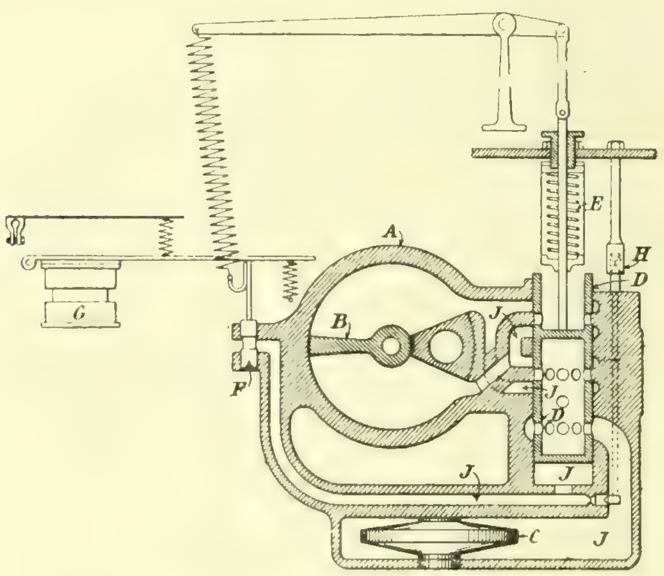


FIG. 7 DIAGRAM OF THE BRUSH REGULATOR.

In addition to these switches on the machine isolating switches are fitted under the floor for the purpose of disconnecting the machine switches from the circuit. These switches are shown in Fig. 9; they are four point switches similar to those fitted on the machines, but having considerably larger spaces. The switch works under oil, and the cast iron box containing the switch is itself enclosed in a cast-iron box, from which it is insulated by large porcelain insulators. These switches have all been tested with a pressure of 110,000 volts alternate current applied for about 10 minutes.

The generators themselves are carefully insulated from earth. The details of the foundations are shown in Fig. 3. The generators are bolted to concrete blocks, which are supported on stoneware insulators embedded in highly insulating asphalte, the space round the beds being filled in with pure bitumen. This makes a very much sounder job, both

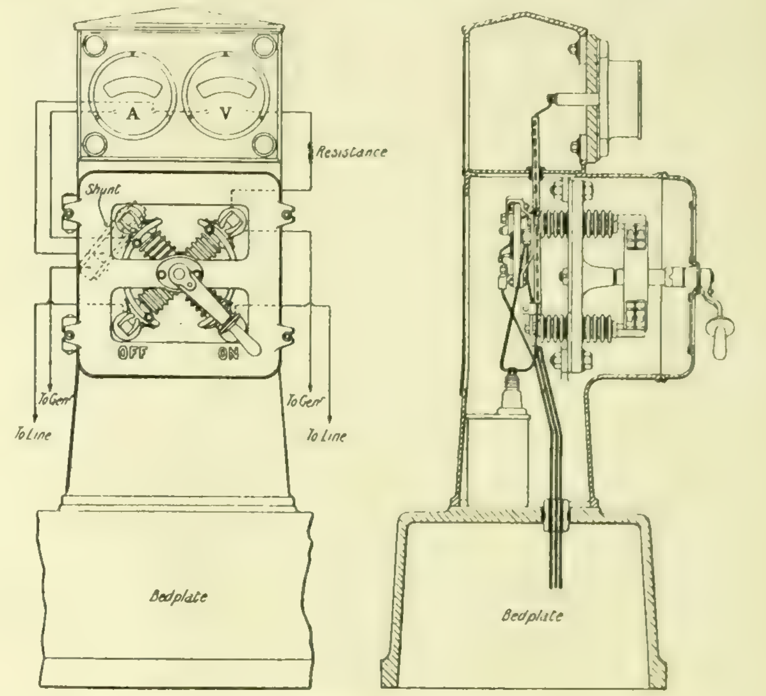


FIG. 8. GENERATOR SWITCH AND INSTRUMENT PILLAR

mechanically and electrically, than the older method of supporting the machines on pot insulators.

The object of the whole design of the cable and gear inside the station is to make it practically immune from either mechanical or electrical breakdown; all live metal is doubly insulated from the point where the cables are attached to the switchboards. The floor itself is constructed of concrete, on which asphalte to the thickness of 2in. is carefully laid. It was necessary to exercise the greatest care in laying the asphalte in order to provide the highest possible insulation. Careful tests were made on the asphalte to ascertain its insulating properties, and experiment indicated that a floor constructed in this way would require many hundreds of thousands of volts to produce a puncture.

In machines designed for such high pressures it is important to limit the pressure that can occur between either pole of the machine and the frame, thus not only reducing the stress on the insulation, but at the same time limiting any possible danger from accidental contact with live parts of the machine. For this purpose a resistance of 0·8 megohm is fitted to the machine frame, the ends being connected across

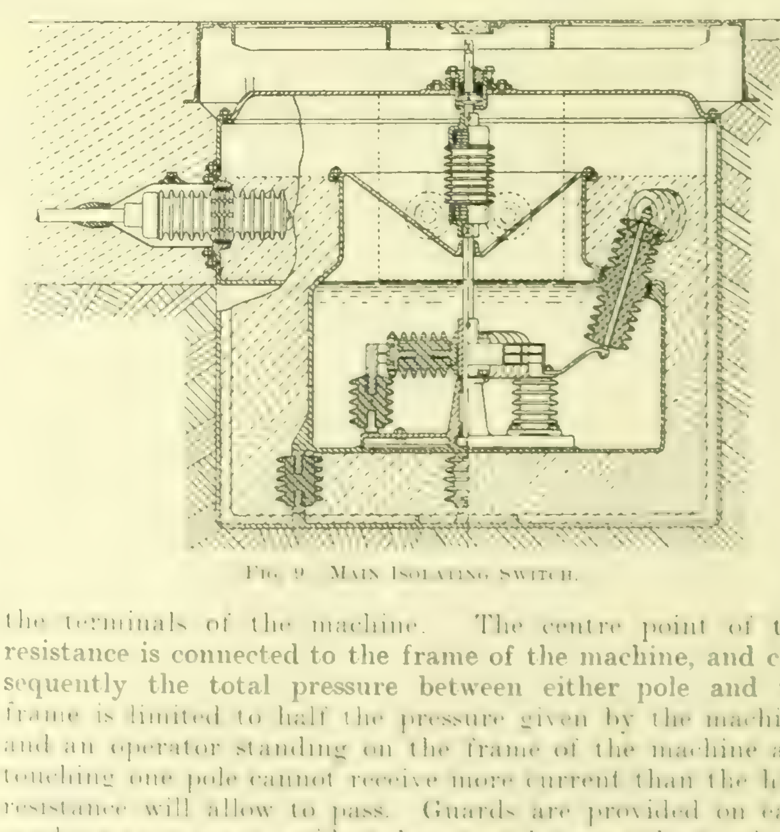


FIG. 9 MAIN ISOLATING SWITCH.

the terminals of the machine. The centre point of this resistance is connected to the frame of the machine, and consequently the total pressure between either pole and the frame is limited to half the pressure given by the machine, and an operator standing on the frame of the machine and touching one pole cannot receive more current than the high resistance will allow to pass. Guards are provided on each machine to prevent accidental contact between the insulated

frame of the direct-current machines and the earthed frames of the alternate-current motors.

Three motor generators are now installed at the power station, two being fitted with alternate-current motors for starting from the alternate side, the third machine being always started by means of the direct-current generator.

Sub-station Plant.—The plant at Southall consists of three direct-current motors—shown in Fig. 10—driving three 250 kw. generators supplying three-phase energy at 3,000 volts 50 cycles. The machines run at a speed of 500 revs. per minute. Owing to the high speed at which these machines run, they are, for their output, smaller, and the commutators are smaller than the generators at the power station. The motors drive the generators through an insulating coupling of a similar type to that used at the power station, but they are not provided with a slipping member. The speed of the machines is kept constant by a regulator of a similar type to that employed at the power station, with the exception that in place of the piston valve being controlled by a solenoid it is controlled by the pressure supplied by the oil turbine. This pressure is balanced against a spring. Since the pressure given by the turbine varies with the square of the speed, a very sensitive speed governor is obtained. Any increase in the speed of the turbine produces an increased pressure, which acts on the piston valve which serves to convey the pressure to one or the other side of the gate which controls the position of the brushes. The motor regulator is provided with a supplementary spring, which prevents shunting in the same way as the springs on the generator regulators. The switch gear in the sub-station is precisely similar to that in the power station, panels of the

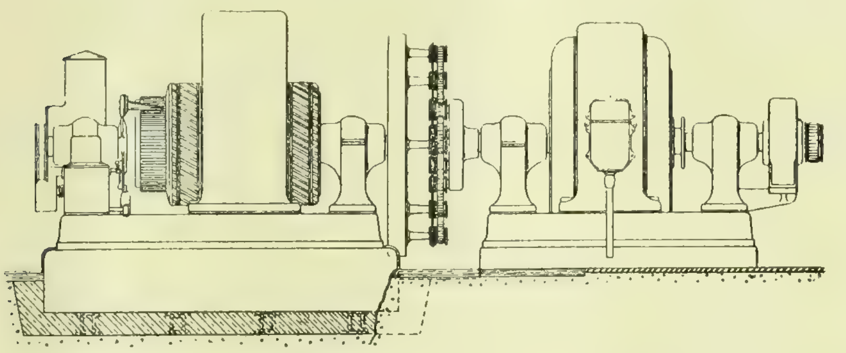


FIG. 10.—MOTOR GENERATOR SHOWING INSULATED FOUNDATIONS.

same type being fitted; the mains are carried to isolating switches, from which cables are laid to the starting switches on the machines, the only difference being that ammeters are not required on the motors, and consequently are not fitted. The generators are connected to the main switchboard, from which the 3,000-volt feeders are carried to the sub-station. The earthing switches are connected to the earth-plates in a similar way to those at Willesden.

(To be continued.)

Rubber from Starch.—A method of producing synthetic rubber in commercial quantities from starch was explained by Prof. W. H. Perkin, of the Manchester University, in a lecture recently delivered before the Society of Chemical Industry. The new process is briefly this. Starch is converted into either of two substances, acetone and fusel oil, by fermentation. These substances are then by chemical means converted into isoprene, the "raw product" from which the ratification rubber is produced. The isoprene can be quickly converted into rubber. Prof. Perkin explained—owing to a discovery made by his colleague, Dr. Matthews—that metallic sodium causes the change to take place very rapidly. A means of producing the acetone and fusel oil had been discovered by Prof. Fernbach, of the Pasteur Institute, who found a germ capable of converting the starch into these substances. Complicated chemical processes which had been carried out in the laboratory were also described. Prof. Perkin exhibited a specimen of synthetic rubber prepared from isoprene nearly 30 years ago by Sir William Tilden, who was present, and he said that even then it had been shown to be capable of vulcanisation—the one real test of its commercial utility. Dr. Otto Helmer, the analyst, had, Prof. Perkin said, verified the result.

THE CORROSION OF STEEL AND ITS PREVENTION.*

BY ALLERTON S. CUSHMAN.

THE problem of the corrosion of steel may be considered from two distinct points of view. On the one hand we might discuss the manufacture of metal specially designed to be slow rusting and resistant to corrosion, while on the other hand we might confine ourselves to a consideration of methods of treatment by the application of protective coatings or in other ways, so that even the usual grades of commercial steels may be made as rust-proof as possible.

It seems to be the general consensus of opinion that the old hand-worked irons which preceded the products of our modern pneumatic processes, possessed a wonderful quality of resistance to corrosion, and it is, therefore, pertinent for us to enquire whether a study of ancient specimens of iron and steel may not point the way to improvement on the modern scale of metallurgical operation.

Before proceeding with this line of enquiry, however, I would like to point out the importance of bearing in mind that the chemical constitution of iron or steel is only one factor of the problem, for the amount and kind of work that a given product receives will profoundly influence its physical character and qualities. We live in a practical age, and it is essential that we should consider our great industrial problems from a practical viewpoint. No sensible person would propose a return to the old hand-worked methods of manufacture, for modern conditions are not conducive to the success of such an industry.

The most ancient specimens of iron that have been studied, as far as I can ascertain, have been recently reported upon by Sir Robert Hadfield, in a paper on "Sinhalese Iron and Steel of Ancient Origin," presented before the Royal Society and also before the Iron and Steel Institute of Great Britain. These interesting specimens taken from the Colombo Museum consist of a rude chisel, a nail, and a bill hook, which date unquestionably from the fifth century, and may, therefore, be said to be about 1,500 years old. Considering that for the larger part of this time these specimens have been subjected to the corrosive influences of nature, they are in a remarkable state of preservation, although showing, as would be expected, some effect of the ravages of time. The chemical constitution of the three specimens was very similar, as shown by the following analyses:—

	Chisel. Per Cent.	Nail. Per Cent	Bill Hook. Per Cent
Carbon	Trace	Trace	Trace
Manganese...	—	—	Trace
Sulphur	0·003	—	0·022
Phosphorus...	0·28	0·32	0·34
Silicon...	0·12	0·11	0·119
Copper	0·90	0·119	0·012

These specimens would, of course, be classified as wrought irons and not as steels, but from the viewpoint of their wonderful resistance to corrosion it is interesting to note that carbon and manganese are absent, with very low sulphur, whereas, according to the standards of modern iron metallurgy the phosphorus content is extraordinarily high. The high silicon content probably represents slag, and if so is not significant. We should expect such a metal to be cold-short and brittle, which it undoubtedly was, but unquestionably material of a very similar constitution could be made to-day in an open-hearth furnace, and subsequently rolled without giving special trouble.

I shall now present some data on some specimens of iron which have been recorded in this country, and which have shown themselves to be extraordinarily resistant to corrosion. The first specimen is an old wrought nail known to have been used in the construction of the Masonic Hall, at Richmond, Va., in 1807. This specimen came into my possession in 1908 with the information that it had been found half-driven into the old oak studding so that the head and half of the shank was exposed to the weather for the major portion of its century of service. It was in a marvellous state of preservation, the

* Paper read before the annual meeting of the American Iron and Steel Institute, May, 1912.

forged edges of the head remaining quite sharp and unrusted. The analysis is remarkably similar to that of the old Sinhalese wrought irons and is as follows: Carbon, 0·03 per cent.; manganese, 0·06 per cent.; sulphur, 0·013 per cent.; phosphorus, 0·25 per cent.; silicon, 0·121 per cent.; and copper, 0·027 per cent.

The next specimen is an old band or sleeve which was attached to a bronze cannon captured from the British by the American troops at the storming of Stony Point, in 1779. The cannon has been used for monumental purposes and has stood for many years exposed to the full force of the elements. The iron sleeve has been wonderfully rust-proof and the old hammer marks made when it was forged are clear and sharp. The analysis follows: Carbon, 0·010 per cent.; manganese, 0·010 per cent.; sulphur, 0·005 per cent.; phosphorus, 0·07 per cent.; silicon, trace; and copper, 0·080 per cent. Here again we find low carbon, manganese, and sulphur, with a tendency towards high phosphorus.

Three iron links taken from the famous old link suspension bridge which was built in 1809, at Newburyport, Mass., and known as the Essex-Merrimac chain bridge, were shown. This bridge was in continuous use until the late summer of 1909, having completed practically a full century of service. The links have proved themselves wonderfully resistant to corrosion under most severe conditions near the seashore. The analyses of three separate links are as follows:—

	Link A.	Link B.	Link C.
	Per cent.	Per cent.	Per cent.
Carbon	0·05	0·12	0·04
Manganese	Trace	Trace	0·01
Sulphur	0·007	0·01	0·006
Phosphorus	0·032	0·07	0·02
Silicon...	0·019	0·047	0·028
Copper...	0·043	0·018	Trace

The above analyses were made in the research department of the American Rolling Mill Company. Material from the same bridge has been analysed and reported by Prof. A. P. Mills, of Cornell University, who concluded that the excellent resistance to corrosion was due to copper, as all the sample links worked on at Cornell showed high copper. The links in which copper was absent were just as long-lived as those which contained nearly one-half a per cent. of that element. In this connection it may be noted that the copper content of Sir Robert Hadfield's old irons was variable, and Sir Robert wrote me as follows, under date of March 19th, 1912: "As regards the effect of copper in adding resistance, all the specimens are more or less alike; whereas, if this element has any influence the nail ought to have shown less corrosion than the others. I think, therefore, you are right in not accepting the theory that the addition of copper will enable iron and steel to resist corrosion."

Returning to the analyses of the Newburyport links, we find again a tendency to low carbon, manganese, and sulphur, with moderately high phosphorus.

A sample of galvanised, corrugated roofing was found on the Isthmus of Panama, where it had been abandoned by the French many years ago. The corrosive influences are so severe on the Isthmus that samples of this material were passed from hand to hand among metallurgists in this country, as an interesting exhibit of durable metal. Although the durability may be largely due to the heavy spelter coating, it is more than doubtful if our modern steel galvanised sheet would last as long in that atmosphere. An analysis of the metal is, therefore, of interest, and is as follows: Carbon, 0·02 per cent.; manganese, 0·04 per cent.; sulphur 0·061 per cent.; phosphorus, 0·427 per cent.; silicon, 0·12 per cent.; and copper, 0·031 per cent. The sample was inclined to be brittle, as we should expect with such high phosphorus; but again we find low carbon and manganese, with sulphur moderate.

It should be stated that the above examples of ancient irons have not been selected in order to prove any point whatsoever. They represent every authentic case of extraordinary corrosion resistance of which I have been able to make a record. I do not even make the claim that these records prove anything, but I submit them to your attention as being highly suggestive and interesting. I have long believed and have so stated in many publications that extreme purity in respect especially to manganese and sulphur is a contributing influence towards durability in a material whether it be classified as iron or steel. I am, of course, not unmindful of the metallurgical difficulties in the way of manufacturing steel free from manganese unless the carbon is also to be eliminated. If the carbon is eliminated, we are, in my opinion, dealing with iron and not with steel, no matter by what process the metal has been manufactured. From the viewpoint of resistance to corrosion, manganese might be tolerated if sulphur was absent, but here again we run into a metallurgical difficulty.

It has recently been shown in some papers presented before the Iron and Steel Institute of Great Britain, that the tendency of steels to corrode increases with increasing carbon up to a certain maximum. This is in accordance with the electrolytic explanation of the mechanism of the reactions which produce corrosion. The electrolytic explanation of corrosion is now very generally accepted by scientific men.

To sum up the conclusions that have been reached as the result of many scientific studies of corrosion, it may be said that homogeneity or freedom from at least excessive segregation is an essential to a high degree of corrosion resistance in either iron or steel. One way to reach homogeneity is to allow little or no impurities to be present to produce segregation, as is done in the manufacture of the very pure irons which are now made in open-hearth furnaces.

The manufacture of commercially pure irons in open-hearth furnaces on the large scale of operation usual in modern steel-making was only a short time ago considered a metallurgical impossibility, and even now in Europe there are metallurgists who do not believe that it can be done. Not so long ago a leading British engineering journal stated editorially that the making of open-hearth metal free from manganese was an impossibility, but even if it could be done the metal would be superoxidised and unfit for rolling or for use.

For many years we have been accustomed to turn to Norway and Sweden, when iron of exceptional purity was desired. Now it can be obtained even purer in this country on a larger scale and for less money. In my opinion the accomplishment of the manufacture of iron of extraordinary purity in the open-hearth furnace should be noted and honoured, as it would undoubtedly have been had its development taken place on the other side of the Atlantic. From a patriotic point of view, if for no other reason, it is satisfactory to reflect that Europe is now beginning to consider this country as a source of supply for the purer irons for which for many purposes there is a growing demand.

We must admit, however, that the manufacture of slow rusting iron or iron alloys is a speciality only to be undertaken by specialists, and that the great mass of steel tonnage that goes into structural material calls for protection from corrosion. We are all more or less familiar with the strenuous efforts that have been made in recent years to improve the methods of coating iron and steel with protective coatings of other metals such as zinc, lead, copper, and various alloys. It is evident that the great mass of steel structural material that goes into service, must depend upon paint coatings for its protection. We all know that there are hundreds of "best paints" offered in the market for iron and steel work. As the only perfect test of paint is a service test, considerable time must elapse and money expended before we can find out the facts. We are also frequently confronted with other difficulties. If, for instance, we have concluded that red lead is a safe prime coater, we are suddenly confronted with the fact that all red leads are not alike and also that the conditions and methods of application are important factors.

I am glad to be able to report that great progress has been made as the result of the application of scientific investigation and principles to the general subject of protective coatings. As the result of a systematic series of exposure tests on steel panels erected at Atlantic City under the auspices of the American Society for Testing Materials, we now know how to select intelligently materials for prime coating iron and steel. We have been able to divide pigments, roughly at least, into classes known as "inhibitors" and "stimulators" of corrosion. The discovery that certain substances when laid out in an oil film on the surface of steel actually accelerate, while others check or retard corrosion, gives us a basis of scientific selections on which to write specifications for protective paints.

A HEAVY GRINDING MACHINE.

WE illustrate herewith the latest addition to the extensive line of grinding machines manufactured by the Churchill Machine Tool Company, Ltd., Pendleton, Manchester. This is a cylindrical grinding machine of massive construction in which are embodied many novel features. The machine will grind work up to 20in. diam., and has a capacity in the stays for shafts 10in. diam. by 14ft. long. Its general appearance is shown in Fig. 1. With a machine of this size it is desirable to so locate it in the shop that a crane may have a clear run over it for the purpose of lifting work in and out of the machine. To this end it has been so arranged that the drive is entirely self-contained. The simple coupling of a motor to the coupling shown in Fig. 2 causes the whole of the motions on the machine to be driven. This arrangement does away entirely with overhead works, which is especially desirable in machines of such large capacity.

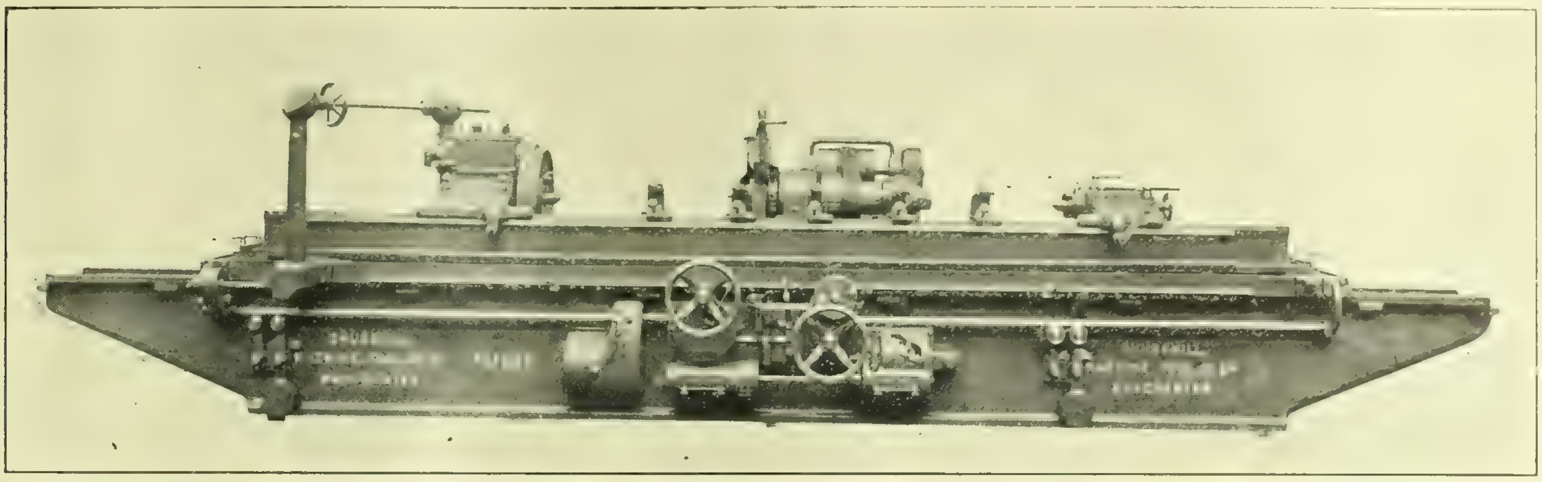


FIG. 1.—HEAVY CYLINDRICAL GRINDING MACHINE, CONSTRUCTED BY THE CHURCHILL MACHINE TOOL CO., LTD., PENDLETON, MANCHESTER.

The grinding wheel is 26in. diam. by 4in. wide, and the machine can also be arranged for a wheel 32in. diam. It is driven direct by belt from the motor coupling shaft through a sliding bracket mounted at the rear of the wheel head, and capable of adjustment to maintain tension on the belt between the top driving pulley and the cone pulley on the spindle. Tension is maintained on the vertical belt from the motor by means of a pulley mounted on the head. The shaft in the sliding bracket, motor coupling shaft, and the tension pulley all run on ball journal bearings. The upper shaft at the rear of the machine, which is driven from the first motion shaft through gears and shown in Figs. 2 and 3, transmits motion to the sliding table and work through gear boxes, and also drives the pump. The drive to the table gear box shown to the right in Fig. 1 calls for no special comment, this being a special design on all heavy grinders made by this company. Incidentally we may say that the gear box has 16 changes of speed, and the table is driven through steel reversing wheels which give an exact reverse, and also in the drive is introduced a slipping clutch to absorb all shock at the point of reverse.

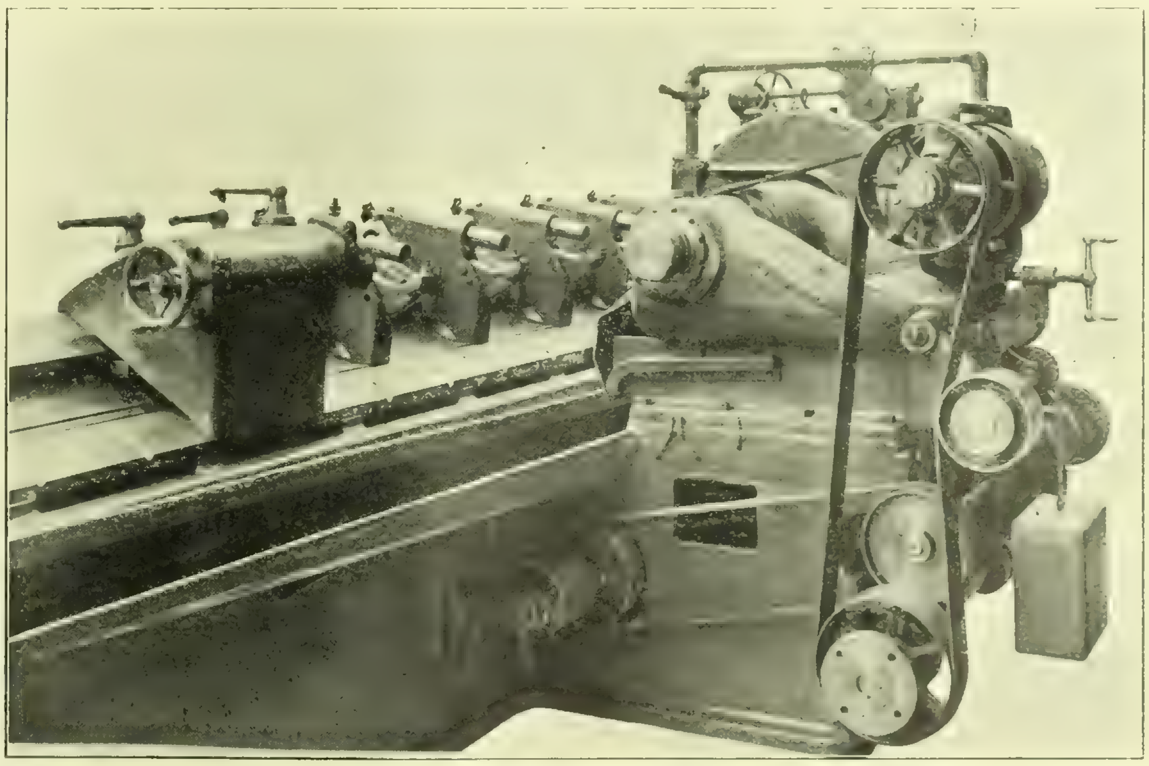


FIG. 2.—HEAVY CYLINDRICAL GRINDING MACHINE.

The work drive is a special feature on this machine. The motion is transmitted by belt through the body into box shown to the left of the large hand wheel in Fig. 1. A friction clutch is arranged in this box for the stopping and starting of the work. From this clutch motion is transmitted to the long shaft in the front of the body, this shaft being carried by the sliding table. From there the motion is transmitted to the work head driving box through the vertical pillar on the table. The adoption of this vertical pillar in the work drive solves the difficult problem of driving a work head which is adjustable lengthwise on the table, and which table has also a swivelling motion for the grinding of taper work, without the necessity of using universal joints, and therefore gives a smooth and powerful drive under varying conditions. All the changes of speed are made in the gear box. Special attention has been given to the design of the wheel spindle and head. These are of especial massive construction, the bearings being of bronze, adjustable for wear, and are self-oiling; they are so proportioned that long life and accuracy are easily assured, but a glance at Fig. 2 shows the massive proportions of this head.

The machine is adapted for the grinding of straight and taper shafts and also crank shafts. It is provided with 16 work speeds, 16 table speeds, and three wheel speeds. Embodied in the design is also the firm's patent quick hand motion to the wheel head. This is a device for the moving of the wheel to or from the work quickly, and is entirely additional to and independent of the fine feed with which all grinding machines are necessarily fitted. On large grinding machines it is often impossible for the operator to see when the wheel is brought into contact with the work, especially on work of large diameter. To overcome this difficulty there is embodied in the patent quick hand motion an indicator which, when once set, shows the operator the position of the wheel in relation to the work. This device is of proved utility, and is being extensively adopted on large grinding machines. The total net weight of the machine as illustrated is 13 tons.

LOCATION OF FEED WATER ADMISSION IN LOCOMOTIVES.*

THE general practice followed in feeding locomotive boilers with water is to inject it through one of four different locations, viz.: (*a*) on the front course of the barrel with individual checks about both side centres; (*b*) on the same course with duplex checks on the bottom centre; and (*c*) on the top centre, as well as (*d*) with individual checks located on the back head of the boiler, provided with internal pipes discharging the water near the front tube sheet.

The common practice is to have feed water enter the boiler in a solid stream, at a low temperature. We think it is pretty well conceded that, on account of feed water being cold and at a lower temperature than the water in the boiler, the uneven temperature causes an undue contraction and expansion of the firebox sheets and bottom flues, these conditions causing, according to local conditions, leaky boilers, premature damage to materials, and also expense in remedying these defects.

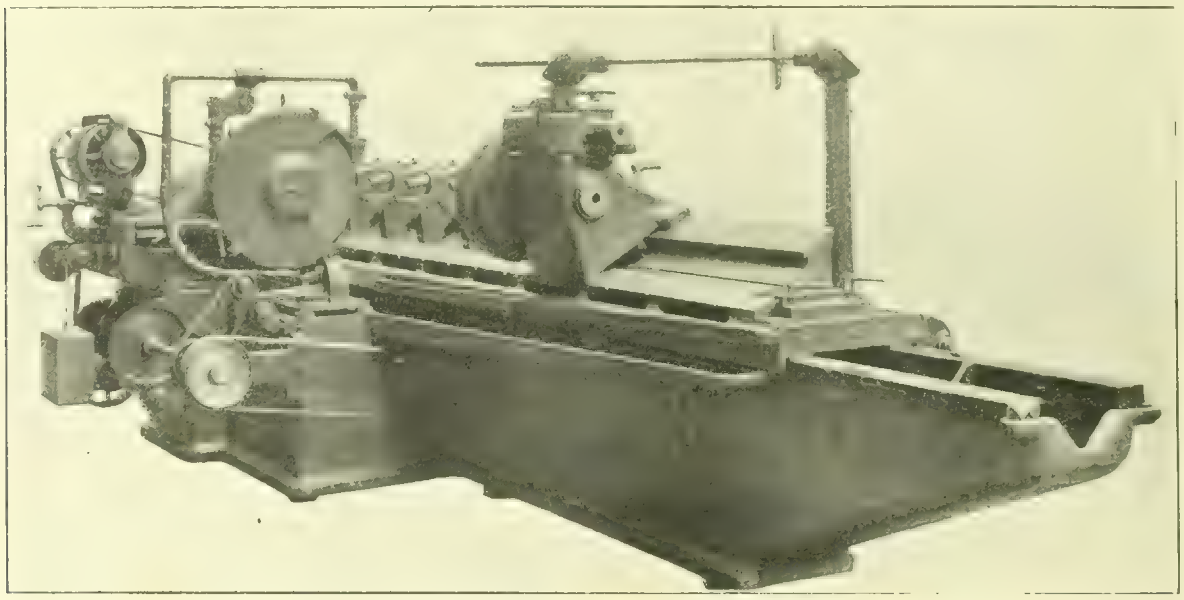


FIG. 3.—HEAVY CYLINDRICAL GRINDING MACHINE. (See p. 769.)

Some roads use a deflecting plate on the inside of the boiler in order to deflect the water up over the flues after it enters the boiler, thereby preventing the deposit of scale on the inside of the shell, between the shell and the flues, which is a source of some trouble. This shows some improvement, but still curtails the life of fireboxes and does not prevent engines from leaking. Another device used to some extent is the upturned elbow in the boiler check. An upturned elbow with a contracted nozzle has been found to be a simple and effective device for equalising the temperature of feed water, but, as near as we can find out, it only brings about a difference of 15° between the temperature at the top and bottom of the boiler.

A more recent device for delivering feed water to a locomotive, and a radical move in the location of boiler checks, is the Phillipps check, with which the feed water is delivered in a solid stream in the steam space. One railroad has 14 consolidation engines equipped with the Phillipps double boiler checks, and it is said to be an improvement all around over the old method of boiler feeding.

There is also on the market another device, known as the Seddon boiler feed device, which was designed and patented by Mr. C. W. Seddon, superintendent of motive power of the Duluth, Missabe, and Northern Railway. This device presents an entirely new idea. The feed water is discharged into the steam space in the shape of a spray; these small drops absorb the heat and fall to the surface of water in the boiler at a uniform temperature. This method causes incrusting solids contained in the water to separate before mingling with the boiler water, and these solids are collected in a sediment pan, thereby leaving sheets and tubes free of scale. Another feature of this sediment pan is that the feed water is held in suspension before being allowed to mingle with water below, until it overflows the flange at the rear of the pan; thus giving double assurance of the feed water becoming heated to the same temperature as water already contained in the boiler. One railroad has 96 engines equipped with the Seddon boiler feed device, and the records, it is said, show some very gratifying results from its use.

Without advocating any special device, or location for admission of feed water, we wish to say that it remains an undisputable fact that this location should be such as to eliminate entirely the damage to boilers, which is caused by delivering water of lower temperature than that contained in boiler. While the water raised by an injector will rise in temperature, tests made years ago show that it will drop to the bottom of the boiler because of its specific gravity. Enginemen often are careless in the handling of injectors, not realising the damage caused by a flow of cold water. Another point which we wish to bring out is the fact that 90 per cent. of boiler failures can be traced below the boiler checks. Our idea is to feed the water in the boiler just as high as we can and spread it as much as we can; if any of the members will try this out they will be very much impressed with the results obtained.

To determine the most desirable location for the admission, a 10 minutes' temperature test was conducted under three of the methods of feeding and like conditions, when the results shown by the accompanying diagram and tables were obtained.

The top thermometer was located at the water line and connected to the firebox, while the bottom one was connected about 18in. above the foundation ring. It will be observed from the sheets that the greatest temperature changes took place when feeding through the bottom of the barrel, because the bottom thermometer dropped 16° Fah. and the top one

Temperature Test on D., M. & N. Consolidation Locomotive No. 312, August 16th, 1911.

(A) Check valve in steam space.
(B) Check valve in water space on centre line of boiler.
(C) Check valve allowing water to flow into bottom of boiler through angle valve (D).
(X) Thermometer on top water line.
(Y) Thermometer on bottom water line just above mud ring.
(Z) Thermometer in feed pipe.

Check Valve.	C open. A closed. B closed.			B open. A closed. C closed.			A open. B closed. C closed.		
Thermometer.	X	Y	Z	X	Y	Z	X	Y	Z
	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.
Before injector was opened	374	352	—	376	352	—	375	352	—
At end of 10 minutes of open injector	377	274	171	376	328	172	376	334	174
Three minutes after injector was closed	376	268		377	317	—	376	346	—
Difference in temperature between time of opening injector and 3 minutes after closing	—	84	—	—	35	—	—	6	—
Difference between thermometers Y and X before injector was opened		22		—	24	—	—	23	—
Difference between thermometers Y and X 3 minutes after injector was closed	—	108	—		60			30	

* Abstract of report of committee, D. G. Foley, chairman, presented before the [illegible]

dropped 95° Fah. Feeding through the sides, the bottom thermometer rose 23° Fah. and the top one dropped 46° Fah. Feeding through the top, the bottom thermometer dropped 2 Fah. and the top one dropped 12° Fah. The fourth method was not tested. It was not in question because it is generally conceded to be an undesirable location for engines operating on bad water, due to the internal pipes becoming full of scale, and they are also subject to breakage, causing damage to fireboxes. Feeding with duplex checks through the top of the boiler was found the most desirable location, because of developing the least fluctuation in temperature around the firebox and tubes, and engines which gave considerable trouble from leakage when fed from the bottom or sides of the barrel were almost free from it when fed from the top, under like conditions, and operating over the same section.

When the water was fed from the bottom the fireboxes except the crown sheet were necessarily renewed yearly. Since feeding from the top locomotives on the same section of road, operating the same train and using the same water have doubled the service with a correspondingly less amount of firebox attention.

The tubes also have given the best results in service and their mileage has been increased 50 per cent. between renewals, when feeding from the top. Cleaning plugs are required close

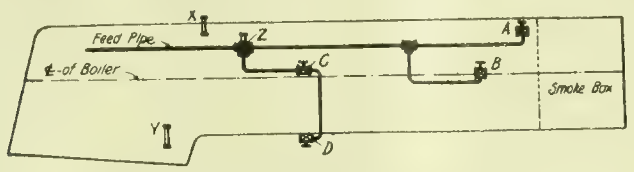


DIAGRAM OF FEED-WATER TEMPERATURE TEST.

to the duplex check when it is applied to the top because of deposits of foreign matter over and between the tubes at the front tube sheet end, and if this location is not kept clean the tubes will leak in the front tube sheet joint.

In our opinion feeding from the top, near the front tube sheet, is the most desirable location for locomotive boilers, because we find the mud and scale better distributed throughout the barrel of the boiler and less lime and magnesia deposits are found adhering to the pressure side of the firebox plates than when feeding from any other location, and this appears to be why better results are obtained.

Temperature Effect around Fireboxes.

Introducing water from the bottom, sides, and top of locomotive boilers with a No. 9 Gresham injector on full and boiler pressure 130lbs.

Minutes. Test.	Test A. Feeding from Bottom. Ther. Temp. Bottom.	Top.	Test B. Feeding from Side. Ther. Temp. Bottom.	Top.	Test C. Feeding from Top. Ther. Temp. Bottom.	Top.
1	255	347	196	347	222	346
2	256	346	197	342	220	345
3	258	334	199	335	220	343
4	258	313	203	322	219	342
5	255	295	206	313	219	339
6	252	281	210	307	219	339
7	247	270	213	303	219	339
8	244	262	216	302	219	340
9	242	258	218	301	219	338
10	239	252	219	301	220	334
* Drop	16	95	—	46	2	12
* Rise	—	—	—	—	—	—

* Degrees.

A 2,400 h.p. Stumpf Engine.—A Stumpf engine of the mid-cylinder exhaust type has been in use since February, 1912, at the Rombacher Iron Works, Germany. This is the most powerful unit of its type ever built. The cylinder diameter is 43in., and the stroke 52in. The engine runs at 120 revs. per minute, giving a piston speed of 17·2ft. per second. The regulation is, it is stated, exceptionally exact. No appreciable drop in speed can be detected even with the highest loads, nor can any over-speeding be discovered when the load is suddenly removed. The engine is used to drive a 24in. rolling mill. It is coupled directly to the rolling mill shaft and has a flywheel weighing 70 tons.

NEW PROCESSES FOR CHILLING AND HARDENING CAST IRON. *

BY THOS. D. WEST.

(*Concluded from page 744.*)

Chilling Produced by Sand-faced Moulds.—It was desired to ascertain whether a chill could be created by air under pressure when prevented by a sand coating from getting directly at the hot surface of a casting. To this end the writer devised the method illustrated in Figs. 7, 13, and 14, the two last of which were experimented with at both foundries. In using the mould shown in Fig. 7 an intervention core was employed, as seen on the left side. This core was about ¼in. thick and well wired so that the head pressure of the molten metal could not break it, when the plates R and S were pulled out together after pouring the moulds. The first test of this series demonstrated the porosity of a sand mould's surface. Although this was a very hard core, the 50lbs. air pressure used carried the air through it, and would have blown all the metal out of its mould had not the valve been closed. The companion bar withstood the air pressure for the reason that the plate S had formed a chilled crust on the face of the metal in the mould before its removal. Further tests with these cores under different air pressures showed that the cores prevented any chilling action, while on the other hand the air was very effective on the opposite side.

The difficulty with this core method lies in the fact that

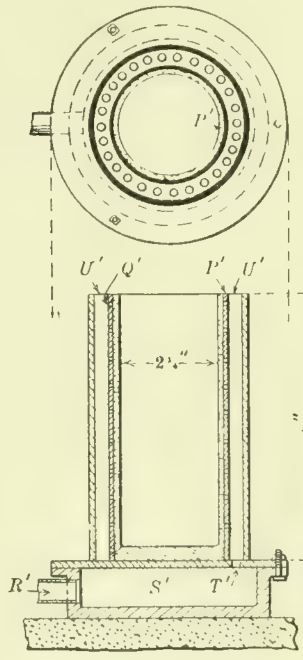


FIG. 13.—PIPE SAND-COATED AIR-CHILLING MOULD.

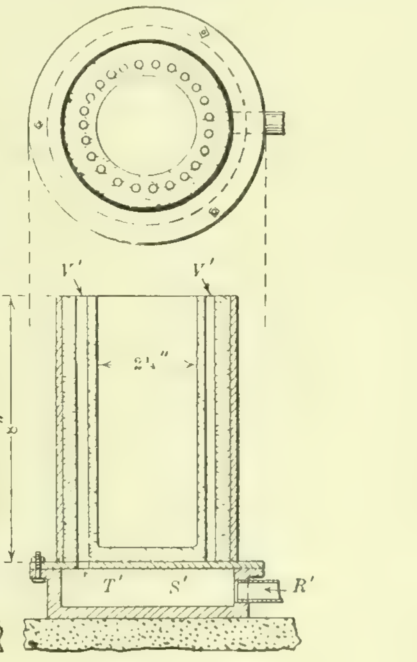


FIG. 14.—ALL-SAND AIR-COOLED MOULD.

air under sufficient pressure to penetrate the core and carry off heat in time to create a chill will pass clear through the metal when the latter is still in a liquid or semi-molten state. This led to the designing of the method seen in Figs. 13 and 14. By a study of the sand-coated pipe P′, it can be seen that any pressure up to 200lbs. and over can be employed without causing the air to impinge against the molten metal, while at the same time it can be more effective than the core itself in conveying heat to its outer surface and then to the atmosphere. The sand coating used on this pipe was but ⅛in. thick, and thoroughly dried. To carry off the gases from the sand the iron pipe was closely perforated with $\frac{3}{32}$in. holes, as at Q′.

Air under 60lbs. pressure entered at R′ to the chamber S′ and passed up through the holes T′ surrounding the pipe P′. The air in the chamber U′ was free to absorb heat from the pipe P′ and to carry it rapidly to the atmosphere. The moulds were poured without any cope or covering, care being taken to fill them only within ½in. or so from their tops. In about 10 secs. after pouring the mould, the air was admitted and kept in action until all the metal was thought to have solidified. A fair illustration of results is seen at M′, Fig. 10. An all-sand moulded, non-treated companion bar was always cast from the same ladle that poured the treated bar. A sample of this is seen at N′ on the right of M′.

* Paper read before the American Society of Mechanical Engineers.

There is little doubt but that the pipe P′ acted as a chilling agent without the use of air, as there was only ⅛in. thickness of sand between it and the face of the casting. In fact, a test made without the air showed that the pipe aided the chilling, since it gave a density to the crust of the casting. Again it is to be kept in mind that as the diameter of the casting was only 2¼in., its contraction would not be sufficient to create a visible space between its outer body and the face of the mould, as is generally created in casting chilled rolls, car wheels, &c. Because a chill would be created by this method as seen at M′, is no positive evidence that air passing through the inside of a hollow roll or car-wheel chiller, &c., would create a deeper chill.

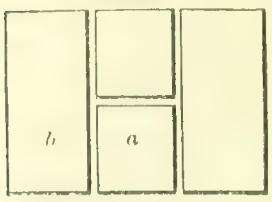


FIG. 15. ILLUSTRATING RETARDATION OF FLOW OF HEAT CAUSED BY JOINTS.

In the all sand mould, Fig. 14, which was also dried, the air passed up through holes T′, which were ¼in. diam. and about the same distance apart, all around the circumference, as seen by the plan view. The air escaped freely around the top at V′. The holes T′ had but about $\frac{3}{16}$in. thickness of sand between their inner exterior and the face of the mould. Castings produced by this method showed a dense exterior or crust of from ⅛in. to ⅜in. thick, and in some instances were slightly mottled. Only in one case was there any display of chill, and this was of an irregular character, ⅛in. to ¼in. thick, created inside of a grey crust about ⅛in. thick. In reality this was an example of inside chill, one of the factors sought in these experiments being to learn if by such methods it could be produced at will and if it was controllable. It was intended also to form holes as at V′ with very thin pipes drilled closely full of $\frac{3}{16}$in. holes, and if a steady pressure of 100lbs. to 150lbs. of air could have been secured, further efforts to learn the practicability of obtaining an inside chill with such, or similar, methods would have been tried.

Study of the principle embodied in Figs. 7, 13, and 14 will suggest ideas and ways and means by which grades of soft iron, aside from chilling iron, can be made more dense or crust-hardened; also by which castings or sections of castings may be cooled to prevent contraction cracks and shrink holes.

Effect of a Joint, or Space, on Transmission of Heat.—It is evident that in constructing chillers to be cooled by air, &c., sufficient consideration has not been given to the question of transmission of heat. An excellent article by Carl Hering on "The Flow of Heat Through Furnace Walls"* might be read with advantage in connection with this paper. Its author offers among other features the illustration seen in Fig. 15, with the following comments: "Moreover, the writer noticed recently in an electric furnace that the temperature of the brick at *a* in the sketch was considerably cooler than at *b*—the difference was so great that it was easily noticeable to the touch. This was no doubt due to the joint which separated the one from the inside of the furnace."

The principle illustrated in Fig. 15 is similar to that involved where such spaces exist as at K, Fig. 4, which greatly retard the absorption by the chiller of heat from the castings. It all emphasizes the utility of filling such a space as K with a heat-absorbing medium that can be moved swiftly from an inlet to an outlet to carry off heat for cooling, hardening, or chilling purposes. It is believed that a study of the conditions will show that a rapid passage of air or other heat-absorbing media through a space as at K, Fig. 4, is very efficient for the purpose of extracting and conveying heat quickly both from the interior and exterior body of a hot casting.

Tests of Heat Conductivity of Sand, Iron, and Air.—These tests were made for the purpose of ascertaining the heat conductivity of moulds, composed of a sand body, and again of iron, as in chillers, instead of having a heat-absorbing medium impinge directly against the hot surface of a casting with exits for the rapid escape of the medium to the atmosphere. The tests for sand conductivity were made by constructing a dry sand core 1½in. square by 7½in. long, with a ⅝in. port hole lengthwise through the centre. This core had part of the outer face of one end cut away to provide an exit for the air forced through the interior of the core. When placed in position the core appeared practically like the chiller seen on the right of Fig. 8. The tests for iron conductivity were made by having a chiller with solid face and other conditions of its position, as seen on the right of Fig. 8.

In conducting these tests for the sand and iron, as well as with air impinging against the surface of the hot castings, only one end of the flask for twin moulds was used. The mould L was formed with the same pattern, Fig. 5, as used for making all other bars. The moulds were poured by a direct flow of the metal from the lip of the ladle. The top of the bars having been covered with sand and a plate to confine their heat so that the thermometer used would read correctly, the air flow was started down the interior of the core or chiller and found an escape at the opening X and up the sides I to the top around Y, thence to the atmosphere, as in Fig. 8.

To obtain the temperature of the escaping air, the bulb of a thermometer capable of registering 500° was held directly above and resting on the surrounding sides of the open space at Y. An assistant recorded the time and the varying temperatures of the escaping air at the first 15 secs. and 30 secs., and afterwards each minute, as seen by lines 5 and 6 of Table II. At the end of 10 mins. the bulb of the thermometer was held at one end of the inlet pipe after it was disconnected, in order to obtain the record of line 4. At the end of 2 mins., and after the plate and sand had been removed from the top of the bar, the bulb of the thermometer was placed so that its frame end rested on the middle of the top end of the bar for 3 mins., that the natural radiation of heat from the bar, seen in the last line of Table II., might be recorded.

The variations in pressures and temperatures seen in lines 3 and 4 are due to changes in the speed of the compressors and to the amount of air being taken from the tank for other

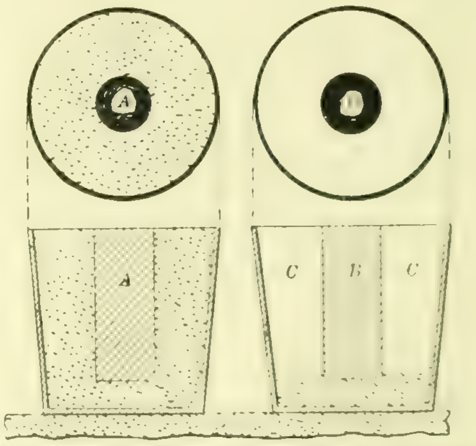


FIG. 16. SPECIMEN BAR CAST IN OPEN SAND AND AFTERWARDS FREED OF SAND AND SURROUNDED BY WATER.

purposes. The seeming inconsistency of the temperature dropping at the start to only 80° and 94°, while that which came from the tank of the compressors is 134° and 124°, as in line 4, is due to the temperature of the core and chiller at the start being that of the atmosphere, as seen in line 2. For these reasons, the in-going air is for a few moments reduced in temperature.

TABLE II.—*Temperature Tests made of Three Casts, October 23rd, 1911.*

		Sand Core.	Chiller.	Face of Bar.
1	Body cooled with air			
2	Temperature of atmosphere, degrees Fah.	52	52	52
3	Pressure of air used, lbs.	55	50	50
4	Temperature of tank air, degrees Fah.	134	124	130
5	Temperature escaping air at 15 sec.	80	94	—
6	Temperature escaping air at 30 sec., degrees Fah.	100	112	200
7	Temperature escaping air at 60 sec., degrees Fah.	116	142	290
8	Temperature escaping air at 2 min., degrees Fah.	120	162	310
9	Temperature escaping air at 3 min., degrees Fah.	126	182	290
10	Temperature escaping air at 4 min., degrees Fah.	130	182	270
11	Temperature escaping air at 5 min., degrees Fah.	134	178	264
12	Temperature escaping air at 6 min., degrees Fah.	136	176	252
13	Temperature escaping air at 7 min., degrees Fah.	138	172	236
14	Temperature escaping air at 8 min., degrees Fah.	140	170	222
15	Temperature escaping air at 9 min., degrees Fah.	140	166	200
16	Temperature escaping air at 10 min., degrees Fah.	138	162	192
17	Heat radiated from the bars 15 min. after they were poured, degrees Fah.	208	172	70

A study of Table II. shows the sand to be the least effective as a conductor of heat, while the iron is not very much better when compared to the conductive power of air applied

* Metallurgical and Chemical Engineering, September, 19[illegible].

directly to the surface of the hot bar, as recorded in the last column, line 17, where it is seen that from the moment the air impinged upon the surface of the hot bars its temperature rose, and in less than 30 secs. after the mould was poured reached 200°.

Further Experiments upon Direct Application of Heat-absorbing Media.— The following experiments were largely responsible for patents granted May, 1912, and pending on direct-cooling and treatment processes by pressure or suction for chilling, hardening relieving internal strains in castings, &c. These are to be utilised wherever a space can be formed adjacent to a casting, either artificially or by the natural expansion of the chiller and contraction of the casting, also when the hot surface of a casting is freely exposed to the atmosphere or not surrounded by its chiller.

Two twin moulds were used for the experiments, each having intervention plates placed as at S, Fig. 7. After the two moulds were poured from the same pouring basin, and a crust was formed on the face of the bars, the two plates were quickly and simultaneously removed from the mould,

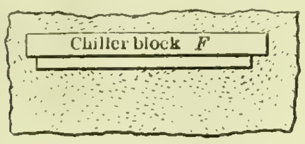


FIG. 17.—MOULD FOR CASTING A CHILLED PLATE.

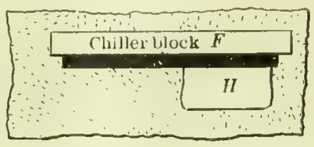


FIG. 18.—MOULD, WITH SPACE H FOR MOLTEN METAL.

forming spaces as at K, Fig. 4. For the first experiments air of 20lbs. to 30lbs. pressure was admitted to one of the pipes, W, Fig. 7, and conveyed directly to the space created by the removal of the plates S through orifices 1 to 8 in the bore of the chiller. The fast darkening of the top edge of the face of the treated bar, compared with that of the companion bar which was cooling naturally, gave good reason to expect considerable difference in the depth of chill and in the density or hardness of the chilled face of the two bars. The intervention plates S were 2in. wide by $\frac{1}{8}$in. thick. A slight coating of oil was given the faces of these plates next the bars to prevent their uniting with the metal, and to permit their being drawn out of the mould quickly at the right moment.

Experiments with Cooled Air.—Experiments were further made with air cooled by passing through a pipe coil surrounded by a mixture of two parts of cracked ice and one part of salt. The temperature was reduced thereby from 85° to 45°, but no greater chilling effect was discovered in the six tests conducted on this plan than in the first series with the air as it came from the tanks. This is as would be expected, since the reduction of the temperature of the air by 40° is so small in amount compared with the temperature of 2,000°, which it may be assumed the surface of the molten bar would have. An increase in the pressure or volume of the air would easily discount all that could be accomplished by lowering the temperature of the air to 40°, as noted.

Superiority of Air Over Metal Chillers.—Tests were also conducted with air at higher pressures. At 50lbs. pressure a chill was created for a depth of $1\frac{1}{8}$in. in the air-cooled bar, whereas the naturally cooled bar had a depth of chill of only $\frac{1}{8}$in., as seen respectively at K′ and L′ in the bars G′ and H′, Fig. 9. The grey body of both of these bars displayed a fine texture bordering on a mottled state. This test removed every possible doubt of the efficiency of air-cooling for chilling. Half a dozen or more of these tests were made before taking up others, and they all verified the results of the first tests.

Later on tests of the same character were conducted by having titanium and vanadium in the metal. Two sets of these samples are shown at W′ and X′, and again at Y′ and Z′, Fig. 10. Here, as in G′ and H′, Fig. 9, the air was by far the most effective in chilling. The air-treated bars showed about $\frac{7}{8}$in. depth of chill, whereas their companions had but about $\frac{1}{8}$in. chill.

In line with these tests a series was made to determine whether air chilling was more effective than chilling by means of a solid chiller held in close contact with its bars. Samples of bars contrasting these two methods are seen at I′ and J′, Fig. 9, the air-cooled bar at J′ having $\frac{3}{4}$in. chill, while the other at I′, produced by the close contact chiller bar, has $\frac{9}{16}$in. chill.

Chilling of iron must be done before all the eutectic of the metal assumes a solid form or any graphite is formed, and with like irons the quicker and more penetrating the cooling action, the deeper and harder the chill. The direct application of a heat-absorbing medium to the surface of a hot casting, as soon as contact with its chiller is broken, or a crust is formed, provides means at a critical moment which cannot but be of material benefit in increasing the utility of cooling, densifying, or chilling and hardening of chillable and other grades of cast iron. It also provides means for securing a softer or lower chilling and using a stronger iron in car wheels, &c., obtaining at the same time the desired depth of chill.

Practicability of Continuing Chilling after the Metal Solidifies.—It has always been thought that in chilling iron the action ceased the moment the molten metal solidified. The writer's late experiments show that such is not the case, but that with chillable iron there exists a period of 20 secs. to 30 secs. or more after the formation of a crust before any graphite is separated out. This was demonstrated as follows: At A, Fig. 16, is shown a casting poured in open sand, while at B it has been freed of its sand, this being done about $2\frac{1}{2}$ mins. after the casting was poured. Space C was then immediately filled with cold water, kept running until the casting was cold. Upon breaking the specimen it was found, if of a high chilling iron, to be a homogeneous body of all-chilled or white iron with a discoloured or reddish centre. But if, instead of surrounding the specimen with water at the expiration of $2\frac{1}{2}$ mins., there were allowed to lapse 3 mins. to $3\frac{1}{2}$ mins. before doing so, the crust exhibited graphitic formation, while the interior body was found to exist in a mottled or all-white state, showing the inside chill to have been created.

Two New Principles in Chilling.—These tests indicate the existence of two laws positive in their action, as follows: First, cooling or chilling is effective in creating or continuing a chill in a casting for a period of 20 secs. to 30 secs. after its molten metal has solidified. This permits a continuation of chilling with castings like rolls and car wheels which break contact with their chillers immediately after the formation of their chilled crust. Second, graphitisation having once taken place in the crust or body of a hot casting, no sudden cooling can restore the carbon to its original combined form, and only by remelting can it be so transformed as to have a chilled or white iron structure.

Difficulties Encountered in Creating an Internal Chill.—With chillable irons any founder can produce a casting having an outside chill with a grey interior; but to produce one having a grey exterior and inside chill, or white body, is another proposition. Mention has already been made of the sensitive nature of such a production. The variable conditions that must be considered and controlled to an exactness in order to create a perfect inside chill are as follows: (*a*) Temperature of the pouring metal; (*b*) temperature of the sand; (*c*) atmospheric conditions and temperature; (*d*) nature of the iron; (*e*) size of the specimen; (*f*) temperature of the water; (*g*) whether the specimen remains stationary in its mould to be cooled or is removed or moved about in a body of water.

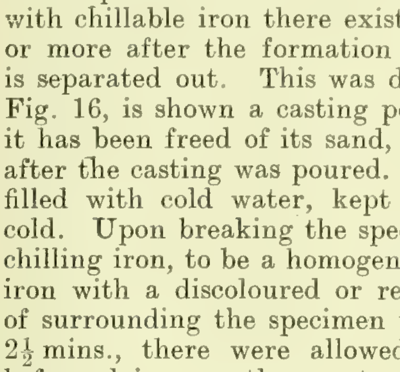


FIG. 19.—CHILLED PLATE WITH HEATING BLOCK ATTACHED AND SEPARATED CASTING.

When it is stated that, for an example, with the size of specimen seen in Fig. 1, there are only some 5 secs. to 10 secs. during 1 min. when the perfect inside chill can be created, all students of this problem will realise that at present it is a hit-and-miss process. The writer has deemed it necessary to give all the above facts, so that anyone undertaking to produce an inside or internal chill will not be led to affirm it an impractical achievement. It will be well to state that the writer is of the opinion that when one can obtain a medium chilling iron in place of the extremes, such will be best for creating an internal chill.

Internal Chilling Tests with High Silicon and Soft Casting Mixtures.—Tests made by the writer, assisted by Mr. W. J. Strangward, superintendent, at the Forest City Foundry and Manufacturing Company, Cleveland, Ohio, showed that the high silicon in their light work mixtures caused graphitisation to take place almost immediately, if not at the moment, of solidification, as the specimens exhibited no white or even mottled internal structure in any of the tests.

Other tests made at the Madison Foundry Company, of Cleveland, upon supposed non-chilling mixtures with silicon around 2·0 and sulphur under 0·08, showed that these percentages of silicon and sulphur marked the division between chilling and non-chilling irons of the usual good working grade of foundry mixtures. The tests showed that if internal chilling could be produced with mixtures having from 2·0 to around 3·0 per cent. silicon, there was a possibility that something was wrong with the physical or the chemical properties of the mixtures.

A feature of these tests with soft irons was that they showed a swelling in place of a shrinkage in their taps; also a greater fluidity of metal, or length of time before solidification took place. Although these bars were but about 1¼in. diam., they remained in a liquid state about as long as specimens 2¼in. diam. cast of the chillable car wheel metal.

Standards for Internal Chilling Tests of Hard and Soft Grades of Iron.—Founders and engineers interested in castings for machining, &c., might well utilise internal chilling tests as a means of determining whether there is anything in the chemical or physical properties of mixtures likely to cause chilled edges, hard spots, &c., instead of waiting for this to be found out in the machine shop. The writer would suggest as a standard for such tests bars 1¼in. diam. and 6in. to 8in. long for mixtures ranging from 1·2 to 3·5 per cent. silicon, and bars 2·4in. diam. of similar length for mixtures having from 0·5 to 1·25 per cent. silicon. In making internal chilling tests care must be exercised not to immerse a specimen in water until a self-supporting crust has been formed, or an explosion of liquid metal may occur. The use of a fair amount of intelligence and caution will guard against such dangers.

Internal Graphitisation of a Chilled Crust.—Being desirous of knowing whether, after the greatest depth of a chill is created, it is possible for the intense heat of an internal body of semi-molten or solid metal to decrease the depth of a chill by graphitisation, the writer conducted the following experiments: An open sand mould having a chiller block F was used, as seen in Fig. 17. The open sand mould was formed by plate patterns ⅝in. and ⅞in. respectively, both being about 5in. deep and 16in. long. After the plates were poured and solidified, a space was dug out for about half their length, as seen at H, Fig. 18. This space was filled with molten metal, left in close contact with the chilled plates until cooled to a dark colour. The molten metal was of regular car wheel mixture, and the tests were conducted at the National Car Wheel Company's plant, Cleveland, Ohio.

Tests were made with the plates at different temperatures from that at which the molten metal would fuse the face of the plate, down to temperatures at which the plates were of a dark colour. Upon removing these plates and body blocks of metal from the moulds, the chilled plates would be separated from the blocks of metal and broken at about the points J and K, Fig. 19, to display any contrast that might exist due to the treatment. Only in one case was the plate inseparable, and in this instance the plate and block were broken by a heavy drop block.

In all of these experiments a drawing of the chill in depth was displayed by reason of the hot molten metal causing a graphitisation of the chilled face abutting it. The experiments made with the hottest plates showed the greatest effect, and such as to produce about a 25 per cent. graphitisation of the chilled plates face that abutted the hot metal. This effect was exhibited by a fairly uniform decrease of the graphitisation down to the coldest plates, which showed but a slight effect of the treatment.

The Institution of Gas Engineers. — The Institution of Gas Engineers, at its recent annual meeting held at the Royal United Service Institution, Whitehall, elected Mr. Corbet Woodall as president for the ensuing year, which marks the jubilee of the institution.

AUSTRALIAN RAILWAYS.*

BY THE HON. J. G. JENKINS.

In dealing with Australian railways, it may be necessary to refer for a moment to the country's location, extent, physical features, and climatic conditions. We have a continent island, lying at the other end of the world, having an area of about three million square miles and a coast line of over 12,000 miles, with for the most part a fringe of hills or low mountains not far from the coast, with vast plains and tablelands broken by occasional hills in its expansive interior, with a variety of climate, tropical, semi-tropical, and temperate, a rainfall varying according to locality from 5in. to nearly 200in., rich soil, and glorious sunshine. Such, in brief, is Australia, with a population of 4½ millions of people, or only one and a half for every square mile of land, while here in the United Kingdom we have 366 for every square mile. These are facts which have to be noted when dealing with a country's railways.

The first railway was started in New South Wales in 1850 by a private company, but the discovery of gold in different parts of Australia about this time caused a general rush of nearly every able-bodied man to the goldfields, so the private company were not able to complete their railway. The same thing happened with one or two private companies in Victoria about the same time, and in both colonies appeals were made to the authorities, and the lines were taken over and completed by the respective Governments, so it is more than likely that the State-owned railways of Australia are the result of the gold discoveries, for from these early experiences other lines were proposed and constructed by the Governments of the different States, and the national system has grown up with the population. A few private lines have been built, but they have mostly been purchased by the Governments. So, in speaking of Australian railways, it is generally understood that one means Government-owned lines.

For many years the railway growth was very slow. In 1855, five years after the commencement of the first line, there were only 23 miles in all Australia, and during the next 16 years, up to 1871, there were only 220 miles more added. From 1871 to 1891, however, 9,000 miles were constructed, and each year since has added to the mileage, until on the 30th June last year there were about 17,000 miles of Government railways, which had cost about £155,000,000, or an average of a little over £9,000 per mile. When this is compared with the great expense of railway construction in this country, it is easy to see that the money spent on railways in Australia is bound to earn a good return as population and settlement increase.

Some of the Australian lines have been rather expensive, the dearest one being from Melbourne to Bendigo, 100 miles, which was built just 50 years ago at a cost of £48,000 per mile. On the other hand, many lines have been built in the different States at less than £2,000 per mile, and I believe one or two lines in West Australia have only cost about £1,000 per mile. These cheap lines have been the means of opening up and developing large tracts of country which would otherwise have remained unoccupied. The money for the construction of the railways has been mostly raised by loan in this country, each particular State dealing with its own lines and becoming responsible for the money borrowed. The mileage, cost, and earnings of the railways in each State are of special interest.

New South Wales has 3,760 miles of Government railways, which have cost £51,000,000, or an average of £13,550 per mile. The gross earnings last year were £6,042,000, and after paying working expenses and full interest on capital, there was a surplus to pay into the State Treasury of £754,000. This was not an exceptional year, for during the six years ending June 30th, 1911, there was a net surplus of over £3,000,000.

In Victoria there are 3,528 miles of railways, which have cost £44,250,000, or an average of £12,500 per mile. The gross earnings for the year ending June 30th, 1911, were £4,900,000, and after paying working expenses, interest on

* Abstract of paper read before the Royal Society of Arts, May 21st, 1912.

capital, and over £100,000 for pensions and gratuities, they had a net profit of £283,000, and for the six years ending June 30th, 1911, they had a net surplus of over £900,000.

South Australia has 1,457 miles of railways, which have cost £12,660,000, or an average of £8,700 per mile. The net surplus last year was £312,000, and for the last six years it was £1,388,000.

Queensland has 4,248 miles of railways, the most of any one State; they have cost £27,300,000, or an average of £6,425 per mile. Total revenue for year ending June 30th, 1911, £2,882,000; net surplus, after working expenses and interests, £163,500; net surplus for the previous year, £218,000. For some years previous the returns had not been sufficient to pay full interest after working expenses.

Western Australia constructed its first railway in 1879, for the development of the copper mines in the Northampton district; since that time the discovery of rich mineral fields has been a great impetus to railway construction. Up to June 30th, 1911, there were 2,633 miles of Government railways open for traffic; they had cost £12,000,000, or about £5,000 per mile, being the cheapest in any of the States. The gross revenue for the year was £1,844,000, after paying working expenses and interest on capital, leaving a net surplus of £224,500, and for the six years ending June 30th, 1911, £884,000.

Tasmania has 463 miles of railways, which have cost £4,000,000, or an average of £8,650 per mile. Tasmania is the only State that has not in recent years been earning a net surplus over and above working expenses and interest on expenditure, but her losses have been small in comparison with the profits in the other States, and the prospects of further traffic over the railways there are encouraging.

Taking the railways in the Commonwealth as a whole, the net surplus over working expenses and interest on capital for the last six years has been over £4,200,000. It seems, therefore, that there need be no doubt about the safety of the money lent to Australia for railway construction.

When Australia's indebtedness is referred to as so much per head of the population, without explanation it looks as if it was a debt-ridden country; but when it is explained that out of the entire indebtedness of between 250 and 260 million pounds, 25 per cent. of it is lent by its own people, whose knowledge of the security is first-hand, and that 155 million has been spent on railways which have paid back to the revenue in surplus profit an amount of over £700,000 each year for the last six, the national debt appears in a different light. Besides this, wharves, waterworks, electric tramways, and other public undertakings are returning a fair rate of interest and increasing in value each year.

The Australian States have adopted a somewhat uniform system so far as the administration of their railways is concerned. Prior to 1888, New South Wales railways were vested in the Minister for Works; in that year an Act was passed to place the control under Railway Commissioners, in order to free them from political influence. Three Commissioners were appointed, but the triple-headed control did not prove altogether satisfactory, so one Chief Commissioner was appointed under an amended Act of 1906. In Victoria, even at an early date, the necessity for removing the control from political influence was felt, and in 1883 Commissioners were appointed by Act. Queensland and South Australia adopted the same system in 1888. Western Australia in 1902 followed the example of the eastern States, and placed its railways under the control of a Commissioner. In Tasmania, where the Government railways are not extensive, the control was, until recently, vested in a Minister, but the Act passed last year followed the example of the other States, and placed the control under a Railway Commissioner.

No one can doubt the wisdom of placing the control and management of the railways under Commissioners instead of allowing them to remain under political control. Of course, railway matters are still discussed in Parliament, for no line can be constructed without an Act authorising it; money can be voted only by Parliament, and important regulations and alterations of rates have to be laid on the table of the House for a time before they become effective. All this gives members who represent railway districts ample opportunity of mentioning real or supposed grievances.

Time will not permit of my dealing with the engineering and other difficulties in the construction of the railway. From what was previously stated, that a fringe of hills or mountains in many places separates the coast from the interior, it will be seen that much expense and skilful engineering were necessary for the construction of many of the lines. Special mention might be made of those leading out of Sydney, west over the Blue Mountains, north over the Hawkesbury River, and south through the Bulli Pass. The Toowoomba line in South Queensland, and the Cairns line in the north, were by no means easy to construct; neither was the line leading through the hills from Adelaide towards Melbourne. Of course, there are no curves on the Australian lines so sharp as they are supposed to be on American tracks, where the brakesman on the back car is said to be able, while going around the curve, to light his pipe from the engine-driver's fire. Some of the Australian curves are sharp enough, however, occasionally to give the passengers the sensation of a real sea voyage.

When the first line of railway was authorised in New South Wales, the Colonial Office sent out a dispatch urging the adoption of the 4ft. 8½in. gauge; but the engineer was strongly in favour of a 5ft. 3in. gauge, and it was started on that basis. Victoria and South Australia also started on that gauge. There was a change of engineer in New South Wales before much work was done, and the new man reverted to the original suggestion of 4ft. 8½in., and all the railways in New South Wales have been constructed on that gauge, while all Victorian lines are 5ft. 3in. gauge. South Australian lines are partly 5ft. 3in. and partly 3ft. 6in. All the lines in Queensland, Western Australia, and Tasmania are 3ft. 6in., while the lines taken over by the Commonwealth from the South Australian Government are also 3ft. 6in. gauge, so at the present time Australia unfortunately has three different gauges—3,760 miles, 4ft. 8½in.; 4,151 miles, 5ft. 3in.; and 8,815 miles, 3ft. 6in. gauge.

The question of adopting a uniform gauge has been discussed for years, and the inconvenience and annoyance to travellers under the present system are frequently mentioned, and generally magnified. The great bar to the adoption of a uniform gauge is the heavy expense in the alteration of the roadway and in the rolling-stock. The cheapest system to adopt would be the 3ft. 6in., but that is not likely to take place. The next least in expense would be the 4ft. 8½in., as all the roadway of the 5ft. 3in. would answer by moving the rails, and many of the cuttings and tunnels even on the 3ft. 6in. would be wide enough for the 4ft. 8½in. line. I notice, by recent reports, that the Commonwealth Government have decided upon this gauge for the transcontinental line from Port Augusta to Kalgoorlie. This will mean a break of gauge at each end of the line, unless South and West Australia alter their gauges accordingly, which is not likely for some years to come.

By the transfer of the Northern Territory from the South Australian Government to the Commonwealth the Federal Government have become the owners of two railways, one from Port Augusta to Oodnadatta, a distance of 478 miles, and the other from Port Darwin to Pine Creek, 145 miles; both lines are on the 3ft. 6in. gauge. These lines, 623 miles in all, have cost £3,420,000, or about £5,500 per mile.

The general understanding on which the Northern Territory was transferred to the Commonwealth was that the Federal Government should construct two transcontinental railways, one connecting West Australia with the east by constructing a line 1,050 miles long from Kalgoorlie to Port Augusta, the other to connect the Northern Territory with the south by building a line about the same length from Pine Creek to some point on the Port Augusta line.

The route of the first of these lines from east to west has been agreed upon, the survey made, and work is soon to commence. Unfortunately there appears to be some misunderstanding over the proposed route for the Northern Territory line. The estimated cost of the construction of these two transcontinental lines is between four and five million pounds each, or, roughly speaking, about £9,000,000;

this, added to the $3\frac{1}{2}$ million liability on the lines already taken over by the Commonwealth, will amount to £12,500,000.

From purely a railway point of view, it is not likely that these lines would prove, for some years to come, payable undertakings. There are, however, two strong reasons for the work. In the first place, all military authorities for years have urged the necessity of these lines for defence purposes, more especially the line to connect Port Darwin with the south, thus affording the opportunity of direct communication with a naval base in the north, where it would be most likely to be needed in time of attack. The second strong reason more particularly for the north to south line is that the Commonwealth, having taken over the Northern Territory, have on their hands 335 million acres of practically undeveloped and unoccupied land, nearly four and a half times as much as the United Kingdom with its population of 45 million, while this vast territory is populated by about 1,000 whites, less than 2,000 Chinese, and a few thousand aborigines. This vast tract of land can only be properly settled and developed by opening up means of ready communication and transport, and Australia is now realising this fact more clearly than it did years ago; and those who have watched the aggressive progress of the Eastern countries, with their overcrowded millions, must see the necessity for speedy development and settlement in Australia.

The great prosperity of Australia during the last few years has given a decided impetus to railway construction, and to-day there are more miles of railway in course of construction, and projected, than at any previous time in its history. Many of these lines, in Queensland, Western Australia, and South Australia, are being cheaply constructed as feeders to main lines, and to open up the pastoral and agricultural lands.

In addition to the Government railways, there are about 1,200 miles of private-owned lines in Australia, about half of which are used for passenger as well as goods traffic, while the other 600 miles are used chiefly for carrying minerals and timber. The capital cost of these lines is between three and four million pounds.

The electric tramways of New South Wales belong to the Government, and in South Australia the Government principally control them in conjunction with the municipal authorities. In the other States the tramways belong to private companies, but will eventually become the property of the corporations. Melbourne has the cable tramway system, and, owing to its expense in construction, it has not extended to the surrounding suburbs to the same extent as the suburban railways have, which the Victorian Government now propose to electrify.

There has always been a division of opinion in reference to the advisability or otherwise of State-owned railways. While, generally speaking, Australians themselves are in favour of the system, there are still some exceptions, who think it would have been better to have kept to private enterprise. From many years' experience in Australia, and from an intimate acquaintance with the working of the railways in one of the States, and a general knowledge of the others, my opinion is that, taking into consideration that the Governments were the owners of the land principally to be developed and settled, and that the settlement could not be effectually carried out without means of transit, the interest of the public has been best studied and preserved by the State-owned system.

It must not be considered, however, that there are no difficulties or dangers in connection with State owned railways. Before the appointment of Railway Commissioners in the different States, the political danger was an apparent one. By placing the construction and control of the railways under Commissioners with extensive powers, this danger has, to a certain extent, been obviated. There is also the danger of strikes, and, although not as likely on the Government lines as on private ones, there is no absolute certainty that they might not take place. There was in 1903 a railway strike in Victoria which was of a somewhat serious character. This strike was brought about by over zealous leaders of the employés against the advice given them by some of the more responsible and cautious men. The result was most unsatisfactory so far as the men were concerned, for instead of their gaining the sympathy of the public, as they anticipated, the inconvenience and disorganisation caused by the strike turned the sympathy to the Government and against the strikers, and in the end the men found, to their sorrow, that there was no good result to themselves, but for some of them loss and disappointment. Since that time there have been no railway strikes except in connection with the tramways in Sydney, Brisbane, and Perth, and in all cases the result has been unfavourable to the strikers.

A statement that is often made against the Government system is that you do not get the best and most able men, and that employés are not as industrious as on private works. But little reliance can be put on these statements, for it stands to reason that Governments can afford to secure the very best men to manage their works just as well as the private companies can. In fact, many of the Railway Commissioners, as well as the engineers and general traffic managers, have been selected from the leading officials of private companies, and some of the private companies have been glad to avail themselves of the services of men who have gained extra experience in Australia.

Travelling accommodation and fares for passengers, and freight rates for goods, compare favourably with the railways even in older and more thickly settled countries. In fact, the freight charges on agricultural, pastoral, and mineral products are in many cases exceptionally low, in order to encourage settlement and development.

The Government ownership of railways in Australia is often used as an argument by advocates of a national system in Great Britain. This is a matter, however, that does not come within the scope of this paper further than to add that the conditions of the two countries, and the circumstances under which the railways have been constructed, are so different that the greatest consideration should be given to such an important proposal. The result of nationalisation might be the exact opposite to that expected by some of its warmest advocates. If the nation as a whole is to benefit, it might mean a great reduction in the number of employés and much inconvenience to traders and residents in certain localities; on the other hand, if the employés and trading public are to benefit by the change, it might result in a heavy national loss.

Youth Electrocuted. — An inquest was held at Hoyland Common, on a youth who was killed on Tuesday morning, the 11th inst., at the Knoll Drift Colliery. He was found dead by the side of one of the electric coal-cutting machines. Dr. F. W. Norton, who had made a post-mortem examination, said that several parts of the deceased's body were burnt, and in his opinion death was due to asphyxia caused by an electric shock. The enquiry was adjourned.

Copper-wire Tables. — Some little time ago the American Institute of Electrical Engineers requested the U.S. Bureau of Standards to make an investigation on the subjects of copper-wire conductivity and temperature coefficient. The Bureau have now issued their report. Their investigation has resulted in the establishment of standard values based on measurements of a large number of representative samples of commercial copper values, which in certain respects are, it is stated, more satisfactory than any preceding standard values. In the investigation it was discovered that the temperature coefficient is proportional to the conductivity. This new law has been corroborated by the Reichsanstalt of Germany and is of considerable importance in electrical measurements. It was also discovered that bending and winding a wire do not change the temperature coefficient, and consequently the internal temperature of electrical machinery may be calculated from resistance measurements with greater confidence than heretofore. A proposal from Germany of a standard conductivity based upon this investigation has been accepted and will probably soon be universally adopted. The report gives a history of wire gauges, showing that the trend of practice is toward expressing diameters directly in decimal fractions of an inch. The report contains fifteen tables, including complete reference and working tables for annealed copper, both in English and metric units. Tables for copper cables and for hard-drawn aluminium wire are also given. The tables have been adopted as the official wire tables of the American Institute of Electrical Engineers

TESTS OF A SIMPLE ENGINE TAKING STEAM AT LESS THAN ATMOSPHERIC PRESSURE.*

BY PROF. R. C. CARPENTER.

So far as the writer can ascertain, there are very few data available as to the economy of reciprocating engines when operating with less than atmospheric pressure, although numerous tests have been made of nearly all types of engines under the usual conditions of steam pressure and vacuum. A considerable amount of data is to be found as to the results of steam turbine tests, especially when of large size, operating with steam of low pressure. The impression generally prevails that the steam turbine produces much higher economy than the steam engine when operating with steam of less than atmospheric pressure.

The investigation, the results of which are given here, cannot be said to prove that the general opinion as stated above is erroneous, but it does tend to indicate that the reciprocating piston engine of small clearances can be operated with low steam pressures and high vacuum with remarkable economy.

The particular engine which was investigated is of the 4 valve type and with cam-operated valve mechanism arranged to open and close with great rapidity. The total clearance space is about 1 per cent. of the piston displacement. The

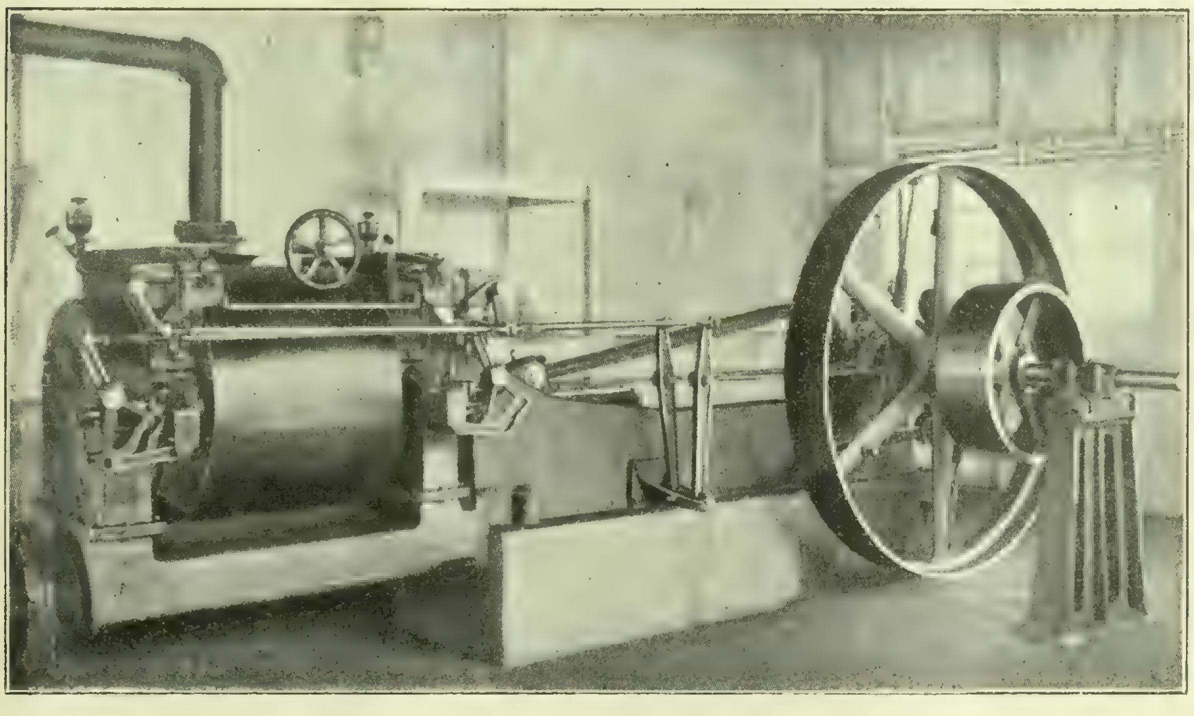


FIG. 1.—20-H.P. SHUMAN-HAINES LOW-PRESSURE STEAM ENGINE.

valves are located so as to make the losses due to clearance a minimum. The results obtained in the investigations could not, in my opinion, have been produced by any engine built 10 years ago.

The cylinder of the engine is 24in. diam. by 24in. stroke. It is double-acting with admission valve seats on the barrel of the cylinder near the end, and exhaust valve seats in the heads. This engine was developed to furnish power from steam generated by the heat of the sun in plate boilers which presented a large absorption surface, and was designed by F. Shuman, general manager of the Sun Power Company, of Tacony, Penn. Its general features were conceived by Mr. Shuman. The engineering features were designed and developed by E. P. Haines.

The engine was developed to meet a special demand for a steam motor of small power that would give the highest possible economy with low steam pressure and a high vacuum. Its design and construction were undertaken by Mr. Shuman after he had thoroughly investigated the possibilities of obtaining a commercial engine or turbine which would meet his requirements. The best guaranteed performance for a 25 h.p. steam turbine which he could obtain from any builder was about 60lbs. per brake horse-power per hour with steam of atmospheric pressure and a vacuum of about 28in. No such turbine has been built, and in the proposals the cost of development would have fallen principally on Mr. Shuman had one been built. As the motor was to be employed for driving a pump, the reciprocating engine at moderate speed possessed many advantages over the turbine. Mr. Haines was quite certain from his preliminary studies that he could construct an engine of about 20 h.p. capacity which would produce a brake horse-power with less than 40lbs. of steam per hour. Several attempts were made before final success was attained; in one of which attempts the entire cylinder and head were lined with soapstone in order to reduce the heat losses. Although this experiment was very expensive, it did not accomplish the desired result. Mr. Shuman only proved by that experiment what was already well known to scientific men, namely, that the principal loss of heat in the steam engine is due to the deposit and re-evaporation of a film of water on the interior walls and not to the loss of heat through a good conducting material.

The Engine.—In general appearance the engine is not greatly different from other engines of similar size, except that its working parts are light and it is provided with a rather long connecting rod. It has an overhung crank and an out board bearing. Its general appearance is shown in Fig. 1. It can be turned readily by hand, showing that the friction loss is small.

Two eccentrics are used which drive rocker arms, one of which operates the steam valves, and the other the exhaust valves. Generally speaking, the valves are constructed so as to reduce the clearance space to the lowest possible limit. The steam admission valves, two in number, are of the slide valve type, arranged to move parallel to the axis of the cylinder on a curved seat concentric with the cylinder. This design afforded steam ports with an opening 20 per cent. of the piston area. These are on the top part of the barrel of the cylinder near each end, and are provided by this construction with extremely short passages into the cylinder, thus making a small clearance loss.

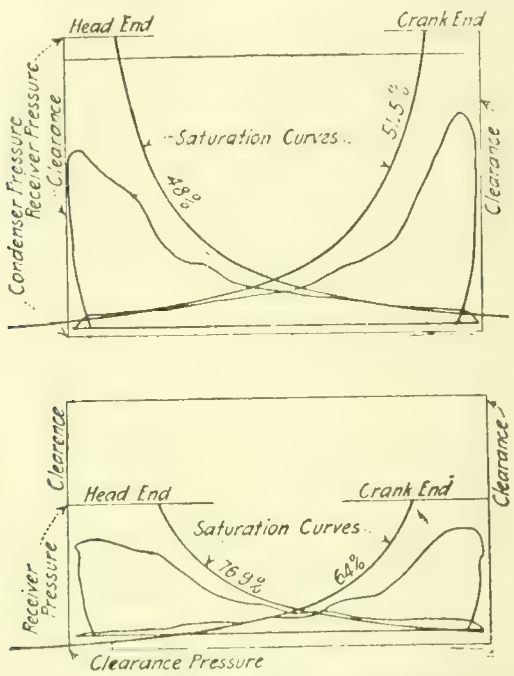
The exhaust valves in this construction are especially novel; they consist of thin steel plates situated inside the cylinder heads and are vibrated in a plane perpendicular to the axis of the cylinder. Such valves are extremely unusual in the construction of steam engines and their operation was studied with a great deal of interest. In structure the valve is a flat thin disc provided with slots which are made to register with corresponding openings in the seat by the action of the valve-moving mechanism. It worked smoothly during the test; it was tight, and its continued use apparently increased its tightness. The fact that it was very thin and that it was held in position by the pressure inside the cylinder, doubtless explains why the results were so good. The area of the exhaust ports when open is very large, amounting to 35 per cent. of the piston area.

The test of this plant was conducted at Tacony, Penn., by Prof. W. M. Sawdon and myself. Because of the fact that the steam pressure was very low and that the work was done almost exclusively with less than atmospheric pressure, the method of testing which had to be adopted was quite unusual. The engine was arranged to exhaust into a surface condenser connected to a vertical air pump. The water of condensation was delivered by a special hot-well pump into one of two tanks, which were placed on weighing scales and provided with suitable pipe connections and valves so that one could be filling while the other was emptying. The hot well pump was provided with a governor for maintaining a constant level in the hot-well. Observations of the water level were also taken

* From the "Sibley Journal of Engineering," May, 1912.

by means of a glass gauge, and a correction applied for differences of level whenever necessary.

The engine took its immediate steam supply from a receiver 24in. by 42in. The receiver was supplied with live steam from a low-pressure solar boiler situated in another building and some distance away, and it also received the exhaust steam from the air pump which produced the vacuum on the system. The live-steam connection from the boiler was provided with a valve, by means of which the pressure was maintained constant by hand regulation. The main supply pipe was exposed to the weather, which was quite cold at the time of the test; as a result a considerable amount of water discharged into the receiver from both sources of steam supply, the height of which was determined by a glass gauge and was regulated by a valve on a drain pipe. During some tests it was sometimes desirable to drain the receiver when the pressure was less than atmospheric; this was accomplished by



FIGS. 2 AND 3.—TYPICAL CARDS FROM THE SHUMAN-HAINES LOW-PRESSURE ENGINE.

connecting the drain pipe to an auxiliary receiver, which was connected to the suction side of the air pump and thereby kept under vacuum.

The steam pressure was measured by a U-tube mercury manometer attached to the steam pipe near the steam chest. This was kept as nearly constant as possible by hand regulation of the live-steam valve controlling the admission of steam into the large receiver. The vacuum was measured by a cistern mercury manometer connected to the condenser. The temperature of the steam was taken by a thermometer placed in the steam pipe near the cylinder. The temperature of the exhaust was taken by a thermometer well in the exhaust near the cylinder. In general, all thermometers and pressure gauges were very carefully compared with standards before and after the test, and the results corrected as necessary.

In order to guard against any water vapour in the discharge from the air pump which should have been charged against the engine, it was condensed, by discharging through a long pipe extending some distance outside the building. It then passed through a trap, was weighed and considered as steam consumed by the engine. A gasometer was also placed in the air-pump discharge, and so arranged that the volume of air pumped in a given length of time could be measured.

Quality determinations of the steam entering the cylinder were necessary in order to obtain accurate results, for the reason that the steam supplied to the main receiver, as already noted, contained a considerable amount of moisture. This problem was a very unusual one, as it required the determination of the moisture in the steam supplied at atmospheric, or less than atmospheric, pressure. In the tests made, the steam pressure varied from slightly above atmospheric pressure to about 7lbs. below.

The scheme of arranging a calorimeter for working under such conditions was quite original, and was worked out in detail by Prof. Sawdon. The results which were obtained were proved, by subsequent tests, to be quite accurate. A separating calorimeter was connected in an auxiliary steam line extending from the main steam pipe to an auxiliary receiver, on which the same vacuum was maintained as on the engine, and through which a fair sample of steam could be drawn by suction. The quality of the steam in most of the tests which I conducted did not differ greatly from 96 per cent. In a few of the tests conducted with very low pressures the quality approximated 90 per cent.

Indicator diagrams were taken during the test, special springs being carefully calibrated for the pressure conditions under which they were operated. Fig. 2 represents the type of indicator diagram which was obtained when the entering steam, as measured in the receiver, was about ½lb. above that of the atmosphere. Fig. 3 represents the form of diagram when the initial steam in the receiver was about 7lbs. less than that of the atmosphere. On both the diagrams submitted, a saturation curve is drawn as a reference line. It will be noted that the expansion line is a long distance from the saturation curve at the point of cut-off, especially for the case of the higher steam pressure. However, it will be noted that these lines intersect before release, indicating that the moisture during expansion had re-evaporated.

With steam about 1lb. above atmospheric pressure and with a vacuum of 28in., the engine required 31·6lbs. of steam per brake horse-power hour. With the same steam pressure, but with a vacuum of 28·8in., steam consumption was 28·8lbs. per brake horse-power hour. These two tests indicate the very material effect of a high vacuum under such conditions of pressure. With a steam pressure of about 8lbs. absolute (6·75 below atmosphere) and 27in. vacuum, 37·8lbs. of steam were required per brake horse-power hour. With the same steam pressure, but with a vacuum of 28·66in., 35·7lbs. of steam were required per brake horse-power hour. As compared with the Rankine cycle, the efficiencies vary from 43·8 to 52·4 per cent., depending on the load and steam pressures. On the whole, the results will certainly compare favourably with any published results of any small steam turbines which I have seen. An independent test of the same engine was made by E. P. Haines a few weeks previous to the tests made under my supervision, and these tests showed substantially the same results.

Mr. A. S. E. Ackermann, of London, made a series of independent tests on this engine a few months later than those which I have reported. Mr. Ackermann sent me the general results of his tests and also a diagram on which he had plotted his results and those which I obtained. His diagram is appended (Fig. 4). This diagram was constructed by using the total brake horse-power as abscissas and the total water consumption as ordinates. The plotted results all fall remarkably near a straight line. The fact that the results of the tests of many kinds of prime movers, when plotted in a similar way, fall in a straight line, has been proved by

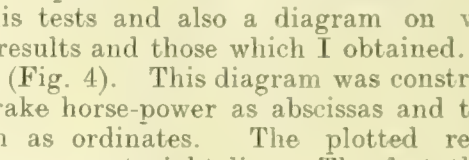


FIG. 4.—DIAGRAM OF TEST RESULTS ON LOW-PRESSURE ENGINE.

numerous experiments, and this empirical law is for this reason a great aid in determining the accuracy of independent tests made on the same prime mover. The fact that my tests and Mr. Ackermann's fall on the same straight line indicate the substantial accuracy of both series of tests. The straight line which characterises results plotted as explained is frequently referred to as Willan's line. The diagram also shows the steam per brake horse-power per hour for different load conditions.

Colliery Cage Mishap. An accident occurred at the New Watnall Colliery on the 11th inst., through a supposed case of over winding. Fourteen workers were in the cage, and had an unpleasant experience as it neared the bottom of the shaft, which it struck with some force.

REPORT ON A DISASTROUS LOCOMOTIVE BOILER EXPLOSION.

THE official report has just been issued on the disastrous locomotive boiler explosion which occurred at San Antonio, Texas, on March 18th last, and of which brief particulars, accompanied with photo views, were given in our issue of April 26th (see page 507 ante). The report was conducted on behalf of the Interstate Commerce Commission by Mr. John F. Ensign, chief of the Federal Locomotive Boiler Inspection Bureau, and his assistants, and is reproduced in part as follows:—

The engine, No. 704, belonged to the Galveston, Harrisburg, and San Antonio Railway, and exploded while standing on a yard track just outside the company's engine-house at San Antonio, Texas, the result being the deaths of 26 persons, serious injury to 32 others, and the more or less complete wreckage of all of the buildings in the immediate vicinity of the accident.

The locomotive was a heavy passenger one of 4—6—0 type, using crude oil for fuel. It was built in March, 1908, by the American Locomotive Company. The firebox was of three-piece construction crown-bar type. The working steam pressure was 200lbs. per square inch. The barrel of the boiler was made of steel $\frac{3}{4}$in. in thickness in three sections or courses, constructed with butt longitudinal joints with diamond-shaped welts. The dome was located on the third course. The wrapper sheet was $\frac{3}{8}$in. steel, the back head sheet $\frac{1}{2}$in. steel, the back flue sheet $\frac{1}{2}$in. steel, and the firebox door sheet, crown, and side sheets $\frac{3}{8}$in. steel. The firebox was stayed with rigid bolts of $\frac{7}{8}$in. diam. at ends, reduced to $\frac{3}{4}$in. at centre of bolts, four rows of Tate flexible bolts of 1in. diam. at top of firebox and two rows at each end, staggered at top corners. The crown bolts were driven fit with countersunk heads, $1\frac{1}{8}$in. diam. at the bottom end and 1in. diam. at the top end, extending through crown bars with nuts on top. The crown sheet was supported by 15 crown bars, which were supported from wrapper sheet by 168 sling stays, $\frac{5}{8}$in. by 3in., and 12 sling stays $\frac{1}{2}$in. by $2\frac{3}{4}$in. The flues, numbering 355, were of 2in. diam. The boiler was equipped with three 3in. Crosby safety valves. The locomotive had been in shop for several days, and was being prepared for service.

At the time of the explosion an employé of the railway company was engaged in setting the safety valves. The force of the explosion was such that the boiler was literally torn to pieces. One piece, consisting of wrapper sheet 21ft. 4in. wide and 10ft. 9in. long, with 12ft. of mud ring $4\frac{1}{2}$in. by 5in. attached to the same, as well as the dome and a portion of the dome course 5ft. 9in. by 14ft., together with a portion of the second course, the total weight aggregating approximately 16,000lbs., was carried ahead and to the right a distance of about 1,200ft. The boiler head, which was 6ft. 6in. wide, and 8ft. in height, weighing approximately 1,250lbs., was hurled in the opposite direction a distance of 1,200ft., passing through the back and side walls of a two-storey frame residence. A part of the first course, the weight of which was approximately 900lbs., was also carried ahead and to the right a distance of about 2,250ft., and was buried in the ground over 5ft. A piece of the second course, 60in. by 72in., weighing about 900lbs., was blown through the walls of the blacksmiths' shop and fell about 75ft. from the scene of the accident. The remaining portion of the boiler, consisting of the smokebox and front flue sheet, a part of the first, second, and third courses and throat sheet, also the back flue sheet and about 150 flues, were torn from the locomotive frame, falling bottom upward about 25ft. forward from where the locomotive had been standing. The crown sheet with flange of flue sheet and one-half of the door sheet were blown down between the frames, as were also the side sheets of firebox. Six crown bars remained attached to the crown sheet, the rest of the crown bars, nine in number, being torn away from the crown sheet and wrapper sheet. The side sheets were torn into three pieces approximating 200lbs., 500lbs., and 600lbs. in weight, respectively. Both of the driving wheels were forced off the back axle, which was broken about 2in. inside of the right wheel centre and 6in. from the end thereof. Both of the main driving wheels were started on the axle, the frames bent and twisted, both piston rods and the top of the cylinder saddle were broken. The tender was broken from the locomotive and blown backward about 100ft. The property damage was estimated to be about £9,450—£2,400 to the locomotive and £7,050 to buildings.

The evidence tendered at the enquiry brought out the following facts: Locomotive was out of service from February 21st to March 18th, 1912, for repairs, during which time the following boiler work was done: Two hundred flues reset, one back head brace repaired, one front flue sheet brace and two throat stays repaired, eight stay bolts removed, safety valves ground in, steam gauge tested and hydrostatic test of 250lbs. pressure per square inch applied. Repairs were completed about 5-45 p.m., March 17th, and the locomotive fired up, but no steam was raised. The locomotive was again fired up about 6-10 a.m., March 18th. Safety valves first opened at 7-30 a.m., at which time steam gauge registered 50lbs. pressure. Safety valves were screwed down and again opened at about 8 a.m., when gauge registered 150lbs. pressure. There is no evidence indicating that the safety valves opened at any time subsequent to 8-0 a.m. The locomotive had a heavy forced oil fire from 8-0 to 8-55 a.m., at which time the explosion occurred.

An employé of the railroad company was engaged in setting the safety valves at the time of the explosion, and although the evidence showed the gauge had been tested, there was no evidence that the siphon pipe leading from gauge to boiler had been cleaned between the valve and the boiler, which is the point where it would be most likely to be obstructed; neither is there any evidence to show that the valve was open.

The damage to the boiler, as well as the direction in which the various parts of the boiler were blown, indicates conclusively that the firebox sheets were the first to give way, as the boiler head was blown backward and all other parts of the boiler were blown forward, the flues, flue sheets, and smoke arch being simply turned over forward and thrown to the left, while the wrapper sheet with a part of the dome course with the dome attached and other pieces of the shell sheets were blown for long distances forward and to the right.

Owing to the damaged condition of the safety valves and inability to recover the springs and valves, a test thereof could not be made. The castings with the adjusting screws were found, one of which had no lock nut on it. The hexagon-shaped heads on the adjusting screws had the corners twisted off, after which a Stillson or pipe wrench had apparently been used in an effort to screw them down further. One of the adjusting screws was bent and the bottom end was upset or burred by the pressure that had been put on it. The condition of the threads on the adjusting screws indicated that they had been recently screwed down more than $\frac{5}{8}$in.

A careful examination of the crown-bar sling stays showed that they were made of wrought iron, while the specifications called for steel. The sling stays were badly stretched and reduced in section at the eyes where they failed, indicating a gradual rise of pressure in the boiler. Five 1in. bolts were used to attach the sling stays to the crown bars and to the wrapper sheet, where $1\frac{1}{4}$in. bolts should have been used; $1\frac{1}{4}$in. bolts were specified on the drawings, except on the front crown bar, where 1in. bolts were specified. The crown bars in this boiler were not supported on the sides of the firebox, as was customary in the older type of crown-bar boilers, therefore all the support was from the sling stays.

Five crown-bar sling stays taken from the locomotive were tested by the United States Bureau of Standards to determine the load the stays would support when 1in. and also when $1\frac{1}{4}$in. bolts were used. The bolts used in making these tests were those which were in use in the boiler at the time of the explosion. Two stays, tested with 1in. bolts, failed with a total load of 26,650lbs. and 21,840lbs., respectively. Three stays, tested with $1\frac{1}{4}$in. bolts, failed with a total load of 30,000lbs., 33,890lbs., and 31,620lbs., respectively. Using 21,840lbs. as the strength of the sling stays having 1in. bolts, we find the stays had a factor of safety of only 2·67, and using the highest test figure of 26,650lbs., we find the factor of safety to be only 3·26. Calculation shows that sling stays, fitted with $1\frac{1}{4}$in. bolts, had factors of safety of from 3·67 to 4·15. The tensile strength of the material in the sling stays was shown by test to be 43,200lbs. to 48,300lbs. per square inch, and the elongation 18 to 40·5 per cent. in 2in. Tests of the sling stays show that the failure was caused by the bolt holes being drilled too near the ends of the stays.

Eighty-six stay bolts, nine of which were in left side, 63 in right side sheet, and 14 in flue sheet, were found broken at the wrapper sheet and adhering to the firebox sheets. Twenty-six of these stay bolts were found to have been fractured, *i.e.*, partly broken before the explosion. The remaining 60 were in such condition that it cannot be positively stated that they were fractured prior to the accident, but the fact that they broke at the wrapper sheet and did not pull through the firebox sheets indicates a defective condition. Three stay bolts taken from the boiler were tested by the United States Bureau of Standards, and the material was found to be of good quality.

The steam gauge and its connections were destroyed, so that an inspection of them could not be made, but it is probable that the steam gauge did not indicate the correct pressure. This could be caused by a defective gauge or some obstruction in the siphon pipe, or by a valve in the siphon pipe being closed, or nearly so. An inspection of a locomotive of the same class disclosed the fact that it had two valves in the siphon pipe. When these valves were open the handle of one formed a right angle with the pipe and the other was parallel with the pipe. This arrangement of valves is very confusing and creates a dangerous condition, in consequence of which one of them was ordered to be removed. It is not known whether or not such an arrangement of valves existed on the locomotive which exploded.

The evidence shows that the law and the rules governing the inspection of locomotive boilers were disregarded by the railway company's inspector and the officials in charge of such work at this point in the matter of making and properly certifying to the reports required by law. A report stating that the safety valves had been set was sworn to on March 16th, 1912, by the railway company's inspector and the roundhouse foreman who signed it as the officer in charge of such work. The evidence shows conclusively that the safety valves had not been set at that time, and as a matter of fact it was while this work was being done, on March 18th, that the explosion occurred. The evidence also shows that the inspector failed to witness the testing of the steam gauge and that the injectors had not been tested at the time this report was made out, notwithstanding which facts he certified under oath that this work had been done.

The opinion was expressed at the investigation that nitroglycerine or some other high explosive was used, but nothing was found to support such an assertion. The question has been raised by those who suggested this theory as to whether excessive steam pressure could cause such complete destruction of a boiler. The most violent explosions on record have been caused by excessive steam pressure. The destructive effects of boiler explosions are not caused by the steam alone which is contained in the steam space at the instant the initial rupture occurs, but is due to the enormous quantity of steam which is instantly generated from the water contained in the boiler. In the case of this locomotive the water level was high, the pressure very high, and the explosion terrific. Careful calculations show that the stored energy in the boiler at the bursting pressure of the barrel was sufficient to raise the boiler approximately a mile high. The flues and firebox sheets show no indications of having been overheated, and the evidence showed that there were three gauges of water at the time of the explosion.

It is our conclusion that this explosion was due to excessive steam pressure, which was caused by an employé of the Galveston, Harrisburg, and San Antonio Railway Company tightening the adjusting screw of the safety valves, resulting in an accumulation of steam pressure beyond the endurance of the boiler. Tests made of the parts of the boiler which evidently failed first demonstrate that the pressure on the boiler at the time of the explosion was greatly in excess of the allowed working pressure. Therefore the steam gauge, either on account of the gauge itself being defective or an obstruction in the siphon pipe between the gauge and the boiler, did not correctly indicate the pressure. The railroad company was at fault in requiring or permitting inspections and reports to be made in a manner which was not in accordance with the law, and in allowing such important and responsible work as setting safety valves to be performed by an employé of whose experience and judgment the testimony shows they knew practically nothing, and in keeping a boiler in service for which the factor of safety as shown by test was below the recognised standard.

The rules governing the inspection of locomotive boilers, setting of safety valves, testing of gauges, and similar work are sufficiently comprehensive to ensure safety if properly and intelligently complied with. However, in endeavouring to obviate a recurrence of an accident of this character the necessary action has been taken making the use of two steam gauges obligatory when setting safety valves, one of which must be so connected that it is in full view of the person engaged in setting such safety valves. Similar action has also been taken requiring the siphon pipe and its connections to the boiler to be cleaned each time the gauge is tested.

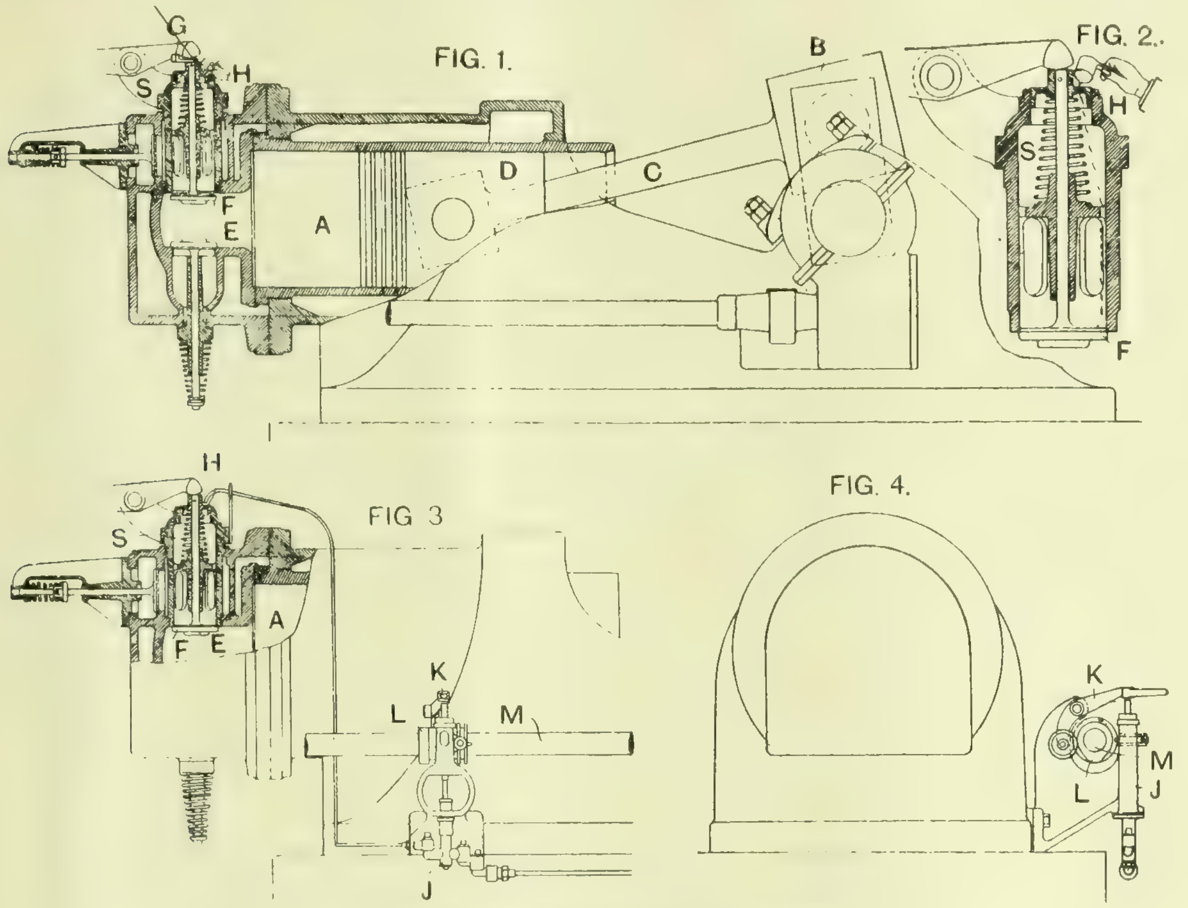
ELECTRICAL HAULAGE IN MINES.

At a joint meeting of the Yorkshire branches of the National Association of Colliery Managers and the Association of Mining Electrical Engineers, recently held at Leeds, a lecture on "Electrical Haulage in Mines" was delivered by Mr. W. C. Mountain, in the course of which he dealt with the three systems of haulage main rope, main and tail, and endless rope. Comparing the two latter, he said that, assuming it was necessary to bring, in 10 hours, 600 tons from a distance of a mile in-bye, 280 h.p. would be required for main and tail haulage, and 75 h.p. for the endless rope system. In choosing a system, they had to be guided largely by circumstances, but points to bear in mind were that with the main and tail system they had to deal with a load consisting of the weight of the rope, weight of the tubs, and weight of the coal; while with endless rope the tubs balanced, the rope was practically balanced, and all they had to deal with was the net weight of the coal which they were moving, plus the friction of the rope. As to comparative cost of working, he quoted two examples: A colliery dealing with 4,000 tons per day on the main and tail system, where 20 men were required in the tub shop to keep the tubs in repair, and another dealing with 3,000 tons per day on the endless rope system, where only five men were required for tub repairs. The life of the rope was one year on the main and tail system, and 3½ years with endless rope, which went to show that the constant running on the endless rope plan was much easier on the rope than on the main and tail system. He was not one of those advocates of electricity who thought it should go everywhere. He did not think it should be put in places in a mine where there was likely to be sufficient gas to cause an explosion. Prevention was better than cure. However well they made their electrical machinery and totally enclosed it, there was the personal element to be considered. There were thousands of places in mines where electricity could be used with perfect safety, but it was a mistake to try to spread it too far and run the risk of an explosion by putting motors in unsafe places. For such places he recommended compressed air, placing the compressors as near as practicable to the haulages, and driving them by electric motors. He advocated electric controllers where they could be satisfactorily used, in preference to oil or metallic controllers.

The Cracking of Crane Hooks.—In a recent issue of "Stahl und Eisen" reference is made to the cracking of crane hooks. In one particular case the hook links at the sides of a yoke for carrying ladles of molten steel showed cracks on the side facing the ladles, but the cracking developed only in those hooks nearest the open end of the furnace building and thus exposed to the weather. The cracking was thought to be due to the combination of local heating from radiation from the iron and the chilling from exposure to the weather. A steel of moderately hard structural grade, which had been purified by the addition of silicon, was employed for the hooks, and the conclusion was drawn that a softer steel without the additional silicon should be used for these hooks. It was also stated that in similar cases very coarse crystal formation results from local heating, and a case where the side of a ladle hook cracked was reported. Frequently the hooks are found to be highly brittle and break under side shock even when not subjected to a load.

METHOD OF STARTING GAS ENGINES.

A METHOD of starting gas and other internal-combustion engines in which a succession of charges of petrol or other inflammable liquid are introduced into the cylinder or into the space behind the piston and exploded by suitable ignition gear has recently been patented by Mr. A. R. Bellamy, Spittlegate Iron Works, Grantham. With this method not only is a starting impulse obtained, but also a number of subsequent impulses, thus rendering the starting of the motor easy and positive. Fig. 1 is a sectional side elevation of an internal-combustion engine illustrating the method of starting by introducing the petrol through the open charge valve. Fig. 2 is a vertical section of the charge valve lantern drawn to a larger scale and showing a second charge of petrol being introduced on to the top of the closed charge valve. Fig. 3 is a sectional side elevation illustrating the method of introducing the charge of petrol from a pump to the charge valve. Fig. 4 is an end elevation showing the method of operating the pump from the cam shaft of the engine.



ARRANGEMENT FOR STARTING GAS ENGINES.

Referring first to Fig. 1, A is the cylinder of the gas engine having its crank B, connecting rod C, and piston D placed in the position to obtain the most effective initial stroke when starting from rest. E is the combustion chamber and F is the charge valve, which is shown held open by means of the wedge G, so that a charge of petrol can be introduced by hand through the orifice H on to the top of the charge valve F past the seat of the valve and into the combustion chamber E as illustrated. After the charge of petrol has entered the combustion chamber E the wedge G is withdrawn and the charge valve F is closed by the action of the spring S. Another charge of petrol is then introduced on to the top of the charge valve F as illustrated in Fig. 2. This charge of petrol will enter the combustion chamber E and cylinder A as soon as the charge valve opens on the suction or charging stroke. The first charge of petrol in the cylinder A has in the meantime formed an explosive mixture by mixing with the air in the cylinder A and it is ignited by operating the magneto by hand, and the first impulse is given to the engine. On the crank B making one revolution the second charge of petrol which is lying on the outside of the charge valve F is drawn together with air into the combustion chamber E and the cylinder A by the action of the piston D and forming an explosive mixture is compressed and exploded by the action of the engine and a start is thus effected.

Fig. 3 shows an arrangement whereby further charges of petrol are introduced through the charge valve into the combustion chamber E and cylinder A at the beginning of the charging stroke. This arrangement comprises a small ram pump J attached to the frame of the engine, and which can be initially worked by hand by means of the lever K and, when the engine is got into motion, by the action of the cam L fixed on the cam shaft M. With this construction to start the engine the crank B is placed in the position previously described, the charge valve F is opened as shown in Fig. 1 and a charge of petrol is pumped by hand into the combustion chamber E. The charge valve F is then closed by removing the wedge G, and the explosive mixture in the combustion chamber E and cylinder A is ignited by operating the magneto by hand. On the crank B making one revolution the cam L on the cam shaft moves the lever K which operates the pump J and a further charge of petrol is forced on to the top of the charge valve F ready to be drawn into the cylinder A on the first suction stroke of the piston D. By these means a series of explosions can be obtained until the engine has attained a sufficient speed, when the lever K can be thrown out of action either by sliding the cam L on one side or by any other well-known device, whereupon the supply of petrol to the charge valve F will be discontinued and the engine turned on to its own supply of gas or other inflammable vapour with which it is working.

The method described is particularly applicable to the starting of double or multiple cylinder engines, since a charge of petrol can be introduced into the combustion chamber of one cylinder of the engine and further charges of petrol introduced on the top of the charge valves of any other cylinders, so that when the starting impulse is obtained in the first cylinder the charges of petrol which are lying on the tops of the charge valves of the other cylinders will successively be drawn into the combustion chambers on their suction strokes and impulses will be produced in all the cylinders, one following the other, thus effectively starting the engine. A pump can also be attached to each cylinder, or a pump with a plunger for each cylinder can be used for the purpose of introducing the charges of petrol on to the charge valves.

A New Type Large Steam Collier.—There was launched on the 18th inst., from the yard of the Blyth Shipbuilding and Dry Docks Company, a new type of coal-carrying vessel, built on what is termed the arch principle, patented by Mr. Maxwell Ballard. This vessel measures 279ft. by 40ft. 1½in., with a draught of about 18ft. 3in., and has a height of deck above water of about 7ft. The deadweight capacity is 3,100 tons, and the service speed 12 knots. She will be the fastest collier in the North Sea, and has been built to fulfil all Admiralty requirements for coaling the fleet at sea. The vessel is fitted with eight quick-working winches and special gear arrangements, electric lighting and signalling. She has been built according to Lloyds 100 A1 class, is intended to be absolutely self-trimming, and will have the deepest and clearest holds and hatchways of any vessel of the size yet constructed. The saving of first cost to the owners—W. A. Souter & Co.—the Sheaf Steam Shipping Company, Ltd., of Newcastle-on-Tyne, is stated to have been no less than 11 per cent. upon the hull, while there will be secured 150 tons more deadweight capacity than is obtainable in an ordinary type vessel of similar dimensions.

FUEL AS A FACTOR IN LOCOMOTIVE CAPACITY.*

BY DR. W. F. M. GOSS.

THE power developed by a steam locomotive is derived from the fuel it consumes. Other things being equal, the greater its rate of fuel consumption the greater will be its capacity. Success in the development of this problem long ago characterised the locomotive as the hardest worked of all types of steam plants. This characterisation is based upon the fact that the draught which urges the locomotive fire is unusually strong, its value as measured by a draught gauge under normal operating conditions ranging from 5in. to 12in. of water; that this strong draught results in the burning of from 100lbs. to 200lbs. of coal for each foot of grate per hour, and a rate of evaporation which may exceed 16lbs. of water per foot of heating surface per hour.

The draught, the rate of combustion, and the rate of evaporation are matters which have been subject to little change during the last quarter of a century, but the demand for increase of power has been present throughout this period. The demand has been met by increasing the dimensions of the locomotive. Boilers and cylinders have gradually been made larger, and all the details of mechanism have been designed to control and transmit the increase in power for which these changes have provided. The result is the modern locomotive; a machine of unprecedented power, a complete steam power plant which, as represented by a recent design, is capable of developing a horse-power for each 121·4lbs. weight.

But the weight of the modern locomotive cannot be greatly exceeded except at the expense of extensive improvements in track or through the adoption of an arrangement of wheels which will permit the load to be much more widely distributed than at present. As it is not likely that the demand for higher power will cease, the problem of supplying it is one of more than academic significance. It presents two possible lines of solution, both of which are of especial interest to the members of this association. One possible line of development is through the better adaptation of fuel to the needs of locomotive service, and the other is through the better adaptation of the locomotive to the requirements of the fuel which it has to burn. It is my purpose to discuss briefly the possibilities of increasing locomotive power by attention given to each of these lines of development.

Anything which will successfully promote the combustion of fuel in the firebox of a locomotive will at the limit operate to increase its power. Every pound of coal effectively burned represents a definite output in the form of power at the drawbar, and if through care in the choice and preparation of the fuel the rate of combustion can be materially increased, it is evident that the maximum capacity of a locomotive may be advanced. This fact is lost sight of when locomotives performing service, in which maintenance of schedule is a matter of great importance, are supplied with coal that is bad in its composition and which is a mixture of the finest dust with lumps of every possible size. Conditions of service which demand high power will justify unusual care in the selection of fuels. The coal used under such conditions should have a high thermal value, and it should be low in clinker and ash. It should be sized before it is put upon the locomotive tender and if necessary it should be washed and sized. One who looks upon sized coal in a car and then upon a carload of run of mine coal and considers that on the grate the combustion of coal can only proceed as air can pass through the bed and around the individual particles of coal, will easily understand the superior advantages offered by the sized fuel. A principal advantage of the briquetted fuel so much used in foreign railroad practice is to be found in the fact that the briquettes are of uniform size. When the coal fired is made up of pieces of uniform size, it forms a bed on the grate in which the interstices between the pieces of coal are uniform and the admission of air over the entire area of the grate is in finely divided and uniformly distributed streams. The result is that every part of the fire is maintained in a condition of maximum efficiency, the temperature of the firebox will be higher than when mixtures of lumps and fine coal are fired; the rate of combustion will be greater, and, as a consequence, the capacity of the locomotive will be increased.

* Paper read before the International Railway Fuel Association.

The power of a locomotive cannot be increased indefinitely merely through the proper selection of fuel, but the limits of its maximum performance may be materially extended. Through care in the selection of fuel a small locomotive may be made to perform the service of a larger one, a saturated steam locomotive may be made to perform the service of a superheating locomotive of the same class, and a large locomotive may have its power limit materially increased. There are no objections to the general introduction of especially prepared fuel for locomotives excepting those of cost. The fuel bill of the railroads is already an enormous one, and those who are responsible will always hesitate before permitting an increase in the purchase price per ton. But the ultimate cost, when measured in terms of service given, will be found in many cases justifiable. Under present practice, railroads in their desire for some increase in power do not hesitate to increase the weight of their locomotives by giving them larger boilers, by raising their steam pressure, by the adoption of compound cylinders, and by the addition of superheaters. All of these are expensive measures, but they have been justified in practice by the results obtained. The more careful preparation of fuel is to be looked upon as a means to an end. It constitutes an embellishment in locomotive operation and is not different in purpose from embellishments in design. It will add to the expense, but will give a return in increased power which at the head of important trains may be greatly needed for the maintenance of service. I believe that a great opportunity, which as yet has been but little appreciated, lies awaiting the attention of the prophet who will proclaim the gospel of increased power of locomotives through the more careful selection of their fuels. The time is at hand when lump coal will be washed and sized, and when the fine coals will be washed and briquetted. These processes, excepting that of briquetting, are inexpensive processes and a demand for their employment will soon be forthcoming from the railroads.

The alternative plan whereby the power of the locomotive may be increased, is that which provides for a development of its design along lines which will give it greater capacity to consume the indifferent fuels which under present practice are commonly supplied it. What changes need be made in present practice to provide a greater fuel-burning capacity? The first requisite in the development of such a design is a large grate. The fact is recognised that grate areas have increased enormously during the last 25 years, that whereas their area used to be less than 20 sq. ft., they now have an area which is often more than 70 sq. ft. If a design could now be made which would permit the present maximum grate area to be doubled, several important results would at once be secured. First, while the total amount of fuel burned per unit of time might be materially increased, the rates of combustion per unit area need not be increased, it could even be reduced. The increase of power would be proportional to the increase in the total fuel burned, while the reduced rate of combustion would avoid the necessity for special care in the selection of fuel, would allow the use of fuels now normal to locomotive service; would operate greatly to reduce the loss of fuel in the form of sparks, and would prolong the period during which the locomotive could be kept in continuous operation.

For example, when 6,000lbs. of coal are burned per hour on a 60ft. grate, the rate of combustion is 100lbs. per foot of grate per hour and the spark loss with many fuels represents fuel values which approach 10 per cent. of the coal fired. The collection of ash and clinker on the grate so much impedes the draught as to require a thorough cleaning of the fire after a run in passenger service of from 100 to 150 miles. A greater distance, if attempted, must generally be run at reduced power. With a large grate these conditions are all changed. The burning of 6,000lbs. of coal on a 120ft. grate would reduce the rate of combustion to 50lbs. per foot of grate per hour, and the spark loss to 2 or 3 per cent., and would permit continuous operation for a passenger run of 300 miles between the cleaning of fires. It is true that the larger grate would be at some disadvantage with reference to losses in the form of fuel left on the grate at the end of the run, and in the larger amount required to cover the grate in the process of starting fires; but these would be entirely neutralised by the possibility of increased mileage between the starting of new fires. With the larger grate, only half as many new fires would need to be made per thousand miles run as were formerly required. While the same total amount of coal is burned in each case, it is

evident that the 8 per cent. saving in spark losses would at once be made available as an 8 per cent. increase of power; also that among the possible variations in the method of taking advantage of the presence of the larger grate will be included the possibility of increasing the rate of combustion. For example, an increase in the total fuel consumed from 6,000lbs. to 8,000lbs. an hour, would increase the power capacity of the locomotive by 33 per cent. and would involve rates of combustion which, judged by present-day standards in locomotive service, would be accounted low. If the rate of combustion were forced to a total of 10,000lbs., the increase of power would be 66 per cent. and the rate per unit area of grate would still be below the maximum now common in locomotive service. There is, therefore, much to be accomplished by increasing the grate area of a locomotive. If the output of power remains unchanged, it will permit lower rates of combustion, a reduction of spark loss, and the use of inferior grades of fuel. If, on the other hand, the rate of combustion per unit area of grate remains unchanged, the output of power may be increased in proportion to the increase in the area of the grate.

Locomotive grates having an area of 150ft. or more would necessarily involve some new departures in locomotive design. As the width of such a grate could not greatly exceed 7ft., its length would need to be from 20ft. to 25ft. This may mean a complete abandonment of the existing type of locomotive boiler and the substitution therefor of some new type, but it does not necessarily imply such a change. It does mean, however, the adoption of an articulate form of locomotive which will admit of a space of 25ft. or more between the two systems of wheels. It should be possible either to increase the spacing of the frames over this space or to drop the frames so low that the firebox and boiler with attachments may have an unobstructed area the full width of the track clearance for all heights 3ft. or 4ft. above the rail of the track.

In working out details, automatic stoking must be provided for. This can best be done by having the stokers feed transversely across the boiler from both sides of the firebox. The stokers themselves may be either of the chain belt or of the Roney type, or they may consist of any simple feeding mechanism, delivering to fixed inclined grates. They would be very short in the direction of the fuel movement, probably not more than 30in. or 32in. in length, and they would discharge on a flat dump grate running the whole length from front to rear of the firebox. The aggregate width of the individual stokers on each side would, of course, be from 20ft. to 25ft., but they would be split up into as many different units as would best provide for the construction of short arches over them. By such an arrangement, the green coal would pass under the mud-ring of the boiler and under a short arch, where it would ignite. It would gradually be pushed forward toward the centre of the firebox to the flat dump grate, where it would be met by fuel coming in from the other side. The inward movement of coal from both sides towards the centre of the grate would, of course, proceed throughout the full length of the firebox, that is, for a distance which might be as great as 25ft. The fact that the ignition of the fuel would be under an arch would make the combustion nearly or quite smokeless, the mild draught would make the cinder losses small, while the low rate of combustion per unit area of grate, and the provisions for cleaning supplied by the stokers and dump grate, would permit continuous operation at full power for a very long period.

Narrow hoppers supplying these stokers would open up along the whole length of the firebox on both sides to the full width allowed by the track clearances. The operating mechanism of the stokers, which would be beneath them, would be allowed the same total width. An extension of these hoppers upward on both sides to the level of the top of the boiler or higher, would provide space for all the coal necessary for a run. No coal would be carried on the locomotive tender and none would need to be rehandled on the locomotive. It would all be loaded at once into an extension of the stoker hopper, and its weight would be added to the wheel loads of the locomotive.

In the discussions of the preceding paragraph, I have assumed that the general type of boiler employed would not be materially different from that now in service. Difficulties would, of course, appear in the construction and maintenance of a stay-bolt firebox 25ft. in length, and whatever the outside form of the boiler might be, some special provision would need to be made in the working out of its construction. A demand for a firebox of such dimensions would doubtless call out various means for supplying it. There would probably be no difficulty in constructing a Jacobs-Shupert firebox of any desired length. The boiler would be so located on the frames of the locomotive that its back end would be just in advance of the first of the rear system of driving wheels, and a footplate carrying all of the auxiliary machinery of the locomotive would extend rearward over the axles of these rear wheels and perhaps over the wheels themselves. A fire door as usually placed would supply the fireman an opportunity to inspect his fire, and guided by such inspection he would be able to so control the operation of the several stokers as to maintain uniform conditions throughout the length and breadth of the grate. The barrel end of the boiler would extend out over the forward system of wheels. So much for the arrangements involving a normal boiler. If it should be desired, an attempt could be made to work out the details of the design, using an entirely new form of boiler, such, for example, as a boiler of the water-tube type, but it is not likely that the adoption of any such new type would of itself simplify the general problem as herein outlined.

In conclusion, permit me to say that I appreciate thoroughly the danger of attempting within the limits of a few paragraphs to outline successfully a locomotive design that is entirely new. I appreciate also the many difficulties to be met in applying any such conception. I cannot even claim that I have yet given the matter such attention as will permit me to say that all difficulties are surmountable, but I am convinced that the general scheme is sufficiently promising to justify any study which is likely to be bestowed upon it. My purpose in presenting it is to place before the members of this association in as forceful a way as possible the importance of larger grate areas in locomotive practice. If the capacity of locomotives is to increase in the future as it has in the recent past, and if locomotives are to be supplied with such grades of coal as are now commonly used in locomotive service, such a change will be found imperative.

SURFACE LEAKACE WITH ALTERNATING CURRENTS.

AT a meeting of the Physical Society of London held on May 31st, Mr. G. L. Addenbrooke presented an account of some "Surface Leakage Experiments with Alternating Currents." Experiments on dielectrics at different temperatures and over a wide range of periodicity showed that the losses found were in some cases partly due to surface leakage. When this latter was eliminated and the data obtained with the surface leakage and without were compared, it did not seem as if the portion of the losses due to surface leakage could be accounted for by assuming that it was constant at all periodicities, as is the case with the losses in metallic conduction. Measurements were therefore made to ascertain the behaviour of the surface leakage alone. For this purpose strips of tinfoil were pasted on a sheet of glass 1in. apart, and the relative losses with an alternating current of 42 periods and a continuous current were measured, the pressure being the same in both cases. The following are the results:—

State of Film on Glass.	Resistance, Megohms	Relative Losses. Continuous.	Alternating.
Ordinary day	300	1	3
Drier day...	570	1	4
Film dried first in sun and cooled ...	770	1	5
Another glass surface	50,000	1	15 approx.

The power factor was high in all cases. Similar experiments with ebonite showed a much higher ratio for the losses—namely, 1:40. The ratio in the case of porcelain insulators was as high as 1:60 on a dry day, but part of this leakage might be through the material. The relative leakages between the primary and secondary of a small induction coil and a small transformer were respectively 1:45 and 1:8. In these cases also the leakage was doubtless partly through the insulation. Further experiments described showed that the moisture present must be in a very attenuated state for the differences in the losses found to become sensible. Ordinary

water, even in very thin films, did not show the effect. The striking similarity between the foregoing results and results obtained by measurements made of these losses through dielectrics were pointed out. The suggestion seemed warranted that in both cases the effects might be due to the same fundamental cause—viz., the presence of a very diluted electrolyte.

COAL DUST IN MINES.

At the 56th general meeting of the Institution of Mining Engineers, recently held in London, Mr. W. E. Garforth, the president, took as the subject of his address the danger of coal dust in mines and the means of minimising this danger. He said that universal recognition of the danger of a coal dust explosion might be said to date from May 30th, 1908, when convincing demonstrations of explosions of coal dust free from any admixture of gas were given at Altofts before the members of the Coal Dust Committee of the Mining Association of Great Britain. But there were still many phenomena connected with the explosive character of coal dust which required further investigation. In this connection he drew attention to a valuable paper on the resinous structure of coal by Mr. James Lomax, of Bolton, which was read before the members of the Manchester Geological Society last year. The information on the occurrence of resinous matter in coals, mentioned in that paper, was an important contribution to the coal dust question, as it emphasized the fact that coal dust from certain seams might be more explosive than had hitherto been imagined.

With the aid of the microscope, and sometimes with the naked eye, it was possible to see the resinous spores and the resin bodies which some coals contained. With the microscope it was possible also to recognise the character of the dust which floated in the air of a mine, and to become conversant with the alterations which coal underwent when exploded, as shown in material gathered from the damaged roadways of a mine after an explosion. Indeed, it was to be expected that the microscope would prove to be as helpful in mining engineering as in the sister sciences of geology and petrology. The resinous character of some coals was so apparent under the microscope that the degree of danger of the material might be seen and judged simply by direct observation. The varying proportion of highly inflammable constituents in a seam, seen when various sections of coal had been cut, also served as another factor which might assist to explain differences in the intensity of certain explosions. Some microscopical sections revealed holes giving coals a cellular appearance which had suggested to some workers the possibility of their being reservoirs of mine gases.

By far the most important series of experiments at Altofts were those connected with what had come to be known as the stone dust remedy. To test the efficacy of stone dust in checking an explosion that had already travelled some distance, a zone of inert dust was placed in the path of a coal-dust explosion, and the results were compared with other experiments in which a dustless zone was substituted for the stone-dust zone. In the result the dustless zones, which at one time were suggested as a remedy, were proved ineffectual. In his opinion the gallery experiments amply confirmed the opinion he had formed in 1886, that an explosion would continue to be propagated wherever there was a full supply of coal dust, and great destruction would result, but that it would rapidly die out on roads where stone dust was present in abundance. The positive action of the stone dust in limiting the extent of the explosion by rendering the coal dust non-explosive resulted, also, in decreasing the amount of deleterious gases formed. Inasmuch as it was estimated that 80 per cent. of the deaths in a colliery explosion were caused by carbon monoxide poisoning, the importance of preventing the distillation of coal dust and the formation of poisonous gases could not be over-estimated. As additional proof of the value of inert dust as a mitigant of the danger of coal dust, a further series of experiments were carried out, in which it was sought to prevent the primary ignition of coal dust by diluting the coal dust with stone dust. Highly successful results were obtained. The higher the percentage of inert matter present in the dust, the greater the difficulty in causing explosion to be propagated, and the less the violence of the resulting explosion. With equal percentages by weight of coal dust and stone dust no explosion could be obtained, even with five times the amount of dust which caused explosion when pure coal dust was used.

The value of stone dust was therefore established. But this proof was of mere academic interest unless the remedy could be easily and cheaply applied, without interfering with the health of the workmen, or introducing any fresh danger, such as falls of roof and sides. The management of the Altofts Collieries had now had 3½ years' practical experience in the application of stone dust in the mines under their charge. The principle they had adopted was to strew stone dust wherever there was coal dust, that was, on all the mechanical haulage roads, the neighbourhood of junctions where tubs bumped against each other, &c. Twelve-and-a-half miles of such roadway had now been treated. The stone used was obtained from the "ripping" of the roof of one of the seams, was ground to dust in a pulveriser on the surface, sent down the pit in tubs, and distributed by hand by youths working with their backs to the ventilating current to prevent unnecessary inhalation of the dust. Near the pit bottom and main junctions the first dressing of stone dust was sufficient to fill up all the ledges and crevices so that the dust assumed an angle of repose. It was not then so easy for more coal dust to be deposited. Where screens were situated near the downcast pit and coal dust was carried into the mine from the surface extra heavy dressings were applied. As soon as the stone-dust surface was overlaid with a film of coal dust, a brush or "brush rake" was passed over the surfaces exposing fresh stone dust. When this surface had been again overlaid by coal dust a fresh dressing of stone dust was applied; much of the coal dust dislodged by the stone dust fell to the ground and was overlaid by the excess of stone dust falling from the roof and sides. This system of frequent stone-dusting was carried out wherever the deposit of coal dust was rapid. On the ordinary haulage roads the dressings of stone dust did not need to be so frequent, and the system was modified accordingly. But in all cases as soon as a roadway lost the grey appearance of the stone dust and assumed a darker shade of coal dust, fresh stone dust surfaces were exposed or the stone-dusting was renewed.

Many ways of applying stone dust had been tried, but none had proved so successful as application by hand, for by this means the dust could be better directed and be projected with the requisite force to dislodge the coal dust and take its place. The gallery experiments proved that the finer the stone dust the more positive its action in checking an explosion, owing to the increased surface exposed to the action of the flame and to the greater ease with which it was raised and kept in suspension by the blast. Experience in the mine had shown that a small proportion of the stone dust should consist of coarser particles to give it sufficient body to enable it to be thrown with the requisite force against the upper ledges of a roadway, thereby displacing the coal dust. The application of stone dust by compressed air jets left something to be desired in that generally the coal dust was not removed by the stone dust and the stone dust was deposited irregularly, so that there was generally more than necessary near the distributing centres and too little elsewhere.

During the first 12 months practical application of stone dust in mines at Altofts the cost was ascertained to amount to only ½d per ton of coal raised. The management of the collieries had since gained sufficient experience to enable them to reduce this cost materially. During the year 1911 and the five months ending May, 1912, the cost per ton of coal was found to be less than $\frac{1}{20}$d., and in two of the seams was less than [illegible]d. During this period over 20,000 yards of roadway were treated with stone dust.

Up to the present the only disadvantages experienced from the use of stone dust had been that in some cases it had necessitated the more frequent cleaning out of tub greasers, and had occasionally interrupted electric bell circuits. The former could be avoided by covering over the greaser boxes with brattice while the dusting was proceeding, and the latter could be obviated by thoroughly examining bell circuits and removing any dust which might have lodged on the wires. Stone-dusting would undoubtedly prove of great benefit in those mines where the management had installed or intended to introduce electricity. He was of opinion that dangers of explosions of coal dust from electrical causes would be con-

pletely counteracted by the rigorous application of stone dust.

He had been aware for the past 20 years or more that the men engaged in enlarging the roadways by breaking down the stone or shale roof, and in driving cross-measure tunnels in coal mines, had not suffered in health from the shale dust and had retained a robustness quite equal to that of the coal miner. Still, with a view of getting further information he obtained some time ago certain samples of dust which had been suggested or were actually being used, for stone-dusting in mines, in order to learn if these or other rock dusts were suitable, having regard to the effects on the health of the miners if inhaled in large quantities. These, which he discussed in the reverse order of their suitabilities, were granite, spent sand, flue dust, carboniferous limestone, china clay, chalk, and argillaceous shale or clayey bind dust. The last was inert, did not distil off gas, was innocuous when inhaled, and was a non-astringent. Among the dusts met with, none appeared to fulfil so well the physiological combined with the preventive conditions of a material suitable for dusting a mine as clayey bind dust. It was easily pulverised, and had a specific gravity suitable for its work, and its particles were more or less rounded and not glassy. The percentage of magnetic iron in it was low. The cool nature of the clayey bind dust rendered it easier to handle than flue dust, and it was not so unpleasant to taste nor so injurious to breathe.

COMBINED CRANE LOCOMOTIVE.

THE accompanying illustrations show a design of combined crane locomotive, in which separate electric motors are provided for revolving the crane and lifting the load, the invention of Messrs. R. & W. Hawthorn, Leslie, & Co., Ltd., and Mr. C. E. Straker, Forth Banks Works, Newcastle-on-Tyne. Fig. 1 is a side elevation of the locomotive, and Figs. 2 and 3 are respectively cross-sections on the lines A and B of Fig. 1. The locomotive is of the tank type with ordinary boiler, and the crane is entirely carried on castings C provided at each side of the boiler bolted to the top of the locomotive frame, and fastened together at the top over the boiler. On these supports is fixed the lower path D for the turntable rollers, and the turntable E is provided with brackets to which the crane jib is bolted or riveted, the jib having a counterweight and the lower path D provided with a central pillar F about which the turntable E revolves. Electric power is used for revolving the crane and for lifting the load. For this purpose a dynamo G is fixed in any convenient position on the locomotive and driven by a turbine H supplied with steam from the locomotive boiler. The crane is revolved by a motor J through a worm K on the motor shaft L meshing with a worm

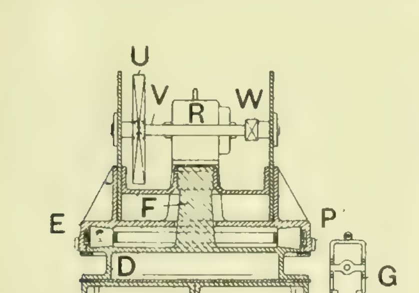


FIG. 2.

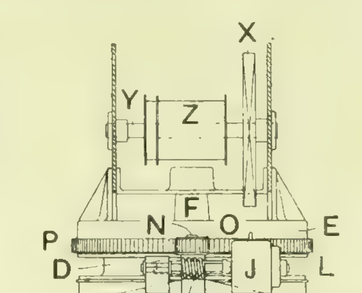


FIG. 3.

COMBINED CRANE LOCOMOTIVE.

wheel M on a vertical shaft N, which shaft carries a spur pinion O engaging a rack P which is part of or fixed to the turntable. Another motor R is used for lifting the load, this motor being carried by the turntable to the rear of the centre of the crane, and through a spur pinion S on motor shaft T gearing with a wheel U on shaft V on which is a pinion W gearing with a wheel X on shaft Y revolves a horizontal drum Z on shaft Y forward of the centre of the crane. The lifting rope or chain is coiled on this drum and is led over a pulley on

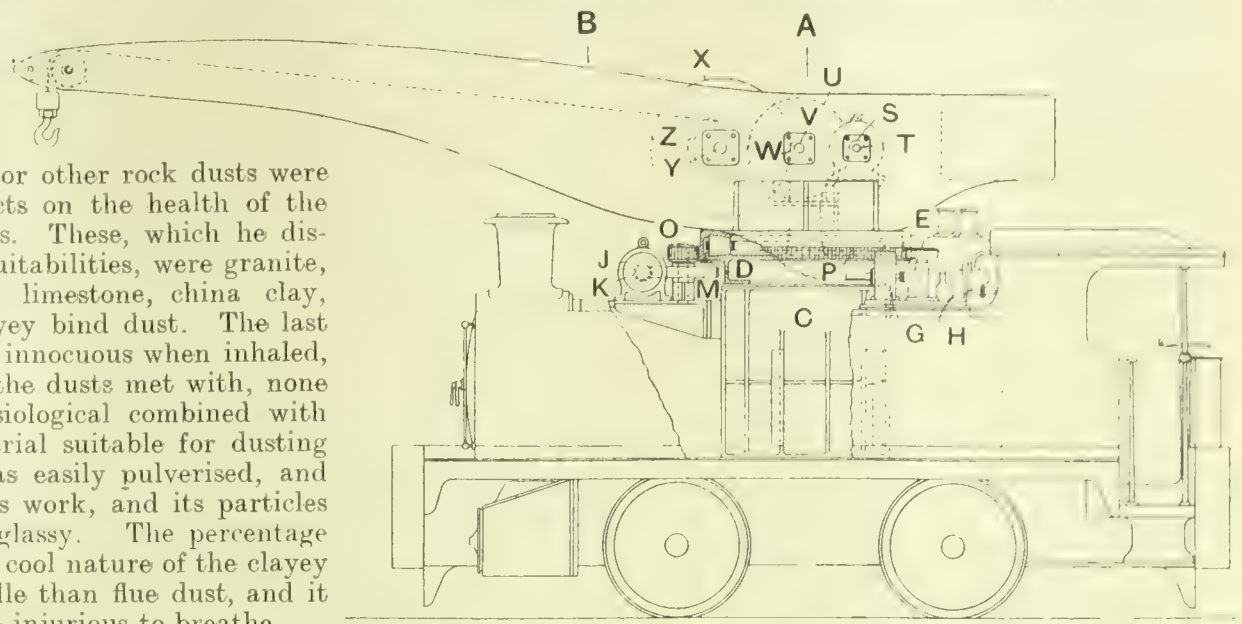


FIG. 1.—COMBINED CRANE LOCOMOTIVE.

the jib end. Suitable connections are provided between the dynamo and the motors, and the operation of the dynamo and motors is controlled from the cab of the locomotive.

TESTS OF CHILLABLE IRONS.*

BY THOMAS D. WEST.

THE paper presents an original series of tests of chillable irons, made during September, 1911, to the close of February, 1912. Before proceeding with the tests it was desired to find what size of bar should be used with different grades of iron to produce a bar of all grey iron and at the same time a companion bar that could be wholly chilled, or of a white iron, both poured from the same basin or ladle. Sets Nos. 1 and 2 show that bars $1\frac{5}{8}$in. diam. are suitable for various grades of chillable metal having its silicon ranging from 0·90 to 1·20. The balance of the sets show $2\frac{1}{4}$in. diam. bars to be suitable for many grades having a range of 0·50 to 0·90 per cent. silicon. It is to be understood that in either of the above the constituents, other than silicon, are generally the same as used in the making of such castings as chilled car wheels and rolls. In some cases the larger bars may be used for higher silicon metal, this depending chiefly upon the metal being high in sulphur and no ferro-manganese being used. While the round bar is advocated for a standard, it is to be understood that there are cases of experimental work such as presented in this paper, where square bars may be advisable, but for ordinary practice to obtain comparisons in mixtures, grades of metal, &c., the round bars are to be preferred. For moulding the square bars three flasks were constructed, each being adapted to cast three or four bars. These bars were 2in. square by 24in. long. For casting the round bars, two chiller moulds, having a bore of $1\frac{5}{8}$in., later on bored out to $2\frac{5}{16}$in., were used in connection with two pipe sand moulds.

Methods for Obtaining and Alloying Metals to Test their Efficiency.—In casting sets for these tests, the bars were poured with the regular metal from a reservoir ladle under the cupola spout, with a capacity of about 7 tons, and carried to the moulds in a "bull ladle" which held about 250lbs. Twelve ounces of ferro-manganese was thrown into the ladle, in order to secure the same composition as used for car wheels where 2lbs. to $2\frac{1}{2}$lbs. of ferro-manganese is added to every 700lbs. or 800lbs. of metal. After the bars were poured of this regular wheel metal the bull ladle was again filled as often as needed and vanadium or titanium, or both together, added according to the tests to be made, along with the 12 ozs. of manganese. The ladle was allowed to stand for three or four minutes to permit the alloys to melt thoroughly and mix with the metal. A $\frac{1}{4}$in. rod was used to agitate the metal to help bring any oxides

* Paper read before the American Society of Mechanical Engineers.

created by the alloys to its surface. The two, three, or more bull ladles of metal required for a set were taken from the reservoir ladle before any additional tap of metal was run into it from the cupola.

Method of Casting and Chilling the Alloyed Metal.—In pouring either of the above alloyed metals with the regular metal to obtain a set of square bars, a set of round bars would be poured with the same ladle. In casting the square test bars, some had a 2in. by 2¼in. chiller on two sides, as illustrated at T C in the end view of Fig. 1, so as thoroughly to chill the bar to make it all white iron. Others had a wrought plate ¼in. or ½in. thick as desired, on one side of the bar only, as at P C, in order only partly to chill one side of the bar. Bars to be free of chill, were surrounded with sand as seen at A G. In some cases two totally chilled bars and one all grey bar might be cast in the one flask. Again, two partially chilled, one totally chilled, and one all grey bar might be cast in one flask. This order could be changed in providing for three to four bars being made in a flask.

The character of the chill, or grain of iron, is given in the tables under the heading fracture. Should an all sand moulded bar show a slightly mottled grain in its fracture instead of being all grey, the words slightly mottled are inserted. Should the fracture be strongly mottled the notation is the word "deeply" in the place of "strongly." In cases where the depth of a partly-chilled bar was measured the thickness of the chill is given in connection with the statement that one side was chilled.

To indicate that one of the vertically cast sides, also the cope surface, or the nowel face of a bar is in tension when testing a bar, the words nowel, cope, and side are placed on the line with the respective bar in the column headed tension. This will be better understood by referring to Figs. 2 and 3 where the side and end view of the bars are shown in two ways of being tested. In the case of round, as well as square bars that are cast on end, as were Nos. 84 and 88, it makes no difference which way they are placed on the distance supports D, Figs. 2 and 3, when being tested.

The width and depth as well as the diameter of all the tested bars are given in Tables III. X. to permit a checking of the modulus of rupture column; also present data for other formulæ for computing variations in the size of the bars shown. It is to be understood that the records of all tests given are of solid bars and complete fractures; as should there have been a slight flow in any of those tested it would have been in the compression face of the bar where it could have no effect in reducing its strength.

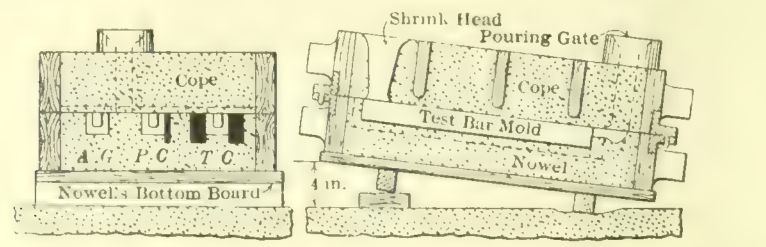


FIG. 1. SECTIONAL VIEWS OF MOULD FOR MAKING THE SQUARE TEST BARS

Methods Used for Transverse Testing and Practicability of Drop Tests.—All transverse tests on both round and square bars, Tables V. to IX., except tests 59 and 77, were made with a 12in. span, and all drop tests of Table X. with an 8in. span; all others were tested for the transverse and drop test on a 12in. span, as seen in Figs. 2 and 3. Tests 59 and 77 were made with a 10in. span. All drop tests of Tables V. to IX. were made with a 12in. span and all drop tests for Table X. were made with an 8in. span. The drop tests were made with a 25lbs. weight, having the first drop at a height of 6in. and raised 6in. higher for every blow until breaking the bar. If, for example, 6 is the number in the drop column of the tables, it means that the weight dropped once at each of the respective heights, 6in., 12in., 18in., 24in., 30in., and 36in., before breaking the bar. The bars for the drop tests, Tables V. to IX., were obtained by taking the long end of the 24in. long square bars after they had stood one transverse test. This is why two kinds of tests with the same bar are given under the same test number.

A comparison of the drop tests with the transverse tests shows that where a bar is strong transversely it generally shows a relatively high strength under the drop test. This was also true in the case of nearly all of the roundbars having a 6in. span, but these tests are not given herein. For castings that are subject to shock or sudden impact, such as car wheels, rolls, shears, dies, &c., the drop test should grow in favour. The apparatus costs little and the time required is less than that needed in any other method of testing.

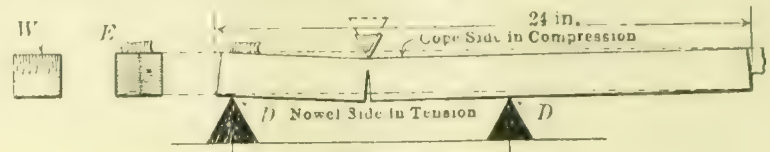


FIG. 2. END AND SIDE VIEWS OF A TEST BAR MADE IN MOULD FIG. 1

W shows gray side in tension and strong position; *E* shows horizontal plane of chill crystal in tension and weak position.

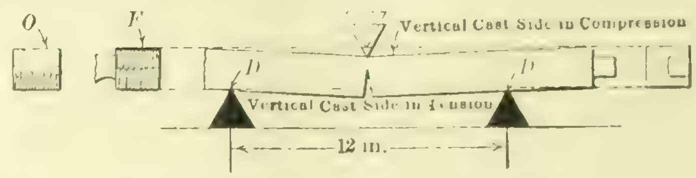


FIG. 3. SECOND TEST ON A 2 IN. SQUARE BAR

O shows chilled side in tension and weak position; *F* shows vertical plane of chilled crystal in tension and strong position.

Treatment and Analysis of Regular Car Wheel and Alloyed Metals.—No special complete analysis is given of the respective sets other than that in Table I. This is owing to the fact that car wheel mixtures or analyses, from one foundry at least, vary but little. Table II. gives the vanadium and titanium constituents of the test bars. Analyses of metal taken directly from the reservoir ladle before the ferro-manganese was added showed this metal to contain around 0·40 manganese. The drillings for regular car wheel metal analyses are taken from blocks about 2in. by 2½in. by 8in. cast in all sand so as to leave a grey body in the metal, which will agree closely with the grey between the plate and the body back of the chill of a car wheel.

Sensitive Conditions Requiring Consideration and Control in Testing Chillable Irons.—Table III. shows that bars 1¾in. square and 1⅝in. round are too small for regular car wheel metal. This is seen by the all-sand bars 3, 5, 8, 10, and 12, showing a fracture a little too strongly mottled instead of a fair grey structure. These sizes of bars are recommended only for chillable irons ranging from 0·90 to 1·20 per cent. in silicon for use in general

TABLE I.—*Range of Chemical Analysis for Chilled Car Wheels.*

Silicon.	Sulphur.	Manganese.	Phosphorus.	Combined Carbon.	Graphite Carbon.
0·55 to 0·65	0·100 to 0·150	0·55 to 0·70	0·270 to 0·320	0·60 to 0·70	2·70 to 2·90

TABLE II.—*Analysis of Sets Alloyed with Vanadium and Titanium.*

Set No.	Oz. of Vanadium in 225lbs. of metal.	Oz. of Titanium in 225lbs. of metal.	Per cent. of Vanadium in test bars.	Per cent. of Titanium in test bars.	Per cent. of Manganese in test bars.
9	10	—	0·06		0·65
11	—	10	—	0·02	0·72
13	22	—	0·12		0·64
15	—	22	—	0·07	0·60
18	[illegible]	10	0·04	[illegible]	[illegible]
19	8	15	[illegible]	[illegible]	[illegible]

TABLE III.—*Transverse Tests 1¾in. Square and 1⅝in. Round Bars and Crystallisation.*

Test No.	Fracture.	Width.	Depth.	Tension.	Maximum Load.	Deflection.	Modulus.	Set No.
1	All white	1·73	1·72	nowel	[illegible]	0·016	[illegible]	1
2	All white	1·68	1·69	cope	[illegible]	0·028	[illegible]	1
3	Slightly mottled	1·75	1·76	side	[illegible]	[illegible]	[illegible]	1
4	All white	1·59	diameter	—	[illegible]	0·023	[illegible]	1
5	Slightly mottled	1·60	diameter	—	[illegible]	0·065	[illegible]	1
6	All white	1·69	1·64	nowel	[illegible]	0·028	[illegible]	2
7	All white	1·71	1·71	side	[illegible]	0·042	[illegible]	2
8	Strongly mottled	1·72	1·79	side	[illegible]	[illegible]	[illegible]	2
9	All white	1·60	diameter	—	[illegible]	[illegible]	[illegible]	2
10	Almost white ..	1·56	diameter	—	[illegible]	[illegible]	[illegible]	2
11	All white	1·59	diameter	—	[illegible]	0·021	23.370	3
12	Strongly mottled	1·58	diameter	—	[illegible]	[illegible]	[illegible]	3

practice. The foregoing is a general statement requiring modifications in some instances. A comparison of the strength of bars 4, 5, 11, and 12 with 9 and 10 shows the cases in which strongly mottled iron of the same metal, also iron tending to all white, as No. 10, will give exceptional strength. Many other round bars 1⅝in. diam. were made, but broken with the

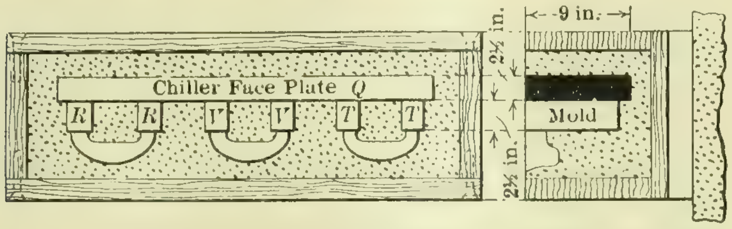


FIG. 4. OPEN SAND MOULD FOR MAKING COMPARATIVE CHILLING TESTS.

sledge to check these fractures. The two odd bars 11 and 12 are shown chiefly to demonstrate the distinction they display.

When a bar is of such a size that it is sensitive to assume a mottled form, it is very likely to go further and become almost white, and with the same iron, temperature of metal, and character of mould, there is as much chance to obtain a strength of 7,760lbs. as 5,540lbs., as seen for bars 10 and 12. But this sensitive condition must be avoided in order better to make comparisons between an all-chilled bar and an all-sand cast one of the same size, form, and metal. To do this, it is necessary to have the sand cast bars sufficiently large to prevent

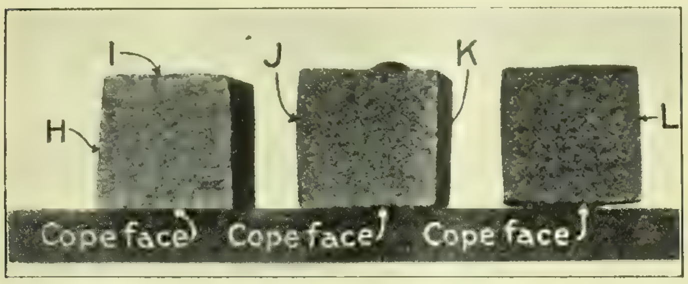


FIG. 5. SET OF ALL CHILLED, PARTLY CHILLED AND ALL SAND SQUARE BARS CAST FLAT.

TABLE IV.—*Transverse Tests of Variable Depths of Chill with Low Chilling Irons.*

T'st No.	Fracture and per cent. of chill.	Width.	Depth.	Load.	Deflection.	Modulus	Set No
13	Not chilled ; clear grey iron ..	1·01	1·51	5,615	0·098	43,900	4
14	Chilled one side ; 10% white	1·00	1·50	4,360	0·085	34,900	4
15	Chilled two sides ; 25% white	0·96	1·44	3,270	0·056	29,600	4
16	Not chilled ; clear grey iron ..	0·98	1·46	5,175	0·105	44,500	5
17	Chilled one side ; 15% white	1·03	1·48	4,220	0·069	33,700	5
18	Chilled two sides ; 20% white	1·02	1·45	4,390	0·079	36,900	5
19	Not chilled ; clear grey iron ..	0·97	1·47	5,000	0·103	43,000	6
20	Chilled one side ; 1% white ..	1·00	1·47	5,610	0·108	46,750	6
21	Chilled two sides ; 100% white	1·01	1·47	6,400	0·080	52,800	6
22	Not chilled ; clear grey iron ..	1·00	1·46	4,350	0·157	36,700	7
23	Chilled one side ; 5% white ..	0·99	1·43	4,550	0·159	40,500	7
24	Chilled one side ; 20% white..	1·06	1·50	4,200	0·137	31,700	7
25	Chilled two sides ; 50% white	1·02	1·50	2,300	0·110	18,050	7

TABLE V.—*Bars* 26 *to* 30 *had* 12*oz. Manganese;* 31 *to* 34, 12*oz. Manganese and* 10*oz. Vanadium in* 225*lbs. of Metal.*

Test No.	Fracture and per cent. of chill.	Width.	Depth.	Tension.	Load.	Deflection.	Modulus.	Drop.	Set No.
R 26	Chilled both sides. All white iron	2·04	2·00	nowel	15,150	0·030	33,420	4	8
R 27	Chilled ¼in. one side ..	2·10	2·05	nowel	14,330	0·036	29,230	6	8
R 28	All grey iron	2·12	2·08	nowel	23,860	0·070	46,820	9	8
R 29	All grey iron	2·31	diameter	—	25,750	0·095	63,710	—	8
R 30	Chilled. All white iron	2·21	diameter		14,620	0·030	41,330	—	8
V 31	Chilled two sides. All white iron	2·08	1·97	nowel	16,100	0·030	35,900	4	9
V 32	Chilled ⅜in. one side ..	2·05	1·99	nowel	15,370	0·035	34,080	5	9
V 33	All grey iron	2·08	2·00	nowel	22,020	0·070	47,640	9	9
V 34	All grey iron	2·32	diameter	—	23,430	0·070	57,300		9

Set *R* poured with regular iron. Set *V* poured with vanadium in regular iron. Set *T* poured with titanium in regular iron.

their taking a mottled form, and still not so large as to prevent their being absolutely chilled, or all white iron to their very centre, when cast in an all-iron mould or chiller of the same diameter. Much experimenting may often be necessary to learn to know the best size to adopt for making a comparison between the white and grey of special chillable irons. It will be seen by the tables having the 2¼in. round bars, that even with this increase over the 1⅝in. diam., some of the larger bars show a slightly mottled fracture with the silicon around 0·60. This could have been largely avoided by baking or drying the sand moulds, as those used in the tests shown were all of green sand. To increase the size of the round bar would assist this feature, and such could be done to the extent of having it 2¾in. and possibly 3in. diam. and still produce a perfect, all-chilled bar for a companion to an all-sand cast or grey one having the silicon around 0·60.

It is important therefore to describe the structure of fractures when recording tests of chillable iron and in making comparisons with all-chilled and grey bars or otherwise. It all shows that in some cases, it may be necessary to experiment in order to obtain the diameter best suited to give a knowledge of the relative strength of the white and grey of chillable irons. This does not prevent the adoption of a standard to be used the world over for tests for chillable irons. All that is necessary is to state the structure of the fracture, diameter of the bar used, per cent. of silicon, and possibly other constituents, should they vary much from those given in Table I.

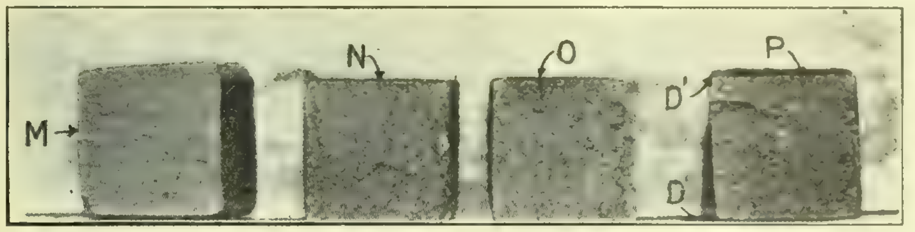


FIG. 6.—SET OF ALL CHILLED, PARTLY CHILLED AND ALL SAND SQUARE BARS CAST ON END.

Erratic Effects of Chilled Crystals and Interlacing of the Grey with them.—Table IV. presents a few of the many tests made with chillable metal, having about the following composition: silicon 2·0, sulphur 0·06, phosphorus 0·04, manganese 0·30. The bars were made in a converter steel foundry and tested by John H. Nelson; all others were tested by H. E. Smith. In testing this set, the load was applied in the deep direction of the bars which were all cast on end. Tests 13 to 25 illustrate the erratic qualities of partly-chilled bodies, accounted for by the interlacing of the white with the grey and the depth of mottled iron back of the chilled body.

In partly-chilled sections, the temperature of the chiller to chill the iron, and of the metal to pour the mould, and the

TABLE VI.—*Bars* 33 *to* 39 *had* 12*oz. Manganese; Bars* 40 *to* 44 12*oz. Manganese and* 10*oz. Titanium in* 225*lbs. of Metal.*

Test No.	Fracture and per cent. of chill.	Width.	Depth.	Tension.	Load.	Deflection.	Modulus.	Drop.	Set No.
R 35	Chilled both sides. All white	2·14	1·98	nowel	22,420		48,108		10
R 36	Chilled $\frac{7}{16}$in. one side ..	2·03	2·07	nowel	18,990	0·037	39,170	3	10
R 37	All grey iron	2·12	2·04	nowel	25,740	0·075	54,700	11	10
R 38	All grey iron	2·27	diameter		25,520	0·077	66,570	—	10
R 39	Chilled. All white iron	2·22	diameter		13,440	0·024	37,477	—	10
T 40	Chilled both sides. All white	2·02	1·97	nowel	16,100	0·031	36,960	4	11
T 41	Chilled ⅜in. one side ..	2·07	2·00	nowel	15,130	0·032	33,280	5	11
T 42	All grey iron	2·06	1·99	nowel	21,870	0·074	48,250	9	11
T 43	All grey iron	2·32	diameter		23,400	0·059	57,180		11
T 44	Chilled. All white iron	2·22	diameter	—	17,110	0·028	47,711	—	11

TABLE VII.—*Bars* 45 *to* 49 *had* 12*oz. Manganese; Bars* 50 *to* 54, 12*oz. Manganese and* 22*oz. Vanadium in* 225*lbs. of Metal.*

Test No.	Fracture and per cent. of chill.	Width.	Depth.	Tension.	Load	Deflection.	Modulus.	Drop.	Set No.
R 45	Chilled both sides. All white	1·99	2·02	nowel	16,460	0·030	38,220	5	12
R 46	Chilled ⅜in. one side ..	2·10	2·00	nowel	14,380	0·035	30,810	7	12
R 47	All grey iron	2·08	2·01	nowel	23,790	0·090	50,960	11	12
R 48	All grey iron	2·29	diameter	—	23,910	0·078	60,730	—	12
49	Chilled. All white iron	2·22	diameter	—	15,610	0·022	43,520		12
V 50	Chilled both sides. All white	2·00	1·98	nowel	16,030	0·035	36,800	4	13
V 51	Chilled $\frac{7}{16}$in. one side ..	2·10	2·02	nowel	14,090	0·030	29,600	3	13
V 52	Grey, slightly mottled	2·05	2·00	nowel	24,800	0·065	54,440	7	13
V 53	Grey, slightly mottled	2·27	diameter	—	25,580	0·060	66,710	—	13
V 54	Chilled. All white iron	2·20	diameter	—	17,890	0·025	51,250	—	13

degree of dampness in the sand, have an effect both on the depth of chill, and on the structure of the metal for a considerable distance beyond the place where the white ceases. These are all factors difficult to control in regular practice, but the more that is known concerning them, the better will be the design, make, and use of the castings. The variable hardness of mottled and grey bodies, interlacing with the white iron of chilled bodies, are displayed by the hardness tests, Table XII.

Transverse and Drop Tests of Grey and Chilled Bars Alloyed with Vanadium and Titanium.—Tables V. to IX. present an original series of tests comprising the following features: (*a*) Comparison of strength, deflection, chill and contraction, in all-chilled, partly-chilled, and grey bars of the same metal. (*b*) Comparison of square and round bars to emphasize the utility of the latter for a standard. (*c*) Comparisons of transverse and drop tests to show their conformity, and practicability of the latter. (*d*) Comparisons of hardness created by the rate in cooling, giving chilled, mottled, and grey fractures in the same metal. (*e*) Effects of ferro-manganese, vanadium, and titanium in the same metal and size of section, when of a chilled, mottled, and grey structure.

Results of the above comparisons in connection with those to be derived from a study of the tables are given throughout the paper.

Notable Difference in the Strength of the Chilled and Grey Sides of a Partly-chilled Casting.—It will be seen from tests in Table X. that when the chilled face is in extension, as with tests 92, 94, and 96, the casting is much weaker than when the grey or mottled body is in extension, as with tests 91, 93, and 95 of set 22. This is a quality having heretofore received very little, if any, thought. When fully considered it will be seen to be of great importance in the making and use of different lines of castings.

TABLE VIII.—*Bars 55 to 59 had 12oz. Manganese; Bars 60 to 64, 12oz. Manganese and 22oz. Titanium in 225lbs. of Metal; while Bars 65 to 68 were free from Manganese and other Alloys.*

Test No.	Fracture and per cent. of chill.	Width.	Depth.	Tension.	Load.	Deflection.	Modulus.	Drop.	Set No.
R 55	Chilled both sides. All white	2·00	2·00	nowel	15,980	0·030	35,960	1	14
R 56	Chilled ½in. one side. Balance mottled	2·00	2·07	nowel	18,140	0·038	38,100	1	14
R 57	Grey iron. Corners chilled	2·02	2·00	nowel	22,720	0·070	50,610	7	14
R 58	Grey iron, slightly mottled	2·25	diameter	—	26,000	0·075	69,640	—	14
59	Chilled. All white	2·24	diameter	—	13,830	0·017	33,966	—	14
T 60	Chilled both sides. All white	2·00	1·98	nowel	13,200	0·025	30,300	4	15
T 61	Chilled ½in. one side. Balance mottled	2·01	2·03	nowel	16,840	0·035	36,060	4	15
T 62	Grey, corners slightly chilled	2·05	2·00	nowel	22,080	0·075	48,470	10	15
T 63	Grey iron . .	2·26	diameter	—	25,810	0·08	68,230	—	15
T 64	Chilled. All white iron	2·22	—	—	16,070	0·05	44,810	—	15
S 65	Chilled both sides. All white	2·01	2·01	nowel	11,100	0·020	24,170	3	16
S 66	Chilled ½in. one side. Deeply mottled	2·06	2·04	nowel	10,860	0·030	22,800	3	16
S 67	Grey, corners mottled ..	2·04	2·00	nowel	17,870	0·050	39,420	5	16
S 68	Grey iron, mottled	2·25	diameter	—	24,180	0·065	64,204	—	16

Set S poured with spurious metal containing no ferro-manganese.

The reliability of this set of tests will be realised when it is understood that the respective companion tests having the chilled side in compression and tension were made with the same bar, by the method shown in Figs. 2 and 3. After making two transverse tests of the same bar, there was sufficient remaining for a drop test having an 8in. span. A few of these are tests 83 to 96. Bars 83 to 90 were cast on end, while bars 91 to 96 were cast flat, as shown in Fig. 1, and chilled on one side only to give two of this form for one set. In Fig. 6 is seen a full set of the square bars cast on end, in which M is the all-chilled bar, N the chilled side, and O the grey side of the partly-chilled bars, while P is the all-sand cast bar. The position of the chilled face in the testing is shown at W for both the cast on end and cast flat bars when upward, and at O when downward, seen on the left of Figs. 2 and 3.

Another feature is the great difference between the strength of chilled iron when the lines of crystallisation stand vertical to the load, and when they are turned horizontal to it. In Table III., tests 1, 2, 6, and 7 show a difference of about 61 per cent. for the first two bars, and about 51 per cent. for the second two. The lines of crystallisation are seen in Figs. 2 and 3, where E is the weakest and F the strongest position of the two-sided bar. These qualities were originally discovered by Asa W. Whitney, and are presented here to give data in keeping with the original tests of this paper.

Criticism on and Chilling Effects of Vanadium and Titanium.—William H. Hatfield in a paper "On the Influence of Vanadium upon Cast Iron"* at the March, 1911, meeting of the Iron and Steel Institute, stated, "There is considerable disagreement as to the influence of vanadium." Expressions of this character had much weight in the taking of extra precautions when testing these alloys, in the belief that the results might settle some of the disputed points. Information of the chilling qualities of the alloys is given in the three following paragraphs and in the various sets of Tables V. to IX., as tests 27 and 32. It required but a few tests to show that the difference in the pouring temperature of the metals, due to the cooling effect produced in melting the alloys, was such as to make the depth of chill shown in Tables V. to IX. an uncertain factor for these tests. This is more fully realised when the fact is considered that "hot" metal will chill deeper than "dull" metal.

To obtain more favourable conditions for rapid pouring and less travel of metal than was offered by the mould, Fig. 1, cupola chill blocks were made after the plan and end views in

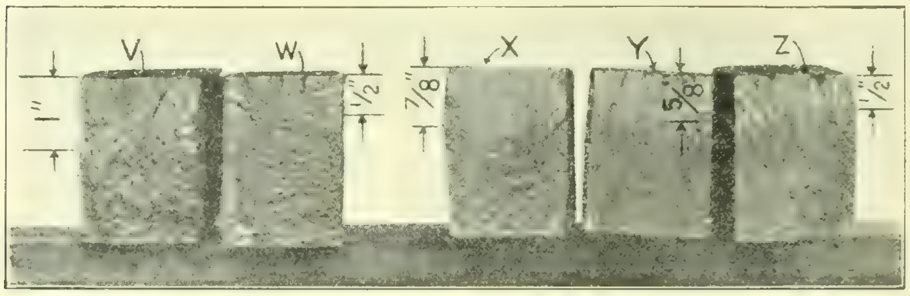


FIG. 7.—SPECIMENS AFFECTED BY COOLING AND VARYING PERCENTAGES OF VANADIUM AND TITANIUM.

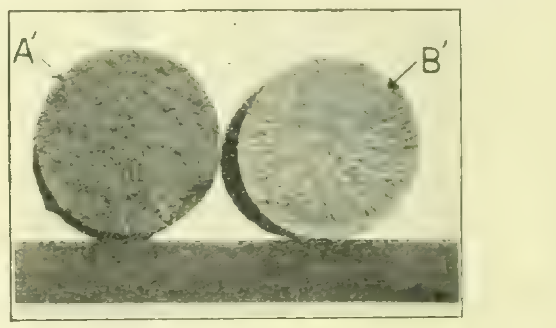


FIG. 8.—SPECIMENS OF ALL CHILLED AND ALL SAND ROUND BARS CAST ON END.

TABLE IX.—*Bars 69 to 72 had 12oz. Manganese; Bars 73 to 77, 10oz. Titanium and 5oz. Vanadium: Bars 78 to 82, 12oz. Manganese, 15oz. Titanium, and 8oz. Vanadium in 225lbs. of Metal.*

Test No.	Fracture and per cent. of chill.	Width.	Depth.	Tension.	Load.	Deflection.	Modulus.	Drop.	Set No.
R 69	Chilled both sides. All white	1·98	2·02	nowel	18,480	[illegible]	41,170	5	17
R 70	Chilled ½in. one side. Balance mottled	2·01	2·50	nowel	[illegible]	[illegible]	[illegible]	6	17
R 71	All grey iron	2·05	2·05	nowel	[illegible]	[illegible]	[illegible]	11	17
R 72	All grey iron	2·27	diameter	—	[illegible]	[illegible]	62,660	—	17
TV 73	Chilled both sides. All white	2·02	2·00	nowel	12,330	0·025	27,47[illegible]	—	18
TV 74	Chilled ½in. one side. Balance mottled	2·05	2·07	nowel	[illegible]	[illegible]	[illegible]	6	18
TV 75	All grey iron	2·10	2·04	nowel	[illegible]	[illegible]	[illegible]	11	18
TV 76	All grey iron	2·29	diameter	—	[illegible]	[illegible]	[illegible]	—	18
TV 77	Chilled. All white iron	2·21	diameter	—	[illegible]	[illegible]	[illegible]	—	18
TV 78	Chilled both sides. All white	1·96	[illegible]	nowel	[illegible]	0·030	[illegible]	4	19
TV 79	Chilled ½in. one side. Balance mottled	[illegible]	[illegible]	nowel	[illegible]	[illegible]	[illegible]	[illegible]	19
TV 80	All grey iron	[illegible]	[illegible]	nowel	[illegible]	[illegible]	[illegible]	8	19
TV 81	All grey iron	2·2[illegible]	diameter	—	[illegible]	[illegible]	[illegible]	—	19
TV 82	Chilled. All white iron	2·2[illegible]	diameter	—	[illegible]	[illegible]	[illegible]	—	19

* The Journal Iron and Steel Institute, Vol. LXXXIII., No. 1, page [illegible].

Fig. 4. The pair of chilled blocks R were poured with the regular car wheel metal, cooled down to nearly the same temperature as that for pouring the chill block moulds V and T having the vanadium and titanium alloys in their respective ladles. This method emphatically demonstrated that the vanadium increased the depth of chill, or held the carbon more in its combined form, while the titanium operated in the opposite direction. Numerous tests were made following this plan, some of which had a ½in. chiller face plate in place of the 2½in. plate Q, and all of them were effective in the same direction as to their respective results.

TABLE X.—*Transverse and Drop Tests of One Side Chilled Bars alternated to be in Compression and Tension.*

Test No.	Fracture and per cent. of chill.	Width.	Depth.	Load.	Deflection.	Modulus.	Drop.	Set No.
83	Grey iron, slightly mottled	2·09	2·06	21,070	0·045	42,760	7	20
84	Chilled four sides. All white	2·12	2·18	23,380	0·040	41,770	15	20
85	Chilled ⅝in. one side. Balance mottled. Grey side in tension..	2·06	2·05	21,590	0·030	43,435	9	20
86	Chilled 9/16in. one side. Balance mottled. Chilled side in tension	2·07	2·03	20,430	0·035	43,111	7	20
87	Grey iron, slightly mottled	2·11	2·07	19,420	0·045	38,664	8	21
88	Chilled four sides. All white ..	2·06	2·20	22,150	0·020	40,532	15	21
89	Chilled 11/16in. one side. Balance mottled. Grey side in tension..	2·10	2·04	19,880	0·050	40,947	8	21
90	Chilled 11/16in. one side. Balance mottled. Chilled side in tension	2·06	2·06	13,660	0·030	28,132	6	21
91	Chilled ¼in. one side; ¼in. mottled. Grey side in tension	2·11	2·15	23,760	0·070	43,861	14	22
92	Chilled ¼in. one side; ¾in. mottled. Chilled side in tension	2·13	2·06	17,260	0·035	34,373		22
93	Chilled ¼in. one side; ¾in. mottled. Grey side in tension	2·12	2·10	21,760	0·055	41,914	7	22
94	Chilled ¼in. one side; ¾in. mottled. Chilled side in tension	2·13	2·06	13,190	0·025	26,378		22
95	Chilled ½in. one side; 1in. mottled. Grey side in tension	2·11	2·03	20,350	0·055	42,127	5	22
96	Chilled ½in. one side; 1in. mottled. Chilled side in tension	2·13	2·13	15,720	0·030	29,281		22

One test with the three sets of moulds, Fig. 4, gave a difference in the thickness of chill as seen at X, Y, and Z, Fig. 7. The set R was poured with the regular iron; the set V with the vanadium, and the set T with the titanium alloyed metal, there being 1lb. of each alloy in about 175lbs. of metal.

Further experiments having 2lbs. of titanium in the 175lbs. of metal gave a thickness of chill seen at V and W, Fig. 7, of 1in. and ½in. respectively as marked in the cuts. In the belief that by increasing the amount of titanium the chill might be wholly prevented, 4lbs. was put into the metal for two tests. This did not act as effectively as the 2lbs. and showed that iron could not be prevented from chilling beyond a certain limit by its use.

Effects of Vanadium, Titanium, and other Factors on Contraction.—Tests to obtain contraction were made with both round and square bars and are given in Table XI. The 2¼in. round bars show the contraction for a length of 12in. and the square bars for 22in. The ratios for contraction of the bars cast on end agree closely with those of the bars cast flat. The regular irons are fairly uniform in their contraction. The vanadium bars show a greater contraction than those containing titanium, the latter having the least of any of the metals. The spurious metal of set 16 having no ferro-manganese in it, shows the greatest contraction. The most radical difference exists between the all-chilled and all-grey bars.

Effects of Vanadium and Titanium on Strength.—In making deductions of the relative strength for the alloy mixtures, &c., the round bars were selected chiefly on account of their uniform structure and greater uniformity of results. Fig. 8 is a good illustration of the uniformity of the metal as it comes in round bars rather than in square ones. The grey round bar A′ shows a much better uniformity of grain structure than exists in the square bars L and P, Figs. 5 and 6. These last present irregular patches of grains embodying every structure from white at the corners D′, interlaced with mottled, leading to a grey centre, sensitive to change with the least variation in the dampness or character of the sand, hardness in ramming and temperature of pouring metal. This irregularity of structure is likewise apparent in the all-white square bars H and M, Figs. 5 and 6, when compared to that seen at B′, Fig. 8.

The titanium bars show an increase of strength over the regular bars of 27 per cent. in the white iron with bars 39 and 44, Table VI., and 32 per cent. in the white iron with bars 59 and 64, Table VIII.

The vanadium shows an increase of strength of 9 per cent. in the grey iron, with bars 18 and 53, and 17 per cent. in the white with bars 49 and 51, both of Table VII.

The spurious bars which have no ferro manganese or other alloys in them, show a decrease of strength of 7 per cent. in the grey iron, with bars 63 and 68 of Table VIII. No comparison of the white iron in the round bars can be given, since there are no chilled round bars for this last set; but the contrast is so great in the square chilled bars 55 and 65, which show the white of the spurious metal, that it is safe to consider them 30 per cent. weaker than the regular iron.

Some tests having shown vanadium and titanium beneficial in increasing the strength, it seems reasonable to suppose that all the other sets having them alloyed in the regular metal should show a similar tendency. It may be that in a car wheel metal there is a definite absorption of the alloys necessary to increase materially the strength of the grey and white. By the use of large round test bars for making the relative comparison in these irons, further experimenting with this grade of metal along practical lines should establish beyond any doubt the question of such a limit.

Comparison of Partly-chilled with Wholly-chilled and Grey Bodies.—In conducting this series of tests, bars were cast having only one side chilled as companion bars to the all-chilled and grey bars, as seen by the second test, Tables V. to IX. It will be a surprise to many to find that in all the tests, excepting the two of set 14, the partly-chilled bars are weaker than the all-chilled or white bars. A good view of these three companion bars is shown in Fig. 5, K being the partly-chilled side.

The weakness of the partly-chilled bars is due to internal strains and scattered amalgamation of the state of the broken carbon of the metals. Bars showing nearly every effect of rapid and slow cooling, and in no wise possessing the homogeneous blending of one character of grains, seen by the wholly white and grey, is well illustrated by H, L, Fig. 5.

All the partly-chilled bars showed the chilled body interlacing the mottled, and the latter blending into the grey, Figs. 5, 6, and 7. This is generally considered to be a stronger section than those where a distinct line marks the separation of the white and grey, and causes conditions such as can still further increase the weakness of partly-chilled castings. Designers should duly consider this factor, so as either to have a strong backing of the mottled and the grey, or to have the chilled side of the casting arranged in compression if practical, when strains or concussions of its work is brought to bear upon it, a feature in keeping with the tests on treatment of Table X.

TABLE XI.—*Contraction of Round Bars Cast on End and Square Cast Flat.*

Set No.	Round bars, all chilled.	Round bars, all grey.	Square bars all chilled.	Square bars, part chilled	Square bars, all grey.
R 12	0·22	0·12	0·47	0·28	0·26
V 13	0·23	0·13	0·48	0·30	0·27
R 14	0·22	0·12	0·47	0·28	0·26
T 15	0·21	0·11	0·43	0·29	0·25
S 16	—	—	0·50	0·36	0·32
R 17		—	0·48	0·31	0·28
TV 18	0·22	0·12	0·47	0·29	0·26
TV 19	0·23	0·12	0·48	0·30	0·27

TABLE XII.—*Brinell and Scleroscope Hardness Tests of Specimens, Fig. 4.*

Set No.	Class.	*H* Bri.	*H* Scl.	*I* Bri.	*I* Scl.	*J* Bri.	*J* Scl.	*K* Bri.	*K* Scl.	*L* Bri.	*L* Scl.
12	*R*	394	65	318	59	179	39	326	55	185	39
13	*V*	377	63	358	60	227	41	403	60	199	41
14	*R*	417	66	403	58	185	38	386	61	175	38
15	*T*	419	68	427	56	211	41	412	58	186	40
16	*S*	452	69	412	59	221	40	413	60	191	42
17	*R*	358	62	390	56	189	39	317	47	173	37
18	*TV*	382	64	375	61	193	40	400	54	183	40
19	*TV*	442	66	422	54	189	41	417	57	179	38

Comparison of Strength in All-white and All-grey Irons.—A feature of this paper worthy of consideration is the strength and deflection obtainable in strictly all-chilled or white iron. It is generally supposed that white iron is very much weaker than grey, and has very little if any deflection. By referring to tests 7, 21, 30, 35, 44, 49, 54, 69, 82, 84, and 88, it will be seen that white iron can be obtained at least 75 per cent. as strong as grey. White iron is the strongest with the crystals

radiating from a centre as at M and B', Figs. 6 and 8. The round bar excels the square in this form of structure.

Spalling Weakness of Chilled or White Iron.—The chief evil of white iron lies in its strength being erratic, and easily spalled. It is believed that founders could greatly increase and control the strength of various grades of white irons and make them much more reliable. Numerous experiments were conducted to test the spalling weakness of white and grey iron and it was found that white bodies do not possess much over one-third the strength to resist spalling blows that exists in the grey or mottled of the same iron. It shows the importance of designing that portion of the casting subject to such blows to contain as far as practical grey or mottled iron.

Hardness Tests of All-chilled, Partly-chilled, and Sand-cast Test Bars.—Table XII. gives Brinell and scleroscope tests of three samples taken from each of the first three bars of sets 12 to 19, a view of which is seen in Fig. 5. The Brinell depressions were produced by a ⅜in. ball loaded with 6,000lbs. and the readings are the weight in kilogrammes sustained by 1 mm. of area of the depression produced by the total load. This is the standard method of testing Brinell hardness. Both the Brinell and scleroscope records are the averages of 4 to 6 tests on a sample. The columns H, I, J, K, and L give the tests of the surfaces indicated by the same letters shown in Fig. 5. Those who conduct these kinds of tests know that there is some variation of hardness over an area although it may not exceed 1 sq. in. The surfaces H had a variation of 3 to 7 points, and I 8 to 15 points, J about 6 points, while L had but 3 points, showing that a greater uniformity in hardness can be expected in all grey bodies than in mottled or chilled surfaces.

The table also shows that directly chilled faces, as H, are harder than those crystallising over a sand surface caused by the heat-absorbing effect of a chiller, some distance from such points, as I. The excessive variation of the surface I is believed to be caused by the curved structure of the heat radiation lines, as they come to the surface at an angle, differing from the straight lines shown on the sides at H.

The spurious iron is on an average harder than the regular iron. The alloys appear to have a hardening effect as compared with the regular iron, or that having only ferro-manganese in it. The irregularity in the effect of the alloy is no doubt due to the variations in the temperature of the metal filling the moulds, and brings about variations in hardness similar to creating an irregularity in the chill, strength, deflection, and contraction of like irons.

INDUSTRIAL AND TRADE NOTES.

Labour Co-partnership.—A largely-attended meeting of representative commercial men and members of the House of Commons was held on the 12th inst. to consider the formation of a consultative council of the Labour Co-partnership Association for promoting co-partnership in the industries of the country generally. This step was agreed to, after full discussion.

Another Shipyard Conference.—Another Grand Conference was held in Edinburgh on Wednesday between the Shipbuilding Employers' Federation and the Standing Committee of the shipyard trades to discuss: (1) The 48 hours week; (2) the organisation of boilermaker apprentices; (3) the general advance of 5 per cent. asked recently by the committee; (4) the advance of 4 per cent. to riveters so as to enable them to pay higher rates to holders-on; and (5) a general discussion on the proposed amendments to the national agreement. As the conference was sitting at the time of going to press we are unable to present the results arrived at.

Increased Activity in Hematite Iron Trade.—The improved demand which has set in for hematite iron in the Furness and West Cumberland district has necessitated an increased production of metals. The Millom and Askam Company have just put another furnace in blast, and they are preparing to re-light their large American furnace at Askam shortly. The Barrow Steel Company have five furnaces in blast, and will in the course of a week or so put a new and improved furnace in blast which will have a yield of about 1,500 tons of metal per week. There are indications of fuller activity at Ulverston, Carnforth, and in the West Cumberland district.

London's New Docks.—The Port of London Authority has decided that the work of constructing a new dock to the south of the Royal Albert Dock should be offered to S. Pearson & Son, Ltd. The cost of that work, based upon a schedule of prices, will amount to about £1,400,000. The contract will include the construction of an entrance dock, 800ft. by 100ft. by 45ft. deep, a main dock, 4,500ft. long, averaging 600ft. in width and 35ft. in depth, with water area of 65 acres; a dry dock, a pasasge connecting with the Royal Albert Dock Railway lines, and six sheds, but not working equipment of the dock. On the south side of the dock, vessels will be berthed at jetties to facilitate barge traffic.

The Boilermakers' Society.—In the June report of the Boilermakers' Society, Mr. John Hill, general secretary, reports that trade continued in a healthy state. The half year's output of ships would create a new record, and the enquiries for new work continued. Capitalists were looking on the industry favourably, and new shipyards and docks were in preparation. The present month would witness three most important conferences—one each on holders-up advance of rates, the apprentice question, and the eight-hours day. This month the branches will also vote for or against the acceptance of a demarcation agreement arrived at between the Engineering and Shipbuilding Federation of Employers and the various trade societies concerned.

The Amalgamated Society of Engineers and the 1907 Agreement.—The Amalgamated Society of Engineers has decided to instruct the Executive Council to take a vote for or against the determination of the terms of agreement, 1907. This agreement binds on the one side the Engineering Employers' Federation, and on the other the Amalgamated Society of Engineers, the Steam Engine Makers' Society, the United Machine Workers' Association, and one or two smaller metal working unions. Originally its provisions were the terms upon which the great dispute of 1897 was settled. In 1907 they were revised, and their title was altered from terms of settlement to terms of agreement. They cover practically the whole of the conditions of employment in engineering, but are chiefly notable for their provisions for avoiding disputes.

Smoke Prevention in Glasgow.—The Sanitary Department of the Glasgow Corporation report a great decrease in the number of prosecutions instituted in connection with the production of black smoke, and of the large number of chimneys systematically watched by the Department 46½ per cent. are now clear of smoke and 27½ per cent. emit only an amount so small as to be far below the line of excess. There are still a number of intermittent offenders. About 10 per cent of the steam boilers in the city have, it is stated, been increased in power, while at the same time their tendency to cause smoke has been reduced. Thirteen per cent. of the firms have installed mechanical stokers and 18 per cent. have fitted smoke-prevention apparatus. In plants used for manufacturing purposes 33 per cent. of those formerly fired by coal are now fired by gas.

China's Industrial Development.—An American Consul, writing from Shanghai, states that China is at the dawn of an era of industrial development, and the demand for plant should increase for many years. He says that local representatives connected with machinery and electrical appliances state that the British and German firms are obtaining more business than their competitors because they study the requirements of the market more carefully than manufacturers of other countries, and have far superior organisations in China. German firms also grant special terms of payment, with the result that any scheme which presents a reasonable prospect of success is financed and German materials are purchased. In regard to electrical machinery, at present there is excessive competition owing to the lack of technical knowledge in China, except in the case of a limited number of purchasers. Consequently few are able to judge the relative merit of machines, and price becomes the standard by which they are usually appraised.

The Industrial Council to Enquire into the Labour Unrest.—The Industrial Council, to which the Cabinet has referred certain questions associated with the prevailing unrest, will, it is understood, commence its deliberations immediately, and take evidence from both employers and workmen. Speaking in the House of Commons a few days ago, the Prime Minister said from experience recently derived the Government considered that one of the chief difficulties in the way of securing industrial peace was the want of any effective method of enforcing agreements which had been arrived at between both sides, and how far these agreements could be enforced on those who were not parties to it. These were considerations for employers and workmen, and the Government therefore proposed to ask the Industrial Council to consider the best method of securing the due fulfilment of industrial agreements, and how far they could be enforced in particular trades. The Industrial Council would take evidence, and report the conclusions they arrived at, which would receive the earnest attention and consideration of the Government.

State of the Skilled Labour Market.—The "Board of Trade Labour Gazette" states that employment continued to improve during May, and by the end of the month was as good on the whole as before the national coal strike. The improvement was most marked in the pig iron, iron and steel, and engineering trades.

The only important exception was the shipbuilding industry, in which production was somewhat restricted through lack of materials. As compared with a year ago, employment in most of the principal industries showed an improvement, which was specially noticeable in the iron and steel trades. In the pig iron, shipbuilding, and building trades, however, there was some decline. In the 392 trade unions, with a net membership of 836,949 making returns, 22,307 (or 2·7 per cent.) were returned as unemployed at the end of May, 1912, compared with 3·6 per cent. at the end of April, 1912, and 2·5 per cent. at the end of May, 1911. Returns from firms employing 453,098 workpeople in the week ended May 25th, 1912, showed an increase of 4·2 per cent. in the amount of wages paid compared with a month ago and of 6·6 per cent. compared with a year ago.

State Aid for Industry in Hungary.—A report on the trade of Hungary by his Majesty's Consul-General at Budapest states that last year 10 factories were established with State assistance, and the further development of 15 others was assured. These establishments represent a capital of £677,000, and give employment to at least 3,700 workmen. Besides the above, 36 factories received machinery to the value of nearly £20,000 on condition of employing 1,150 new workmen. Some 67 factories received State assistance in the form of freedom from taxes, &c. In the case of 20 factories exemption from taxation was prolonged, and a similar privilege was granted in favour of 19 factories, the erection of which is contemplated. In all, State aid to industry during 1911 represents £1,875,000, and has given employment to 7,700 workmen. An experimental institution has been established for making experiments and examining materials likely to develop the smaller industries. Further, the development of the use of water-power in Hungary is engaging the attention of the authorities, and the work of the Commission occupied in considering a reform of the Industry Law (Gewerbe Gesetz) is stated to have made progress.

The Panama Canal and the Shortening of Routes.—Speaking at the Royal Colonial Institute on the 11th inst. on the "Panama Canal and its Relation to the British Empire," Mr. Vaughan Cornish said that, for Vancouver and all other ports north of Panama on the west coast of North America, the canal meant a reduction of 8,400 miles to New York; about 7,000 miles to Montreal; and 6,000 miles to Liverpool. For ports on the west coast of South America, the reductions of distance varied from the above maximum at Panama to zero near the southern extremity of the continent. The average reduction was about 5,000 miles to New York and 2,600 miles to Liverpool. The distance from Yokohama to New York was diminished by 3,700 miles. Shanghai was brought 1,600 miles nearer to New York, Sydney was brought 3,800 miles nearer to New York by way of Tahite, and about 2,500 miles nearer to Montreal. The distance from Melbourne to New York was reduced by 2,600 miles viâ Tahite, and from Wellington, N.Z., by 2,500 miles. Yokohama, Sydney, and Melbourne, at present nearer to Liverpool than to New York, would, after next year, be nearer to New York than to Liverpool. Japan, Korea, the Philippines, and New Guinea, as well as most of Australia, were in the zone or band for which the Suez and Panama routes offered rival advantages.

Prosecutions Under the Coal Mines Act.—Heavy penalties were inflicted by the Potteries Stipendiary at Burslem on the 11th inst. in two prosecutions under the Coal Mines Regulation Act against John Kyle, managing director and agent of the Brownhills and Bentilee Colliery Company, Bentilee, and William Hogg, manager of the company. There were originally 29 summonses against the colliery, against Kyle, and against Hogg, but only eight, three against Kyle and five against Hogg, were proceeded with. For the prosecution it was stated that two of his Majesty's Inspectors of Mines had inspected the mine and found neglect of the regulations to provide proper egress shafts and communication roads. The outlet in the shaft was also found unfenced. Unlocked safety lamps had also been used, and omission had been made of the duty of posting at the pit head the times of lowering and raising the various shifts. For the defence it was urged that there was no real gravity in the charges, considering that for the past 60 years no coal had been got out of the mine except for the last year or two, when sufficient for steam purposes had been obtained. The Stipendiary said that in a mining district it was important that whatever difficulties the management were working under they should set a good example to the workpeople. He inflicted upon the two defendants for the various offences penalties amounting to total fines and costs of £50. 1s.

Co-partnership Bill.—In the House of Commons on the 12th inst. Mr. J. F. Hope, M.P., introduced a Bill to promote the adoption of co-partnership by statutory and other public companies. The Bill was, he said, of a very modest and tentative kind, and, with one partial exception, was entirely permissive in character. It set out a model scheme of co-partnership, and by one of its clauses allowed registered and statutory companies to adopt the scheme without applying to any court for alteration in their memorandum of association, or, in the case of statutory companies, without applying to Parliament. It further allowed them to adopt a scheme, with some modifications, with the permission of the Board of Trade. The root idea of the scheme itself was that there should be at once a standard return for both partners in industrial enterprise—a standard return for labour in the shape of wages, and a standard return for capital. There was no attempt whatever to endeavour to set forth an arbitrary return in the shape of wages for labour. That, he said, must be left to the process of collective bargaining which already existed. He did, however, propose to say in the Bill that the standard return on capital should be 5 per cent., and once that was secured all profits for the enterprise should be divided rateably between the company and its employés. What he meant by divided rateably was this: Supposing a company paid a dividend of more than 5 per cent., for every 1 per cent. more that it paid an extra one twentieth should be added to the wages of its employés. There were further provisions for the issue of new stock to the employés with their consent, and for the adjudication of differences in the county court.

Mr. G. Barnes on Industrial Unrest.—In the course of a recent paper, Mr. George Barnes, M.P., referred to the recent industrial unrest, and said that this was quite justified by the facts, but had as yet but little tangible result, excepting that it had perhaps stimulated public opinion to some hard thinking. Increased wages had resulted in some cases, and easements in labour conditions had been obtained as a result of better organisation; but in the industrial field of action these could be held only as a result of still better organisation, and a sustained and alert pressure in the struggle for life. In other words, they could only be held by an increasingly bitter industrial warfare, in which the disputants would be blinded by passion, in which the proceedings would be characterised by further waste, and during which the incidental suffering must be shared by the community, and would fall most heavily on women and children. He suggested a better way. He submitted that labour, aided by public opinion, should now turn its attention to two things—a legal minimum standard of comfort and a legal standard of hours of labour. Increase of the number employed would follow a reduction of hours in the transport and non-competitive or non-exporting trades or callings. In the competitve trades it was in the essence of things that cost of production should not be materially increased by shorter hours unless, at the same time, the means were provided whereby cost might be lessened by removal of existing burdens. Experience, however, had shown that increased productivity had always followed the reduction of hours. If the working day were shorter and interrupted by only one break for one meal, the workman would work with more goodwill, and probably produce nearly as much as in the longer working day with one or two interruptions.

Recent Legislation and its Effect on Mine Accidents.—Mr. D. M. Mowat, general manager, Summerlee Iron and Coal Company, in the course of some remarks made at a recent meeting of the Mining Institute of Scotland, stated that for the quinquennial period ending in 1907 Scotland's record in the matter of accidents was the lowest known in the history of the country's mining, but since then there had been a tendency to rise. In the light of that fact one wondered how much the upward tendency was due to the Eight Hours Day Act and all the hurry and bustle now contingent on that measure. Nowadays they were expected to get through in less than eight hours what they took 10 hours to accomplish before the Act came into force. The coal industry was face to face with a great deal of new legislation which, he believed, would have an important bearing on this question of safety in mining operations. They had a new Mines Act which came partly into force on July 1st and the remainder on January 1st next; they had the Insurance Act and all that it involved; they had the new Rescue and Aid Order; while they had new electrical rules applicable to mining and an Explosives Order just issued which was almost as big as the Mines Act itself. He understood there were quires of forms under the new Mines Act—and personally he had only seen one-half of them—which managers had to pass through their hands. Indeed, if a manager was expected to do so much clerical work now he questioned if they could expect him to spend so much time underground as in the past. That was a regrettable feature, because he was a firm believer in this, that the safety of the mines depended upon the supervision of the manager and the subordinate officials at the colliery. Altogether he did not think that recent legislation and the consequent hurry and bustle entailed to mining operations thereby would make for a reduction of accidents in mines. He made that statement with the greatest regret, but nevertheless it was his opinion.

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Rotary steam or explosion engines. Wolstenholme. 12686.
Carburetter. Steel & Steel. 12704.
Heat radiators or exchangers. Benham & Sons, Ltd., and Allensby. 12777.
Rotary engine compressor. Powell. 12925.
Gauge for use in measuring or setting out the teeth of gear wheels. Crabtree. 12934.
Mechanical feeders for coal. Watkins & Mason. 13298.
Railway signalling apparatus. Glenn & O'Donnell. 13340.
Gear for driving and reversing metal planing machines. Simpson. 13753.
Appliances for separating dust from air or gases. Samuelson and Backhouse. 16392.
Valves for steam engines and internal combustion engines. De Lissa, and Motosacoche, Ltd. 17201.
Removal of liquid contained in steam or other gases. Fletcher. 17313.
Valve mechanism for internal combustion engines. Soc. Anon. Constructions Industrielles Dijonnaises. 17535.
Apparatus for transmitting power by compressed air. Dunlop. 17944.
Manufacture of iron and steel. Levoz. 18016.
Acetylene gas generators. Scott. 18166.
Rotary pumps. Grouvelle, Arquembourg, & Joret. 21696.
Recovering tin and iron from scrap. Woltereck. 21762.
Method of and apparatus for the production of explosive mixtures for driving gas turbines. Humaran. 23501.
Automatic lock-nut. Pierce. 23527.
Utilising solar heat. Shuman. 23624.
Process of coating iron with other metals. Penner. 23716.
Apparatus for the purification of gases of combustion. Flechtner. 24015.
Safety apparatus for railways. Van Braam. 25224.
Method of and apparatus for the production of explosive mixtures for driving gas turbines. Humaran. 25608.
Process for the production of porous metals and alloys. Hannover. 25702.
Horizontal steam boilers. Smal. 25745.
Water tube boilers. August Reichwald, Ltd. 25976.
Wrenches. Iveson. 26652.
Means for starting and reversing two stroke cycle internal combustion engines. Thomas. 26700.
Roller bearings. Brewer. 28594.
Aeroplanes. Bleriot. 28638.
Ball and roller bearings. Ericsson. 28844.

1912.

Fluid pumps. Knowlson, Irwin, & Cullon. 271.
Manufacture of dies for wire drawing. British Thomson Houston Company. 536.
Socket pipe couplings with bayonet joints. Walter and British Mannesmann Tube Company. 577.
Turbines. Ashton. 856.
Low water alarms and feed regulators for steam boilers. Elletsen. 1249.
Vertical retorts for carbonisation of coal. Duckham. 1347.
Method of and apparatus for the utilisation of explosive mixtures for driving gas turbines. Humaran. 1473.
Spark arrester for locomotives. Read. 1712.
Stop valves. Cockburn & MacNicoll. 2090.
Stop valves. Elkington. 2577.
Distributing valve for single chamber compressed air brakes with reducing valve. Knorr Bremse Akt. Ges. 3961.
Locomotive and other tubular boilers. Caille. 4129.
Device for bridging over the gaps of the rails in annealing furnaces. Kugel. 5757.
Automatic air valves for hot air engines. Model Engineering Company and Wright. 6103.
Valves. Collar. 8166.

ELECTRICAL, 1910.

Electric furnaces. Rathenburg. 28120.
Electrical switching apparatus. Walton. [illegible]

1911.

Electrical heating apparatus. Perry. 12923.
Means for varying the inductance of electric circuits. Schieterstein. 12978.
Electrical contacts. Anschutz & Co. 16440.
Wireless telegraph transmitting stations. Dymond. 17149.
Electric switches. Furneaux & Rock. 17502.
Electric switches. Allison & Arnold. 17788.
Telephones. Gwozdz. 17900.
Systems of electric distribution. British Thomson Houston Company. 19260.
Automatic telephone systems. Siemens & Halske Akt. Ges. 19645.
Telephonic apparatus. Graham. 22634.
Means for varying the inductance of electric circuits. Schieterstein. 23283.
Automatic regulators for electric welding apparatus. Ges. fur Elektrotechnische Industrie. 23943.
Method of manufacturing electric steel castings. Fischer and Schudel. 27377.
Lighting of motor driven vehicles by electricity. Leitner. 27482.
Electric distribution systems. Bijur. 28391.

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Telephone exchanges. Siemens Bros. & Co. 528.
Electrical accumulator. Marino. 2575.
Spark gaps for use in electric circuits adapted for rapid electric oscillations. Thompson. 2768.
Means for holding electrical insulators and conductors. Bullers, Ltd., and Twiss. 3335.
Time-controlled electrical switches. Free. 3830.
Signalling systems for party line telephones. Western Electric Company. 4276.
Covering for electric cables. Beaver & Claremont. 5206.

METAL QUOTATIONS.

TUESDAY, JUNE 18TH.

Aluminium ingot	70/-	per cwt
„ wire, according to sizes, &c. ......from	102/-	„
„ sheets „ „ ...... „	120/-	„
Antimony ...... £27/-/- to	£28/-/-	per ton
Brass, rolled	9d.	per lb.
„ tubes (brazed)	11½d.	„
„ „ (solid drawn)	9⅝d.	„
„ „ wire	9d.	„
Copper, Standard	£79/5/-	per ton.
Iron, Cleveland	54/1½	„
„ Scotch	60/1½	„
Lead, English	£18/5/-	„
„ Foreign (soft)	£17/17/6	„
Mica (in original cases), small	6d. to 3/-	per lb.
„ „ „ medium	3/6 to 6/-	„
„ „ „ large	7/6 to 11/-	„
Quicksilver	£8/-/-	per bottle
Silver	28$\frac{1}{16}$d.	per oz.
Spelter	£25/17/6	per ton.
Tin, block	£207/-/-	„
Tin plates	14/7½	„
Zinc sheets (Silesian)	£29/5/-	„
„ (Stettin; Vieille Montagne)	£29/7/6	„

Trailer Trams for London.—Trailer tramcars are to make their appearance in the streets of London at last, the London County Council having carried their case in the House of Commons. The Commons Committee passed the scheme, subject to the conditions that the trailers should be fitted with brakes to be approved by the Board of Trade; that there shall be no more than two cars together (which means only one trailer) except where approved by the Board, which will also sanction the type of trailer. Trailers are in use in Paris, Berlin, and some American cities.

Launch of a Cruiser.—The unarmoured cruiser "Fearless" was successfully launched from Pembroke Dockyard on the 12th inst. The "Fearless" is the seventh and last vessel of the "Boadicea" class of fast unarmoured cruisers which have been built primarily for service as parent ships to destroyers, it having been decided to build instead a new class of light armoured cruisers. She has a displacement of 3,440 tons, and carries an armament of 10 4in. guns. Her speed, the main feature of her design, is 25 knots, obtained with turbine engines of 18,000 h.p. This speed and horse power have, however, been exceeded by every ship of the type that has yet been tried.

The Mechanical Engineer.

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Edited by
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Superheating in Locomotives.

BULLETIN No. 57, recently published by the University of Illinois, gives a record of some valuable tests by Prof. W. F. M. Goss on the use of superheated steam in locomotive service. Having regard to the extent to which locomotive superheating is now an established principle, it will probably surprise many people to know that it is only about 16 years ago that the first superheating locomotives were put in service on the Prussian State Railways, and it was as a result of the experience gained with these during 1898–1900 that the present extensive adoption on the Continent is based. How rapid the development has been may be inferred from the fact that in 1907 there was in Germany over 1,300 locomotives of the new type running or on order, while the good results obtained by their operation has stimulated a large demand in other countries for German-designed and German-built superheaters. At the present date there are probably over 1,000 locomotives fitted with superheaters in service or under construction in Great Britain alone. They are not all of one type, but by far the major portion of those in use are constructed in accordance with the designs introduced by Herr Schmidt. In the early designs the superheating was effected by tubes placed entirely in the smoke-box, but this practice has rapidly given way and in fact in recent years has been discontinued by the Schmidt firm in favour of the fire-tube design, in which the upper part of the boiler is fitted with two to four rows of large smoke tubes from 4in. to 5in. diam. and in each of which a superheater element consisting of a set of small pipes bent in the form of a double loop, connected at the smoke-box end to a header, is inserted. Each particle of steam passing from the boiler to the cylinder branch pipes has thus to traverse some one of these elements and make four passes through the fire tube in the movement. This arrangement allows a higher degree of superheating than the smoke-box design and lends itself to a draught arrangement that meets the conditions required when steam is being raised or the engine is standing, the flow of heat through the large tubes

being controlled by dampers, which are automatically closed as long as the regulator is closed and which are opened simultaneously by means of a piston working in a small cylinder when the regulator is opened. The restriction of the diameter of the superheating tube is one of the features of the Schmidt design and incidentally illustrates the influence of high velocity of flow of steam over the heating surface on heat transmission, in accordance with the Osborne Reynolds theory and as more recently exemplified in Nicolson's high speed boiler, a German authority stating that for constant temperature differences the rate of heat transmission varies as the square root of the velocity of the steam. The degree of restriction in Schmidt's superheaters is such that when the engine is working at full power with the regulator full open the drop in pressure between the boiler and the valve box is approximately 15lbs., and it is stated that under these conditions the steam velocity through the superheating tubes varies from 325ft. to 400ft. per second. By means of dial thermometers the temperature in the valve box is shown on the footplate, and when this has risen to 300° C. (572° Fah.) the dampers controlling the flow of gases through the superheater tubes are manipulated to prevent the maximum limit of 350° C. (662° Fah.) being exceeded. The natural competitor of the superheater locomotive is the 4-cylinder compound, and the question as to the extent to which this latter type is likely to be displaced is one of considerable interest. The object of both types is of course ultimately the same, namely, to secure economy in working, but economy is a term capable of very wide definition and cannot be expressed in terms of fuel or water alone. Measured on a fuel basis there is probably not much to choose between them, though the lesser consumption of water with superheating is a matter of importance where it forms an item in running costs or is objectionable on account of its impurities and subsequent expense of cleaning. Another advantage of superheating is that economy of fuel can be secured with less complicated mechanism than a compound and thus diminishes maintenance charges. It is not easy to express the exact fuel and water economy secured with superheating as compared with simple engines using saturated steam and still more difficult when compounding is concerned. Figures of percentage gains are liable to be tinctured with partisan prejudices, especially when these are strong and the personal element comes into play as it often does in locomotive matters, and statements that superheating locomotives consume 10 per cent. less coal and 25 per cent. less water than 4-cylinder balanced compounds must be accepted with reserve. Mr. Hughes went into this matter somewhat fully in his paper before the Mechanicals, to which we referred in our issue of April 26th last (see page 506), and we think summed up the comparison pretty fairly. Speaking broadly, his conclusion was that while compounding was advantageous in slow speed goods traffic superheating was more suitable for passenger service of constant loads, and it is mainly in this direction that practice is developing, and about which there is most agreement as regards its economy. Amongst certain foreign engineers the combination of superheating and compounding is being favoured, and a certain number of locomotives have already been constructed in Belgium on this plan. It is claimed that coal economy results, amounting, it is said, to about 7 per cent., but it is doubtful whether this is sufficient to warrant the complication. The two systems are in the main opposed, for the compound, to work effectively, requires steam at high pressure, whereas it is counted as a merit of superheating that without sacrifice of fuel efficiency much more moderate pressures may be used. It is an interesting fact to note, however, that in France, the birthplace of the balanced compound, active interest is being taken in the Schmidt system, and a commission representing the leading railways there, after careful investigation, has made a most favourable report upon it, and while it is not thought likely that superheating locomotives will take the place of the highly developed types of the balanced compounds common in that country, it is admitted that in the freight and switching service many of the simple engines might with advantage be fitted with superheaters. To give an adequate summary of the exhaustive tests conducted by Prof. Goss would occupy too much space; we would refer readers particularly interested to his report, contenting ourselves with its salient features. The advantage of superheating is closely linked with the pressure used, and is, of course, more pronounced at low pressures than at high pressures. Discussing, for instance, the fuel gain in the experimental engine used, it was found that whereas at a pressure of 120lbs. the gain was 17 per cent., it was only 6 per cent. when the pressure was increased to 240lbs. A somewhat analogous result was observed in the comparisons of steam used per indicated horse-power per hour, a saving of 12 per cent. being noted when the pressure was 120lbs., and only 2 per cent. when the pressure was 240lbs. Consideration of these figures shows how difficult it is to express the relative advantages or disadvantages of any particular method of working. As a general proposition, the gains, Prof. Goss observes, from the introduction of a superheater is a function of the degree of superheat employed, and this in turn is limited by the ability of the materials composing the superheater and the exposed parts of the engine to withstand the temperatures involved. The Prussian State Railway prescribes a boiler pressure of 180lbs. and a steam temperature of 572° Fah., with a maximum limit of 662° Fah. In other words, the normal degree of superheating is 190° Fah., and the maximum 280° Fah., but Prof. Goss is of opinion that this range of superheating might be increased by at least one-third without exceeding the limit which has been proved practicable, and since superheat tends to conserve steam supply as the demand for power is increased there seems no reason why this permissible higher range of temperature should not be utilised when necessary. In considering questions of fuel economy, it is, of course, a mistake to assume that a railway company's coal bill can be diminished by anything like the figures indicated in locomotive tests, whether of superheating, compounding, or other innovations. It will be clear, for example, that no part of the fuel used in raising steam, or of the inevitable wastes which occur from radiation, loss through safety valves, or stoppages, can be saved by the application of any method of raising or using the steam, and if the proportion of fuel so used amounts on an average to 20 per cent. of the total, the maximum amount of saving capable of being effected cannot exceed 80 per cent. of the figures given by an experimental test. The ultimate economy of a railway, in fact, involves the whole question of maintenance, and makes any statement of figures little more than approximate at best. Prof. Goss summarises his investigations and their bearing upon American practice by stating that the actual net reduction in the amount of fuel needed for locomotive use by a railroad having all its locomotives equipped with satisfactory superheaters over that which would be required if all employed saturated steam will not be far from 10 per cent. This value is not given as a strictly scientific import, but merely as an estimate based upon a careful study of American practice, and a similar comparison in other countries would doubtless yield other figures.

HIGH-PRESSURE GAS FOR MANUFACTURING PURPOSES.

A PAPER on this subject was read by A. W. Onslow at the recent meeting of the Institution of Gas Engineers. It was, the author said, an easy matter to design gas furnaces to achieve a certain object; but the detail work needed the co-operation of others to continue it. A designer of such plant must aim at perfection in simplicity as well as efficiency. In the old furnaces, the conductivity of fireclay did not seem to be sufficiently taken into consideration. Consequently the combustion chambers were very big, and the flame had to travel over large areas before getting to effective work. The earliest improvements made in case-hardening furnaces was to reduce the size of the combustion chamber, compel the flame to strike at once fireclay, and, by restricting the air supply, to obtain a uniformity of temperature.

Furnaces had, he observed, been in use having dimensions 6ft. by 4ft. by 2ft. for heating articles that needed a space of only 2ft. by 1ft. by 1ft. In this case a bricklayer built up a smaller furnace in a few hours, which was as efficient in action as a permanent one, and could be removed or pulled down when done with. In this way, bar steel, angle, or channel irons could be heated for any purpose; the furnaces being built in a few hours and rebuilt to suit all requirements. To take, as an illustration, ½in. bar steel. Some 2,000 bars could be heated and rolled in a fortnight, and the furnace altered for 2in. bars—a slight modification only being desirable. The furnace for angle and channel irons would be somewhat different, but alterable in half a day by a competent bricklayer. Bar steel could be worked in a continuous line, averaging 60 secs. per inch in thickness of metal, allowing this ratio up to 2in. in thickness; but beyond this size 50 per cent. longer time was desirable for soaking purposes. Refractory material must be prominent in every position, with sheet asbestos lagging; so that it was quite possible, with a few firebricks, fireclay, burners, and lagging, for a dozen different designs to be built up with the same bricks and tiles, giving satisfactory results. For railway-engine wheels, axles, &c., furnaces could be built in the same way. The author recommended, however, that the furnace be made to the size of the wheel or axle, with fireclay inside the bottom, sides, and lid, the latter having a flue outlet and lifting hooks. Four wheels at a time had been thus dealt with—four axles heated vertically in 30 mins., 5 mins. being allowed for "soaking," and the temperature regulated by one stop-cock and the use of a pressure-gauge.

Experience had shown that, with gas at 2s. per 1,000 cub. ft. and coal at 20s. a ton at the furnace, there was very little difference in the cost of the two methods of heating; the difference being in favour of gas, when used for practically all commercial purposes, provided the gas furnaces were designed with a view to the greatest economy. But there were instances where gas was infinitely cheaper, cleaner, and more suitable in every way. The exception was with large furnaces, in which immediate contact of flame with refractory material was difficult.

If high-pressure gas needed instances to justify its existence, one or two only might serve the purpose, viz., its application in the operations of shrinking on, or unshrinking off, coils or large tubes, when, by pumping gas against the steel, the labour formerly occupying weeks could be reduced to about an hour. High-pressure gas was positive in its action, as exemplified by a certainty in shrinking which occupied now 11 minutes against a problematical 25 minutes before its adoption. The time lost by workmen, the uncertainty of the work being properly done, and the cost of doing the work over again, were so great that the saving would be interesting to ascertain. But with gas at 60in. pressure the time could be gauged accurately. The writer could not understand large engineering works not having a high-pressure gas plant—portable, if necessary—for dealing with difficulties as they arose, whether it was for hardening steel shells, annealing tubes, case-hardening armour plates, bending angle irons, crank shafts, or the multifarious work of a ship-building or any engineering works, especially when advice could be obtained from the gas companies at all times.

The author presented the following outline of an ideal workshop lighted and heated by high-pressure gas: A single pipe running round the shop; the initial pressure of gas being, say, 200in., with either a governor or valve with pressure dial for each furnace in use—the various pressures to be previously determined by the shop manager. The following were some of the pressures necessary for various kinds of work: Melting tin or solder, a pressure of 65in.; small furnaces for heating tools for hardening purposes, 65in.; furnace for blueing steel, 65in. to 80in.; case-hardening furnaces, 65in.; lead pot for tempering steel, 150in.; melting metals at 2,000 to 2,600 Fah., 200in.; soldering irons 65in.; for lighting, 65in., or according to the system adopted.

A cheap and efficient means of compressing gas up to 15lbs. per square inch was, in the opinion of the author, needed, as a manufacturer considered the first cost very seriously; and if the adoption of gas under pressure was to become universal, some attention to this branch of the subject was desirable. Burners, the building up of furnaces, loss by radiation, air supplies, &c., had all been satisfactorily dealt with; so that the compressor was now apparently the last factor needing settlement. The fact must be kept in view that if air was to be admitted under pressure it must be continuous. In an instance under the author's knowledge, with one furnace the air pressure was 3lbs. per square inch; but with two furnaces at work, the pressure dropped to 2lbs. per square inch—the two days' results being alike. Some understanding between the consumer and the gas companies' representative might have averted this.

Up to the present, the author had worked upon no fixed principle of determining what the pressure of gas must be against air under pressure; but he had not had an instance yet where gas at 15lbs. pressure was not equal to air at 5lbs. per square inch. There was a rule to be fixed; but the difficulty was due to the relative size of the air duct with gas under pressure. This size was determined in the "Smith-Walter" burner for the quantity of gas, and also in the burner designed by the writer, not only to prevent the objectionable noise of a high-pressure burner, but to provide a mixing chamber before combustion took place. The drawback was that it was possible, under certain conditions, for the burner to light back unless secondary air was admitted. When secondary air was admitted, then it was satisfactory. The secondary air could be superheated. Lighting back could also be obviated by regulating the distance between the end of the burner and the furnace. It was preferable only to provide a flue damper in exceptional cases, and, if one existed, to have it made a fixture. Chimney head was unnecessary with high-pressure gas unless a due proportion of air could not be admitted to the burner. In deciding upon a method of heating, one might have some doubt whether a rotating flame or a straight one was desirable. But in cases of temperature requiring an increasing force (from 400° Fah. upwards), the straight flame was favoured. For a continuous temperature, the rotating flame round the base or side of a vessel was probably more suitable.

Synthetic Rubber Processes.—A special demonstration of the processes employed in the manufacture of synthetic rubber was given on Tuesday last at the offices and laboratories of Messrs. Strange & Graham, Ltd., the organisers of the research group represented by Prof. Perkin at his lecture a few days ago before the Society of Clinical Chemists, at Burlington House, London. The lecture caused considerable public interest in view of the statement regarding the commercial value of the manufacture by the synthetic processes. These were explained and illustrated by Mr. E. Halford Strange, a director of the company. Operations were shown in which starch obtained from maize or potatoes was converted into rubber. It was explained that on the setting up of the necessary large scale plant the cost would be reduced. It was contended that the first phase of the inevitable struggle would be to leave the field divided between plantation rubber and the new synthetic rubber. Some "historic exhibits" of the perfected rubber were shown in illustration of the completed processes to the large company present at the experiments.

BOOK REVIEWS.

The Theory of Practice of Heating and Ventilation, by Arthur H. Barker, B.Sc., B.A., Whitworth Scholar, Lecturer on Heating and Ventilating Engineering at the University College, London. London: The Carton Press, 10¼in. by 7in.; 746 pages; price 25s. net.

As far as our knowledge goes this is the most compendious and exhaustive treatise on the subject of heating and ventilation which has so far been published in this country, and we should doubt if there is any work published elsewhere which is more exhaustive or entitled to greater authority. The author has had a very long and practical experience of the subject, while his scientific attainments and professional position as managing director of a firm specially dealing with the matters involved enable him to speak with great weight. There is scarcely any aspect of the complex questions which enter the subjects of heating and ventilation which will not be found dealt with in an exhaustive and scientific manner, and at the same time the treatment is thoroughly practical. The work in a word is equally fitted for the scientific investigator or the works manager, and we have every pleasure in cemmending it heartily to both.

* * *

The Steam Engine and Turbine, by Robert C. H. Heck, Professor of Mechanical Engineering, Rutgers College. New York: Van Nostrand Company. London: Constable and Co., 9½in. by 6½in.; 631 pages; price 20s. net.

The literature on the steam engine and turbine is so exhaustive that there would seem comparatively little scope for fresh books on the subject. Such openings as do exist are determined mainly by the combination or selection of existing information or by special treatment of problems involved. While the work under notice cannot be said to possess any particular distinguishing feature that would warrant us in according it any special niche of its own it nevertheless compares very favourably with others. The thermo-dynamic aspects of the steam engine and turbine are well presented, and it is mainly from this point of view and as a class or college course text-book that the merits of the book are most pronounced. Although the steam turbine is linked with the steam engine in the title it occupies but a relatively small space in the subject matter, and it seems desirable to point this out to prevent misapprehension.

* * *

Laboratory Instruction Sheets in Elementary Applied Mechanics, by Arthur Morley, M.Sc., and Wm. Inchley, B.Sc. London: Longmans, Green, & Co., 8½in. by 5½in.; 50 pages; price 1s. 3d. net.

The series of sheets here gathered together have been designed with the special object of laboratory class work in applied mechanics, such as the authors use in connection with their own teaching work in the University College, Nottingham, and we do not doubt will be appreciated by teachers who may be organising similar classes elsewhere. A glance through the subject matter of the sheets, which it may be remarked are perforated so that they can readily be detached, reveals their admirably practical and illustrative character.

* * *

Practical Design of Marine Single-ended and Double-ended Boilers, with numerous drawings and tables, by John Gray. London: Constable & Co., 7½in. by 5in.; 84 pages; price 5s. net.

This little book although of limited range is excellent so far as it goes, its main object being to serve as a practical guide to draughtsmen in designing boilers of the type named. The various problems to be solved in such designs are gone over one by one, and the practical way in which they are treated displays an intimate knowledge of boiler construction on the part of the author. It should be noted, however, that the book deals only with the constructive features of the two special types of boilers named.

BOOKS RECEIVED.

Fuel Economy. By W. H. Booth, F.G.S., M. Am. Soc. C.E. A practical work of direct value to all central station engineers and electricians in charge of steam raising plant. London: S. Rentell & Co. Price 1s. net.

Reference Book for Statical Calculations (Rapid Statics). By Francis Ruff. Force-diagrams for frameworks, tables, instructions for statical calculations, &c., for all classes of building and engineering. London: Constable & Co. Price 4s. net.

The Journal of the Institute of Metals, Vol. VII. Edited by G. Shaw Scott, M.Sc. London: The Institute of Metals, Caxton House, Westminster, S.W. Price 21s. net.

Catalogue of Optical and General Scientific Instruments. London: The "Electrician" Publishing Company, Salisbury Court, Fleet Street.

ELECTRIC SHIP PROPULSION.

THE United States collier "Jupiter," which is being built at the Main Island Navy Yard, will, according to the "Electrical World," be the first large vessel to be equipped for electric propulsion. The general scheme embraces a steam turbo-generator set delivering its electrical output to a pair of three-phase induction motors, each of which will be direct-connected to its own propeller shaft. The designer of this equipment is Mr. W. L. R. Emmet. The generating unit consists of a six-stage Curtis turbine connected to a bi-polar alternating-current generator. The motors have 36 poles each, thus reducing the synchronous speed in the ratio of 18 to 1.

The colliers "Neptune" and "Cyclops," now in commission, are sister ships to the "Jupiter." The "Cyclops" is equipped with triple-expansion reciprocating engines and the "Neptune" is equipped with a pair of steam turbines with gear reduction. A comparison of the principal features of these three vessels is given in the accompanying table. The steam consumption figures there given are estimated for the "Cyclops," but taken from preliminary tests in the case of the "Jupiter." These vessels are designed to carry a cargo of something like 12,000 tons. The "Cyclops," during a 48-hour trial, maintained an average speed of 14·6 knots at 92 revs. per minute, with a total indicated horse-power of 6,705 for both engines, and consuming only 1·485lbs. of coal per indicated horse-power per hour.

A recent demonstration of this equipment was given for the benefit of a party of officers of the United States Navy, representatives of shipbuilding firms and naval architects. The full equipment was temporarily erected for a test, with the two motors direct-connected, one operating as a generator to absorb the power of the other. While this arrangement did not afford a means of demonstrating the operation under ship-propulsion conditions, it nevertheless gave a very excellent idea of the efficiency of control and the general performance of the equipment. The trials of the "Jupiter," when completed, will be awaited with much interest.

Data on United States Colliers.

	Cyclops.	Jupiter.	Neptune.
Displacement in tons	20,000	20,000	20,000
Engine or turbine speed at 14 knots, revolutions per minute	88	2,000	1,250
Propeller revolutions per minute at 14 knots	88	110	135
Indicated horse power at 14 knots	5,600	—	—
Weight of driving machinery in tons... ...	280	156	—
Steam consumption, pounds per shaft horse power hour	14	12	—

Artesian Wells in New South Wales.—From figures recently published it appears that on June 30th, 1911, there were no less than 415 artesian wells in New South Wales, giving a total yield of approximately 133,200,000 U.S. gallons per twenty-four hours. In 372 wells the water rises above the surface, in the others pumping is employed. Fifty-four of the wells supply a total area of 3,163,230 acres with water, the aggregate length of distributing mains being 1,800 miles.

THE TRANSMISSION OF ELECTRICAL ENERGY BY DIRECT CURRENT ON THE SERIES SYSTEM.*

BY J. S. HIGHFIELD.

(Concluded from page 767.)

Earthing Methods.—Before describing the actual method of operating the system, it is desirable to give a short description of the considerations which led to the final adoption of an earth return. The commercial advantages were, of course, at once apparent, but before deciding upon the use of the earth for regularly carrying considerable currents, it was necessary

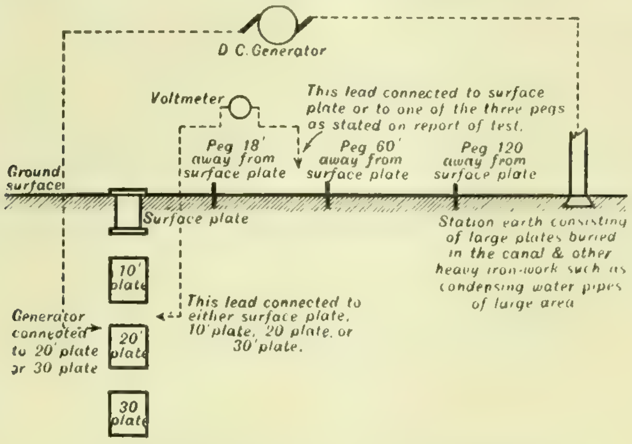


FIG. 11.—SHOWING EARTHPLATES AND CONNECTIONS.

to make sure that such use would not cause interference with other electrical systems, and would not cause damage to property.

M. Thury has carried out a great deal of work on this subject, and both the French and Swiss Governments have appointed committees to enquire into the matter. The town of Lausanne was supplied from Saint Maurice through a single conductor with the earth as the return for 443 days continuously. Iron earth-plates were used, and during the whole time of their use it was found that their resistance changed very little. The current was 150 amperes, and theoretically the plates should have been oxidised away in less than two months, but apparently after a layer of oxide has been formed further action is very slow. The total resistance of the earth connections was about 1·6 ohms, and it was found that no inconvenience was experienced in connection with telegraphs and telephones. The Swiss Commission is still at work on this subject, and doubtless their report, when issued, will contain much valuable information on this interesting subject.

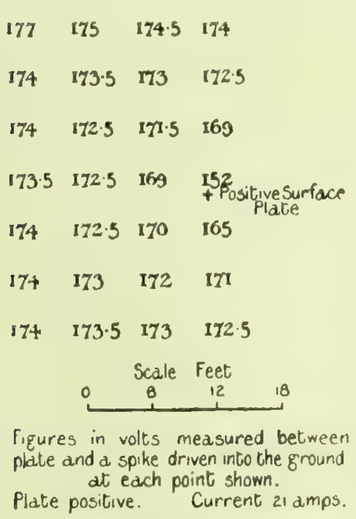


FIG. 12 —AREA OF PLATE.

The geological formation of the Rhone Valley is, of course, altogether different from that near London. It is, in fact, not nearly so favourable for the purpose, consisting largely of highly insulating rock, and the layer of soil and other conducting material is comparatively thin. Further, than that, the Rhone water is so pure that its conductivity is exceedingly bad; it would be truer to state that its insulating properties are high. Consequently, it was felt that before arriving at any decision as to the possibility of the successful use of the earth near London, further experiments were necessary, and it was decided that, in any event, the earth-plates should be situated at a considerable depth below the ground surface, and that connection should be made to them by insulated cables, in order to avoid stray currents in the neighbourhood of the plates.

The experiments were carried out in order to obtain the following information, viz.: (*a*) At what depth below the surface must the plates be buried in order that the effect of currents at or near the surface should be negligible; (*b*) the size of plates to be used and their number; (*c*) the distance apart at which the plates should be situated; (*d*) the value of the earth resistance and its constancy.

In short, the experiments were undertaken to ascertain the best method of adapting the earth as a permanent conductor for industrial currents in such a way as to avoid interference with telegraphs, telephones, or other users. With the first object in view four iron plates were buried in the earth, situated vertically above each other, as indicated in the diagram (Fig. 11). The area of each plate was 4ft. by 2ft. 2in., with the exception of the top plate, which consisted of a length of 6in. pipe. These plates were made one pole of a circuit, the other pole consisting of large masses of iron buried in the ground round the works, chiefly condensing water pipes of very large size, which make an excellent earth, the resistance of which was found to be negligible as compared with the resistance of the test-plates. A steady current was then passed between one of the plates and the station earth, measurements being made between the various points by means of a Kelvin electrostatic voltmeter for the high read-

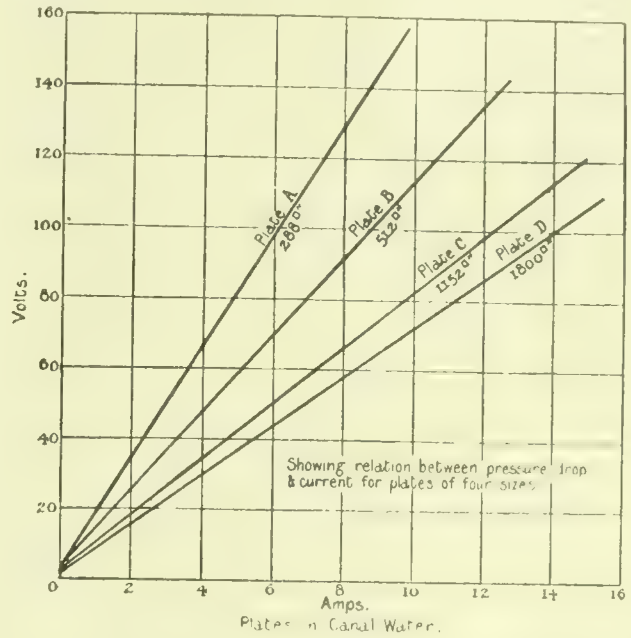


FIG. 13.

ings, and by a moving-coil voltmeter for the low readings. The following observations were made, viz.:—

(1) With a steady current of 20 amperes passing between the earth-plate, 20ft. deep, and the large main earth, the measurements were:—

Between the earth-plate and—

	Volts.
A point 120ft. away	165·0
,, 60ft. away	165·0
The surface earth-plate	163·5

Between the surface earth-plate and—

	Volt.
A point 120ft. away	0·024
,, 60 feet away	0·016

Between the earth-plate, 10ft. underground, and—

A point 120ft. away	0·035
,, 60ft. away	0·024

(2) With a steady current of 21 amperes passing between the earth-plate, 30ft. deep, and the large main earth, the measurements were:—

Between the earth-plate and—

	Volts.
A point 120ft. away	135·0
,, 60ft. away	134·5
The surface earth-plate	133·5

Between the earth-plate, 10ft. underground, and—

	Volt.
A point 18ft. away	0·008

Between the surface earth-plate and—

A point 120ft. away	0·020
,, 60ft. away	0·010
,, 18ft. away	0·004

* Paper read before the Institution of Electrical Engineers, at Glasgow, June 12th, 1912

(3) With a steady current of 21 amperes passing between the surface earth-plate and the main earth, pressure readings were taken between the surface plate and spikes driven into the ground at various points. The results are shown on Fig. 12.

All the above readings were taken with the positive pole of the generator connected to the test plate. The foregoing experiments indicated that the pressure fall occurred in the immediate neighbourhood of the plate—in fact, at the plate itself, and that when the current was carried to a depth of

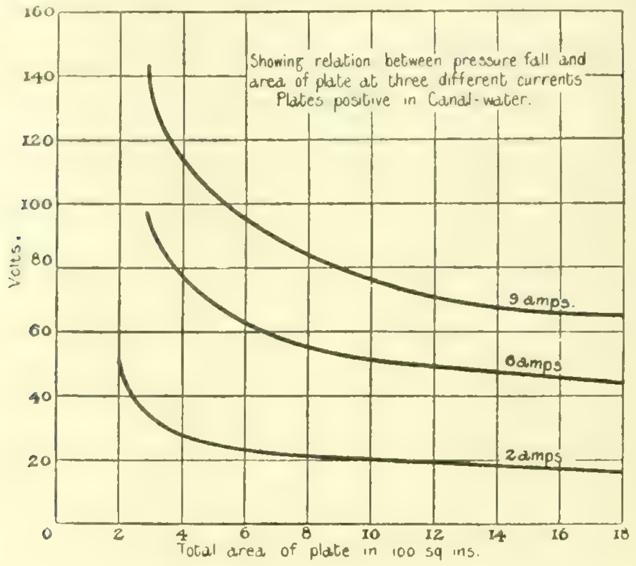


FIG. 14.

only 10ft. the pressure drop in the neighbourhood of the plate was exceedingly small.

Further tests, to make sure of the absence of the possibility of interference, were made by using the pilot wire as the test wire, and taking readings of the difference in pressure between Willesden and an earth-plate in the Brent River, about one mile from Southall, with the current to earth and without. A varying difference in pressure of from 0·6 to 1 volt was observed when the circuit was worked with a completely insulated system, this being due to the London United Tramways

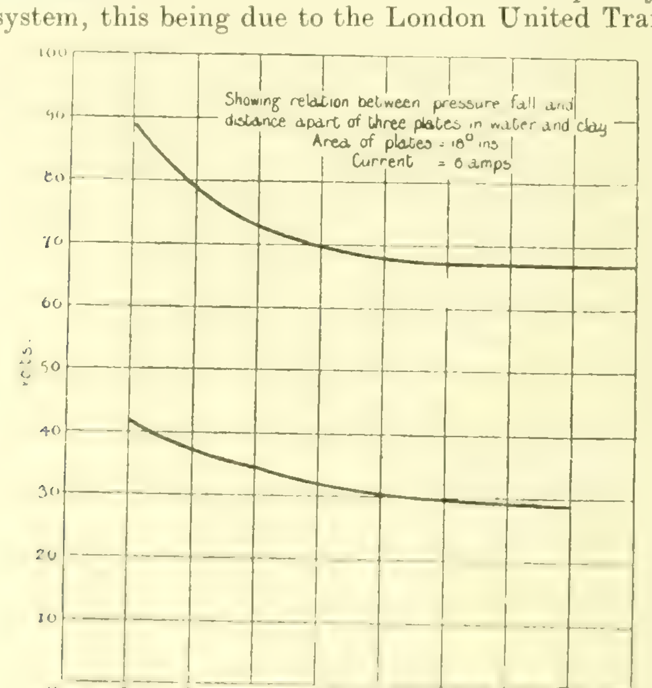


FIG. 15.

system on the Uxbridge Road. With the current flowing through the earth the readings varied at from 1·6 to 2 volts; thus the effect of the earth current was to raise the pressure by 1 volt.

Using the pilot wire connected in parallel with the earth a current of 3 milliamperes was observed without the current in the earth, and 8 milliamperes with 90 amperes flowing, the resistance of the pilot wire being 279 ohms; the difference in pressure between the earth at Southall and Willesden due to the earth current was 1·4 volts. The latter tests were made by the Post office engineers, who kindly gave us much assistance in these investigations.

A series of experiments was carried out with different sizes of plates, and Fig. 13 shows the results of the tests on the various sizes of plates used. The tests were made on plates suspended in the canal, and from the results obtained the curves on Fig. 14 were plotted. These curves show that with a current of 1 ampere per 600 sq. in. of plate, little advantage is obtained by making the plate larger.

Further readings were taken, the results of which are plotted on Fig. 15, with similar plates, in order to show the difference between the conductivity of the connection in water and in clay, and also to show the effect of using three plates situated close together, and the same plates situated at various distances apart. The curves indicate that there is little advantage in spacing the plates a greater distance apart than 6ft. They also indicate that plates buried in clay have more than twice the conductivity of similar plates buried in water. To decide exactly the distance apart at which the plates should be buried a further series of experiments was made, and typical results are shown in Figs. 16 and 17. These tests again clearly indicate that when the plates are buried at a distance of 6ft. practically the maximum conductivity is obtained, and that plates at this distance apart have nearly twice the conductivity of plates 1ft. apart.

Before completing the above experimental work, earths were made at Willesden and Southall in the following way, viz.: At each place three boreholes were made at the positions

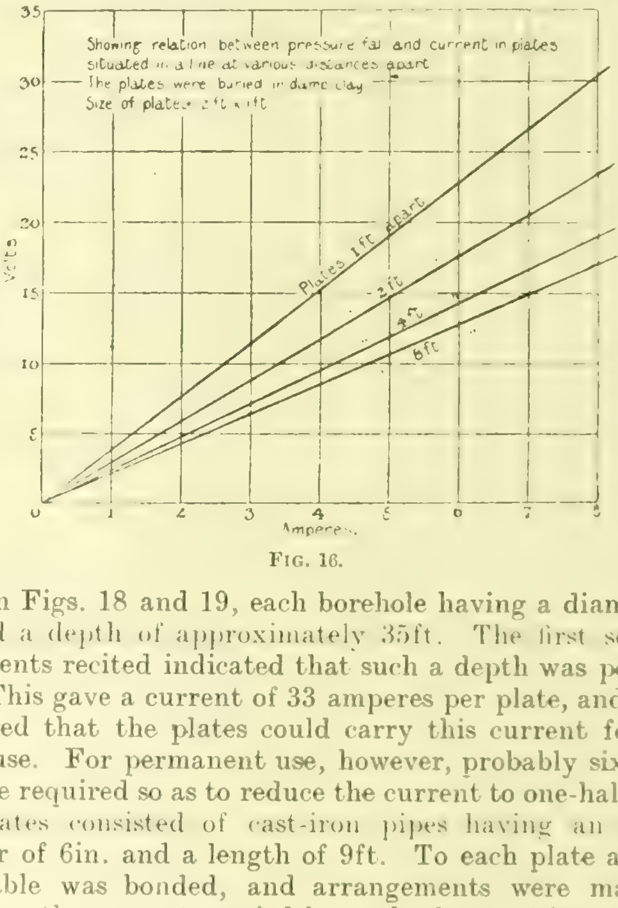


FIG. 16.

shown in Figs. 18 and 19, each borehole having a diameter of 7in. and a depth of approximately 35ft. The first series of experiments recited indicated that such a depth was perfectly safe. This gave a current of 33 amperes per plate, and it was considered that the plates could carry this current for temporary use. For permanent use, however, probably six plates would be required so as to reduce the current to one-half. The earth-plates consisted of cast-iron pipes having an outside diameter of 6in. and a length of 9ft. To each plate an insulated cable was bonded, and arrangements were made for measuring the current carried by each plate. After the pipe was placed in the borehole, the space round it was filled in with chalk, the cable being brought up to the surface by means of an insulated tube. The plates at Willesden are all buried in ordinary London clay, and at Southall in fine gravel, which is generally very dry. After the system was started for permanent supply, careful measurements were made in order to ascertain what variations took place in the resistance of the earth connections. The resistance of the two earths is almost exactly 1 ohm, so that although only three plates were used, the earth is a very effective one.

It may be said generally that all the experiments show that plates buried at a considerable depth offer less resistance than plates buried at the surface. The author is inclined to think that this is due largely to the heavy pressure on the plate when buried at a depth. When the earth is put in parallel with either cable, with 90 amperes in the main circuit, 30 amperes flow through the cable and 60 amperes through the earth, so that the ordinary resistance of the two earths is approximately one-half the resistance of either cable.

In order to ascertain what change took place in the resistance, a current of 90 amperes was allowed to flow through the earth plates for some time, and since the figures may be interesting, they are given at length, as follows: With a con-

stant current of 90 amperes, the fall in pressure was as stated in Table I. An earth will now be made by driving a shaft 5ft. diam. to a depth of 30ft., and six earth-plates consisting of cast-iron pipes, 6in. diam. and 3ft. long, will be buried radially at the bottom; in this way it will be possible to keep a close observation of their condition.

The commercial use of the earth as a conductor may be very great. When used as a spare conductor it saves the cost of a spare cable; the cost of the earth connections is a negligible matter as compared with the cost of the cable, and where a very long transmission is required—say, 100 miles—the advantage is immense. A line of 100 miles, consisting of two 0·125 sq. in. conductors, will have a total resistance of 68·3 ohms, so that with a current of 100 amperes the number of kilowatts required to keep the line charged is 683, or nearly 7 per cent. of the maximum capacity of 10,000 kw. at 100,000 volts. Using an earth return with the same two cables in parallel, and assuming that the earth resistance is 1 ohm (a figure which can be readily obtained) the total resistance would be 18 ohms, and the number of kilowatts to keep the line charged would be 180 kw., or 1·8 per cent. of the total

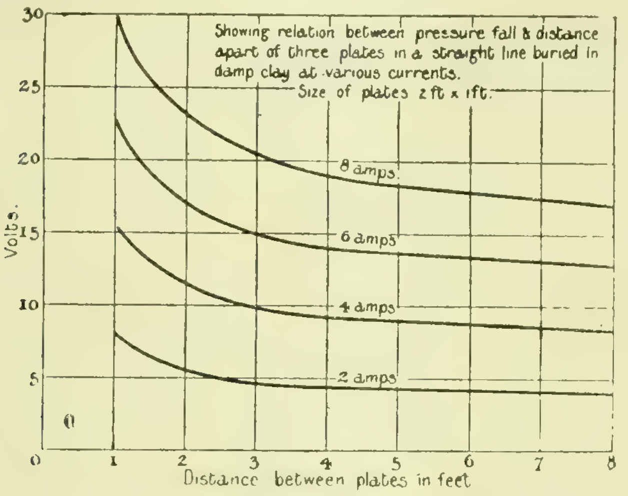


FIG. 17.

capacity of the line. In the latter case, either conductor would carry the full load of the system, so that a complete duplicate transmission system is provided for.

TABLE I.

Date, 1911.	Total Fall. Volts.	Fall at Willesden. Volts.
With the Willesden Earth as Positive:		
July 13	108	48
,, 14	108	48
,, 15	94	43
,, 17	100	48
,, 18	94	48
,, 19	99	50
,, 20	99	50
,, 21	100	49
,, 22	104	49
,, 24	105	49
,, 27 (after rain)	75	26
With the Willesden Earth as Negative:		
July 6	106	—
,, 7	112	30
,, 10 { 10 a.m.	118	29
4 p.m.	122	
,, 11 { 10 a.m.	133	28
12 noon	137	
4 p.m.	143	
9 p.m.*	178	
With the Willesden Earth as Positive:		
July 12 { 10-30 a.m.	78	28
5 p.m.	94	35
,, 13	108	48

* This test indicated that the resistance of the Southall earth was rapidly rising, the drop in pressure being at the rate of 10 volts in 20 minutes; at this point the earth connection was broken.

Efficiency. — In his former paper the author dealt very fully on the question of efficiency; consequently it is unnecessary to take up much time now. The line loss admits of ready calculation, and he finds that the most convenient method is to arrive at the mean power to keep the line charged, to estimate the annual cost of running the necessary plant, and to treat this cost as a standing charge. He has worked out, and shows in the form of curves in Fig. 20, the amount of the line losses at the various load factors, efficiencies, and percentages of the maximum load for which the system is designed. The curves show the value of the losses with a completely insulated system, and for the same system operated with two wires in parallel and with the earth used as the return.

The actual working efficiency of the system described is of little value, as the load at present is small—only some 300 kw.

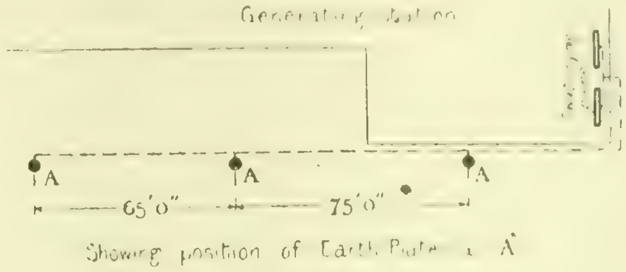


FIG. 18.

For the last six months the ratio of the 3-phase energy sent out at Southall to the direct-current input from Willesden was 77 per cent., and during this time the maximum alternate-current load has not exceeded 275 kw.

Operation. — The actual operating of the plant is exceedingly simple. The first generator is run up to speed by means of its starting motor, either with the mains open or on short circuit, the regulator is set to give the proper line current. An incoming generator is generally started from the direct-current side, and the motor parallel into the circuit. The substation motors are started by opening the switch and rotating the brushes until full speed is reached, when the regulator is put into action; the speed can be very closely adjusted, so that paralleling the sub-generators is a particularly easy operation, one man attending to the plant. With several generators in series all fully loaded, any failure to one necessitating its removal from the circuit results only in the slowing down of the whole plant. When two insulated mains are in use, an earth at any point does not interfere with the supply; the voltmeters at once show which main is injured, and it can be cut out of circuit after the system has been

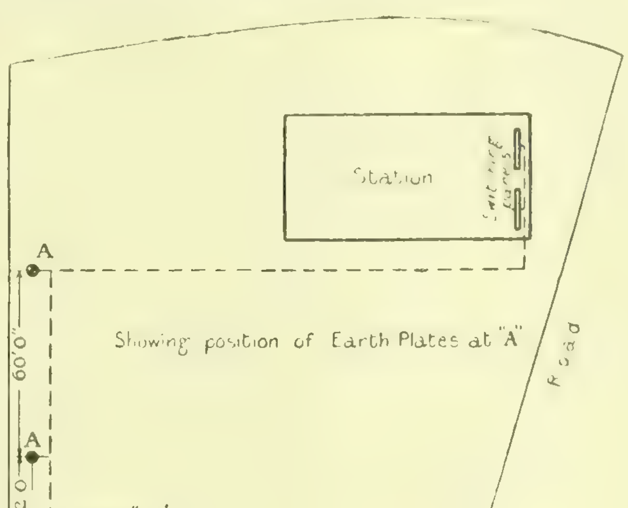


FIG. 19.

earthed at each side of the fault. When running on one cable with earth return, an earth on the cable will cut out all substations beyond the point where the fault occurs.

Size of Generators.—The present safe limit of pressure on a single commutator appears to be about 5,000 volts. Consequently for a maximum line pressure of 50,000 volts 10 machines are required, and if these are driven in pairs, five units of plant are required in the system. The output of each unit depends on the line current adopted; a 300-ampere line would require five units each of 3,000 kw. output.

It does not seem likely that these high-tension direct-current generators can be built to run at steam-turbine speeds; but a turbine drive is now available by the use of the beautiful double-helical gear employed by Sir Charles Parsons for

driving slow-speed propellers in marine work. A very good plant unit would consist of separate high and low pressure turbines, each driving by gearing one or two slow-speed generators. Careful designing is required for the couplings, but there appear to be no serious difficulties in constructing plant units of very large size.

The author believes that the day will come when internal-combustion engines of large size will be used to supplement the steam turbine in our power stations, and for such work the series system offers special advantages, owing to the fact that it is independent of any ordinary speed variations, and is clear of all the difficulties inherent in parallel running.

Cost of the System.—The detailed tables of costs in the previous paper are now in some respects out of date, but the comparative figures are still substantially correct. The cost of a series direct-current power station where either water turbines, Diesel, gas, or reciprocating steam engines are used is generally not more than that of a similar alternate-current station. Where large steam turbine stations can be used, direct-current plant of similar output would be more expensive.

The cost of the sub-station plant and gear, as has been already stated, is about the same as that of an alternate-current motor-generator station working at any pressure suitable for direct use on the motors; if step-down transformers

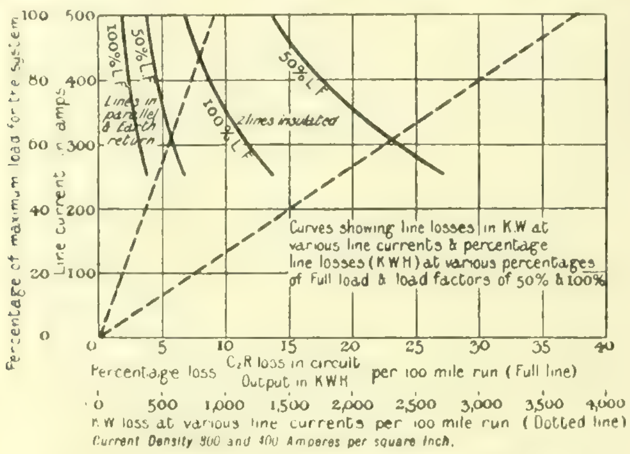


FIG. 20—LINE LOSSES AT VARIOUS LOAD FACTORS.

are required, the advantage will generally be with the direct-current station.

The transmission line is far less costly than a 3-phase line of similar capacity. The actual cost of the line, having a capacity of 10,000 kw. with one cable disabled, worked out at £1,600 per mile; this includes the two cables laid in cast-iron pipes and a telephone cable, and the cost of the earth connections at each end. The cost of a single 3-phase armoured cable of 5,000 kw. capacity at 20,000 volts, including cost of laying, is about £3,000 per mile, or twice the cost without any provision for breakdown. In many cases it is found the cost of an underground Thury system does not exceed the cost of a 3-phase overhead system of similar capacity.

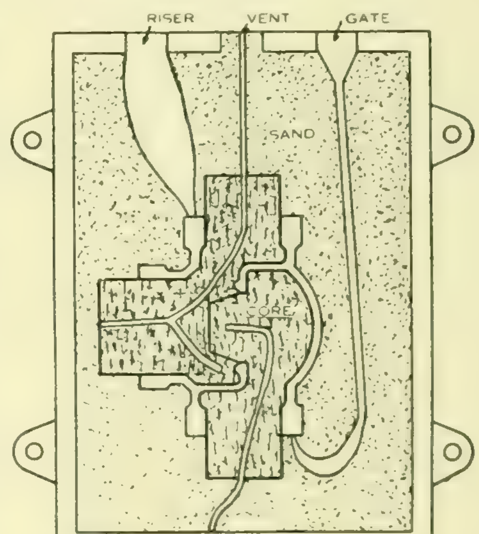
When the author read his former paper it was inferred by some engineers that he suggested that the series direct-current system would displace the better-known parallel systems. This he did not do. He said then, and repeats, that each has its own sphere; that for certain work the series system and series-wound constant-current machines possess great advantages as to cost and convenience over other systems. For very long distance transmission, especially where underground mains are necessary, it is possible where the alternate-current system is not possible. Where energy has to be taken to a great city from a distance, whether from a water-power station or a steam station situated at the coalfields, the underground system offers great advantages as compared with the overhead system in respect of security of supply and cost of maintenance. In many instances the underground direct-current system can be laid at no greater cost than the 3-phase overhead system. The system might be advantageously used for railway supply, especially where water power is available, since it enables a very long line to be fed from a single power station. It is nearly as easy and inexpensive to insulate for 100,000 volts as for 20,000 volts; all that is necessary is to design the couplings and machine insulation for the higher pressure. With this high pressure any practicable distance from a power station is possible.

The series machine is well adapted for any special work where variable speed is required, as for driving, winding, and hauling gear, and for rolling mills. It has been found economical to install a separate series system consisting of a generator and motor, the former driven by a 3-phase motor to drive a single winding gear. The great advantage for these purposes is, of course, the combination of constant torque with any degree of speed variation and the absence of the losses incurred in any form of rheostatic control.

In conclusion, the author is glad to state that the whole of the plant and cables for the western area supply were built in this country. With the invaluable guidance of M. Thury, the company's staff have handled the plant with the greatest success, and the author feels it right to bear testimony to their great help in bringing the work to a successful issue.

BRASS CASTINGS FOR HYDRAULIC PRESSURE.

CASTINGS that are required to withstand hydraulic pressure are among the most troublesome sections which the brass foundryman has to make, as the percentage of leaky castings is usually high. The source of the difficulty lies, says Mr. A. L. Goldsmith, in "The Foundry," in both the metal and the moulding, as the alloy must be dense and close of grain, and the casting should be properly fed and gated. After many discouraging experiences the writer finally devised a means of overcoming all difficulties, a recital of which may prove of material assistance to others similarly situated. The accompanying illustration shows how the mould for a large globe valve should be made when it is desirable to pour it upright. The gate extends to the bottom of the flask, and loops into the lower flange of the casting and a heavy shrinker or feeder is taken off the upper flange as shown. In case it is thought desirable to pour flat, use a medium-size sprue for pouring, and run the gate into one of the end flanges, and from the opposite corner of the other flange take off a heavy riser for feeding purposes. In ramming the mould, tuck the sand tightly around the pattern and ram very soft on top, venting thoroughly with a small vent wire. The temperature at which the metal is poured has an important bearing on the success of the casting. It should be cooled to a point where it will not bite into the skimmer when the latter is pressed down to the bottom of the crucible. The mixture, which, in an experience of 30 years has been found to give the most complete satisfaction, consists of Copper, 80lbs.; tin, 6½lbs.; zinc, 4lbs.; lead, 4lbs.; and old metal, 40lbs. The old metal should be of good quality, either old valve metal, machinery scrap, or government bronze. It must be clean and free from all contamination by aluminium



SECTION THROUGH MOULD FOR LARGE VALVE THAT IS CAST UPRIGHT.

Driving Gear for Automobiles.—A paper entitled "Bevel-driven *v.* Worm-driven Axles," was read by Mr. B. W. Ainsworth recently before the London Graduates of the Institution of Automobile Engineers. The author showed that, provided certain essential principles were observed, the advantage lay rather in favour of the worm and worm wheel as applied to the axle of a modern automobile. The worm mechanism had been shown to possess an efficiency of about 95 per cent and to maintain this practically unimpaired through long periods; the absolute silence when running was also greatly in its favour. Several speakers pinned their faith to the bevel drive, and doubted whether the worm and worm wheel would wear well.

BABCOCK & WILCOX OIL BURNERS.

WE illustrate herewith several designs of oil burners, the invention of Messrs. Babcock & Wilcox, Ltd., 30, Farringdon Street, London, E.C., of the type wherein the liquid flows tangentially into a chamber located behind the discharge orifice, within which chamber a regulatable spindle or plunger operates to vary the capacity of the atomiser.

In the arrangement shown in Fig. 1 a pipe A leads from the source of liquid supply, and is provided with a valve. A pipe B is connected to the supply pipe A, and in the forward end of pipe B is located the atomising tip. This tip comprises a plug C, and a cap D seated on the end of the plug, and having an outlet orifice E. The plug C has a central

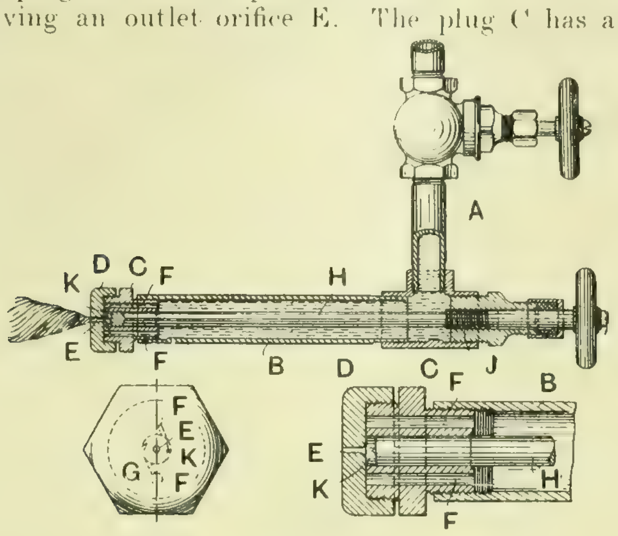


FIG 1.

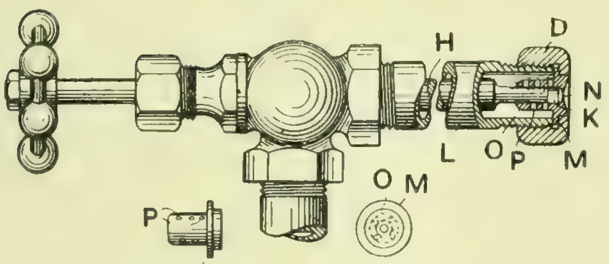


FIG. 2.
BABCOCK & WILCOX OIL BURNERS.

longitudinal bore, and two longitudinal passages F, which are closed at their outer ends by cap D. In the wall between the passages F and the central bore of the plug C ducts G are provided tangential to the wall of the bore, the ducts affording a communication for the flow of liquid from pipe B to the tip outlet. To control the working area of the ducts, there is provided a spindle H, the forward end of which is of such diameter as to fit snugly into the central bore of plug C. To effect the necessary longitudinal movement of the spindle, it is formed with a screw thread J, operated by means of a hand wheel. When the atomiser is not in use, the hand wheel is turned to advance the spindle H within the central bore of plug C, so as to cover completely the outlets of ducts G. If the tangential ducts G extend to the end of the plug C, then the spindle will be seated against the cap D. When the atomiser is to be put in use, the hand wheel is turned to withdraw the spindle H to uncover the outlets of the tangential ducts a distance sufficient to permit the flow of the desired amount of liquid. When spindle H is withdrawn the desired distance, a chamber K is formed in the central bore of plug C between the end of the spindle and cap D, into which the liquid flows, and by reason of the arrangement of ducts G the liquid is given a rapid whirling motion in the chamber by which it is atomised when it passes the outlet orifice E. The amount of liquid sprayed in a given time can be varied without changing the pressure or the temperature of the liquid by simply adjusting the spindle H to vary the area of the opening of the ducts G. The latter being in the same transverse plane constitute, in effect, a single opening inasmuch as the movement of spindle H opens or closes each duct an equal amount.

In the modification shown in Fig. 2 the tip is provided with a series of holes in different transverse planes. In this form the tip is made in a single piece, having a flange M by which it may be clamped to the end of pipe L by a cap D; the discharge orifice N being centrally located in the tip and the outer end of the tip fitting snugly the wall of a central opening in the cap. The inwardly extending neck O of the tip is of less diameter than the interior diameter of pipe L, and is formed with a series of ducts P tangential to the central bore K thereof. The bore K is contracted at the outer end of the tip to form the outlet orifice, and thus provides a seat for spindle H when it is moved to close all of the ducts P. The spindle H is threaded similar to that in Fig. 1, and is advanced or retracted by turning the hand wheel. When the spindle is retracted, a greater amount of liquid is permitted to enter the chamber K through the tangential ducts while maintaining the pressure at the outlet orifice substantially constant; and conversely, the amount of liquid is reduced by advancing the spindle to close some of the tangential ducts without a decrease of the pressure at the outlet orifice.

In the arrangement shown in Fig. 3 the tip Q is of substantially the same form as shown in Fig. 2, except that the tangential ducts R, which permit the flow of liquid to the chamber K formed between the end of plunger H and the end of the tip, are arranged as shown; that is, two or more ducts are in the same transverse plane, but so arranged that a given series of these ducts are on a spiral path, that is, the ducts in this tip combine the arrangement of Figs. 1 and 2. The threaded end of the plunger is engaged by a hand wheel S splined thereon, this hand wheel having a follower T which engages the screw threads. As the hand wheel is rotated the follower T effects a rectilinear movement of the spindle without rotating the same. To indicate the extent of movement

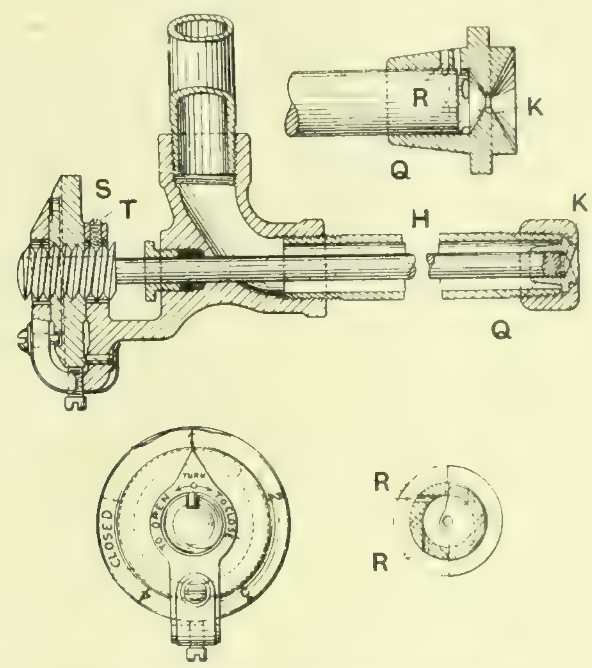


FIG. 3. BABCOCK & WILCOX OIL BURNERS.

of spindle H or the number of ducts open through tip Q when the spindle is retracted, a scale is provided on the hand wheel, the divisions of which correspond to the pitch of screw, or a given movement of the spindle which will open a greater or less number of the ducts in the tip for a partial revolution of the hand wheel. The hand wheel shown is so divided that the movement from zero to 1 may completely open the first row of ducts, and the movement from 1 to 2 may open the second row, &c.

Visit of Learned and Technical Societies to Cornwall.—An invitation has been issued by the Cornwall Joint Reception Committee of several of the leading scientific and technical societies and institutions in Cornwall to the various institutes connected with mining and metallurgy in this country to visit Cornwall between July 16th and 20th, for the purpose of seeing some of the works, mines, quarries, laboratories of the mining schools, &c., in that district. The chairman of the Reception Committee is the Right Hon. Lord St. Levan, Mr. Horton Bolitho and Mr. E. W. Newton are respectively hon. treasurer and secretary, and Mr. G. T. Holloway is kindly acting as hon. secretary in London.

THE CORE ROOM: ITS EQUIPMENT AND MANAGEMENT.*

BY HENRY M. LANE.

THE object of this paper is to bring to the attention of mechanical engineers the fact that by proper study of details in the foundry and core room it is possible to produce castings better suited for machine construction than those now ordinarily furnished, particularly in regard to their interior or core surfaces. For the present purpose a core may be considered as any body of sand that is formed apart from the mould and then introduced into the mould during its construction or after the mould proper is finished. The function of a core is to form certain faces of the casting, either interior or exterior.

Common sense dictates that the faces formed by the core should be as good as those formed by the body of sand comprising the mould proper. This, however, is not generally the case. Until recent times wooden boxes were largely used in making cores and little care was taken. The baked cores were filed to fit one another or the mould. No attempt was made to produce very accurate holes; in fact, the machine shop frequently preferred to cut openings from solid metal rather than to contend with irregular and poorly cored holes full of adhering sand and scale. There is no excuse for practice of this kind, and a machine shop has a right to demand as perfect a finish on the interior of a casting as on the exterior.

Some of the best core-room practice is found in the speciality shops, such as of manufacturers of radiators, pipe fittings, gas stove burners, and automobile engines. In these shops the equipment has been perfected to such an extent that the castings are turned out true to size within limits of a few hundredths or thousandths of an inch, proving that much thought has been spent on the core-room and its equipment. But even in the finest and most progressive plants we find conditions which cause loss of time and money. In some plants where the engineers have given painstaking care to the design and construction of the core boxes and core driers, and are using various types of core machines, they are using sands of such a nature that the ingredients of the sand destroy a considerable portion of the oil or other material used as a binder, necessitating an excess of binder, which means unnecessary expense. Most core-rooms, also, are hampered by some one condition which is considered a fixture, such as an antiquated oven, a cheap local sand, or the prejudice of the foreman in favour of some binding material.

For the past four or five years the author has given particular attention to the problems of the core room. While many foundry friends have been ready to try experiments at his suggestion, there has been difficulty in harmonising their results, or in harmonising results in the same plant when the experiments were carried on a few weeks apart. All have felt the need of improvement in this line, but it required someone to act as a clearing house of ideas, to plan the tests, to see that they were carried out in different plants, and above all, a central laboratory which could unite the results of the different experiments.

At this juncture the Robson Process Company tendered the use of its well-equipped chemical and physical laboratories at Covington, Va., and at the author's suggestion set aside a large room for the installation of core ovens and testing machines. With this laboratory available the co-operation of other manufacturers and dealers was asked and they have all rendered hearty assistance.

ACTION ON A CORE IN THE MOULD.

Introduction of Metal into a Mould.—Before proceeding with a discussion of the subject it may be well to state what happens when a core is surrounded with metal. The action is shown in Fig 1, which represents a portion of a cylindrical casting in the process of pouring, at a point where the mould is about two-thirds full, the metal rising over the core. Metal enters the gate at the left and flows to the bottom of the casting under the core.

At first the mould is full of air, and the moment molten metal enters this air becomes highly heated and expanded, thus instantly creating a pressure in the mould. The inflowing metal must not only expel a volume of air equal to the volume of the mould, but the expansion of the air greatly increases its volume. Then, also, considerable steam is generated as the metal enters, and this too has to be expelled. This mass of [illegible] air and steam escapes through both the mould and the core as indicated by the arrows in the upper portion of the illustration. As the metal fills the mould the gas pressure on the inside is relieved, but a new set of conditions appears which demands a porous mould and core.

If the metal is poured at the proper temperature, a skin or crust of solid metal forms almost instantly on the sides of the mould and the core (see Fig. 1), which prevents the passage of air or gas from the core or mould into the metal, or from the metal into the sand. At first, however, the skin is rather flexible, and should gas be generated in either the mould or the core more rapidly than the vent can take care of it, it may blow back and scab the casting. As the metal rises against the bottom of the core its surface is burned. As a core is dry, no steam is generated during this operation, but the hydrocarbon compounds in the core binder are driven off and forced through the core toward the central vent, as indicated by the arrows in Fig 1.

Gases Formed in Cores.—As long as air is present in the mould or core all forms of carbon are burned or oxidised so that the first gases to be expelled may contain carbon dioxide. As it becomes entirely surrounded with metal the air is quickly exhausted, and from that time on only such hydrocarbon gases as can be distilled off by heat are expelled. From this it will readily be seen that the volume of gas generated in the pouring of metal around any core is largely determined by the volume of volatile hydrocarbons which can be distilled from the core binder.

The baking temperature to which the core is subjected will have an important bearing upon this subject. Certain binders can be baked at a high temperature so as to expel most of the volatile hydrocarbons, and leave little but solid carbon as the core binder, but where this is done an excess of binding material must be used, as the binding power of the hydrocarbon compounds is largely sacrificed. Then, too, if the baking is continued until all of the volatile hydrocarbons are driven out, the volume of the binder is changed to such an extent that cracks or checks will generally be formed in the core. The ideal binder is one which contains sufficient hydrocarbons to give a strong core, but it must not give off during pouring gases which are injurious or even trying to the workmen.

Refractory Base of a Core.—The refractory material of which the core is composed should be of such a nature that it conducts heat but slowly, so that the rate at which the succeeding layers of hydrocarbon are distilled off is sufficiently slow to enable the vent to take care of the gases as they are formed. There are some cases in which it is advisable to increase the conductivity of a core so as to cause it to act as a chill on the metal, and when this is desired the binder problem is still further complicated. After the metal has come in contact with the core and commenced to burn out the hydrocarbon compounds, there should still be some binding properties left to act until the skin of metal next the core becomes sufficiently strong to resist any tendency of the molten mass of metal to cut the core.

Where metal must flow through or over a core it is difficult to prevent cutting or washing by using bonds of a carbonaceous nature only. Clay or a refractory bond of similar nature has to be resorted to; sometimes the surface of the core is protected by silica wash or clay and backing wash. If the binder is present in the core in sufficient quantity to leave a fairly large percentage of fixed or free carbon, the metal is not liable seriously to eat into or burn into the core. In many cases this condition necessitates the use of higher percentages of binder than would be required simply to furnish the necessary strength in the core

CORE ROOM LOCATION AND ARRANGEMENTS

The location and area of the core room are of more importance in the production of castings than most foundrymen realise, since the modern tendency in certain classes of work is to throw an ever increasing responsibility on it, and some complicated castings such as air cooled automobile cylinders are made in moulds that are composed entirely of cores. The definition of a core, as already given, was carefully chosen with this phase of the subject in mind. The location depends upon several factors: the size of the individual cores, the number of pounds of cores used per moulder per day, the strength of the individual cores and the method of handling the cores from the core room to the moulders.

Core-room Area.—A series of observations of the proper area of the core-room, extending over about 15 years, has shown that the core-room varies in area from 10 to over 50 per cent. of the moulding floor. This includes the space occupied by the ovens and core storage but not the core sand storage. In very heavy grey iron work, such as large Corliss engine cylinders, heavy machine-tool castings, large forging machines, &c., the space devoted to core making may be equal to at least 60 per cent. of the active moulding floor space, but in this kind of heavy work about half is usually inactive, because heavy castings must be left in the sand several days to cool, hence the area as compared with the moulding floor is about 30 per cent. of the total.

The core-room proportion in the case of side floorwork in a grey iron foundry is generally much less, because many of the moulds require no cores and as a rule the floors are cleaned each day, so that the entire moulding area is continually active and varies from 10 to 15 per cent. of the area of the side floor.

In the case of loam work frequently only a very small number of cores are used which are not made on the loam floors, but of course when loam work is being carried on drying ovens are necessary and the entire proposition partakes of the nature of a core problem.

For light grey iron or malleable work the area of the core-room depends entirely upon the character of the product. The fact that in the core storage the cores are kept on shelves

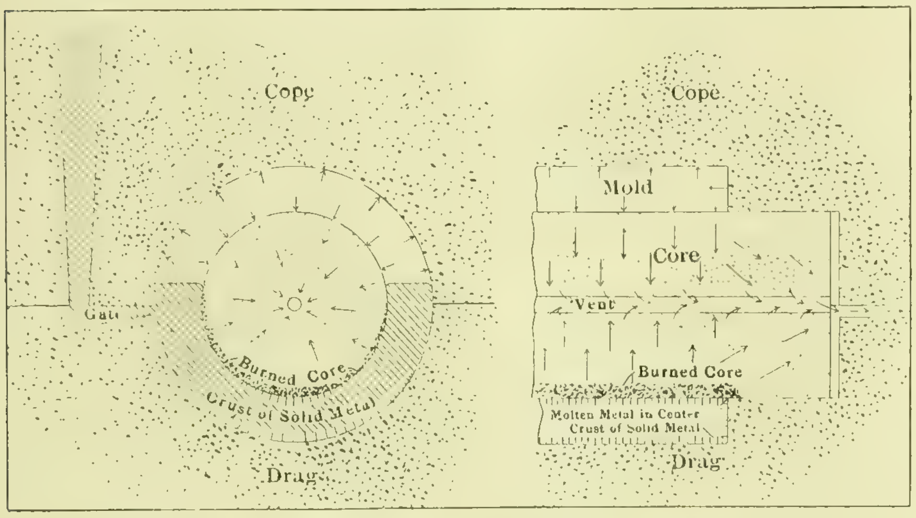


FIG. 1.—MANNER IN WHICH A CORE IS ACTED UPON BY THE METAL AS IT ENTERS.

one above another and the small ones are dried on cars having several shelves, tends to reduce very greatly the total area required. The cores for a given mould usually take up much less space than the mould itself and they are not accompanied by flasks. For grey iron work on automobile castings, including cylinders, the core department will have an area varying from 40 to 60 per cent. of that of the foundry. In aluminium work for automobiles it is about 40 per cent., in brass jobbing shops 10 to 15 per cent., for brass fittings 20 to 25 per cent., while for iron fittings it takes from 20 to 45 per cent.

The core-storage space to be provided is also important. In the case of jobbing work comparatively little room is necessary, since the cores when completed are usually sent to the moulders' floors. Where a line of standard work is being manufactured, provision should be made for carrying at least one-half of a day's supply of cores, and where night ovens are used for baking an entire day's supply.

Handling Warm Cores.—In order to avoid rehandling whenever possible, cores should be sent from the core-oven trucks to the moulders without placing them on storage shelves as this involves an extra handling. This question, however, brings up the advisability of handling cores hot. With many binders under such conditions more binder will have to be used than if they are allowed to cool. One large foundry using a great many oil-sand cores changes its oil-sand mixtures at about 3 p.m. by decreasing the amount of binder 15 per cent. The reason for this is that the cores made subsequently will be run out of the core oven on to the plates and left to cool over night before they are handled, so that the full strength of the binder will be developed. During the day they are ordinarily taken from the plates hot and carried to the moulders. In many cases a saving of 15 per cent. of binder would more than pay for the rehandling of the cores and the placing of a core-storage between the core department and the foundry.

Transportation of Cores.—Where the number of cores used per moulder is so great that the weight of the cores delivered to each approximates the number of pounds of castings turned out by him per day, the problem of transporting the cores becomes serious and must be taken into consideration in locating the core-room. In this there must also be considered the element of breakage. Every core that is broken represents not only the loss of the sand and binder but also of the time expended in making it, the fuel for baking, and other labour in the way of transportation. Every possible precaution should therefore be taken to reduce this item.

If the cores are large and delicate, such as those required in aluminium or light crucible steel castings, they must give way readily before the shrinking metal and should be handled as little as possible, hence the core-room should be near the moulders. If the cores are standard and sufficiently hard so that they are handled in boxes or in piles on boards as in some fitting shops, they will stand transportation a long way, and here it will pay to centralise the core department, equip it with labour-saving machinery, and reduce the cost to a minimum. The cores can then be distributed to the various departments without fear of serious loss through breakage. In the case of heavy work where they have to be handled with a crane, if there are several separate bays or departments it is frequently more economical to provide each section of the foundry with its own core-room and to arrange it so that the main travelling cranes handle them from the core oven trucks to the moulds at one operation.

For transporting cores about the foundry we have platforms, commonly called boats, which are rectangular in shape, made of plank, with heavy battens on the back, supported at four corners by slings from the crane hook. The cores to be moved are piled on the platform and shifted to the parts of the foundry where they are to be used. For handling and transporting medium or fairly heavy cores a device of this kind saves rehandling and guards against breakage. It also does away with confusion in the gangway due in many plants to carrying of cores to the various floors. In some foundries the cores are carried to moulders on a trolley system in boxes or specially prepared cages supported by spiral springs. In other cases spring trucks running on the gangway floor or spring-supported platform cars running on industrial railways are used for the purpose. In the case of medium heavy work, cores weighing 100lbs. to 200lbs., the core-oven truck may be arranged so that each shelf can be lifted off by the travelling crane and used as a boat to carry the cores to the floor; in other cases the entire core car may be picked up by the cranes and delivered to the moulders' floor.

Handling Core Sand.—As the core sand is bulky the problem of handling it assumes considerable prominence in most plants, and this necessitates the location of the core-room in such a position that the sand can be delivered from the railroad cars into the storage bins with the least amount of handling. For the most effective work the sand should be as dry as possible, hence it should be put into storage at a dry season of the year, and at least a nine months' supply provided for. Buying the sand at this time of the year also reduces freight costs by eliminating water contained in the sand during rainy periods.

To sum up the matter, the location of the core-room should be such as to minimise the handling of the cores, being nearer the moulders in the case of very heavy work handled by the main cranes, or in cases where delicate cores are used, as in aluminium or light crucible steel work, and being centralised when they are strong enough to stand transportation. The area will depend upon the product, and a fair estimate may be obtained by taking the number of cores required per man per day, and estimating the number of cores the coremaker will make per day, thus arriving at the number of benches required. The space occupied by coremakers benches is as a rule about 35 to 40 per cent. of the total core room space, the balance being taken up with ovens and storage racks for green and dry cores.

CORE SANDS AND CORE BINDERS.

The term core sand covers a wide variety of materials adapted to different classes of core work and the conditions to be met in the core room necessitate the use of a number of grades of sand in most core rooms. In all core sands the principal heat resisting element is silica, the silica grains also forming what may be termed the backbone of the core.

Ordinary moulding sand rarely contains over 80 per cent. silica, the balance being made up of alumina, oxide of iron, and other impurities. In a moulding sand a certain percentage of clay is necessary to form the bond. They may be divided into bondless or sharp sands for oil-sand mixtures or cores which require a great deal of vent; and the bonded sands and gravels. The sharp sands contain from 97 to 98·5 per cent. silica, while the bonded sands contain from 97 to less than 90 per cent.

Proper Condition of Bond in a Core.—Since a core must be sufficiently porous to vent freely, the sand composing it must be of such a nature that there will be a considerable percentage of voids or open spaces through which the vent may escape. In any core the individual grains of sand must be bound one to another with some material, collected, if possible, at the contact points, thus leaving the spaces between free for vent passages. Anything that tends to roughen the surface of the grains of sand in the passages tends to retard the vent.

Form of Sand Grains.—In concrete and masonry work sharp sand is desirable on account of the fact that it affords a better grip for the cement or lime in the mortar. For core work rounded grains of sand are the best because they give a maximum of vent passages and larger areas at the contact points for the bonding material to act. The strongest cores that the writer has seen used in practice were made from oil-sand mixtures with thoroughly rounded grains of sand, the individual grains being of approximately uniform size.

In concrete work the object is to fill all the voids between the particles of the material with finer stock, so that the final product will be a uniform solid mass. In making cores the requirement is radically different, as it is desirable to have the greatest possible number of fine voids; only they should be so fine that the metal will not tend to follow or flow into them. This necessitates the use of different sized grains in the core sand for different metals. Some of the brass and bronze mixtures are particularly searching and will force their way into cores where iron would lie smoothly on the surface. There are two reasons for this, one that the melting temperature of the brass and bronze alloys is lower than that of the iron mixtures and hence they remain fluid for a longer time in contact with a core; and the other that the iron alloys seem to be more viscous when fluid and will not flow into as sharp corners as the brass and bronze alloys.

Aluminium in some respects behaves like iron in this particular. Sand mixtures which would be perfectly satisfactory for iron or steel or for aluminium may be wholly unsuited for brass or bronze. A brass or bronze containing considerable phosphorus is particularly searching in its action, also an iron containing considerable phosphorus is more fluid than other mixtures and has more of a tendency to cut into a core. From this it will be seen that the selection of a particular grade of core sand must depend to a considerable extent on the metal to be cast.

Early Day Core Practice.—In the earliest foundry practice cores were made from mixtures containing no artificial bonds. A sand was chosen containing enough clay to hold the grains together when dry, and if this showed a tendency to stick to the casting some sawdust or other carbonaceous material was added to the mixture, causing it to fall to pieces next to the casting more easily and clean out better. It is probable that the first artificial core binders used were rye and white flour and pea meal, and there are also records of the use of sour beer. In those days all moulds were thoroughly dried before the metal was poured into them, so that it partook of the nature of a core. To harden and strengthen the face of the mould or core, it was frequently sprinkled with sour beer or molasses water and then dried. When the metal came in contact with the surface, it burned out the carbon of the binding material used at the surface and made it easy to clean out the core.

American and Foreign Practice.—In America demand for a big output and cheap castings has developed a number of lines of foundry practice to an extent not found in any other country. The green sand mould is more universally used here and the variety of core binders exceeds that employed in any other country. At present probably the most common core binder used abroad is what is known as core gum, which is really dextrine, one of the products of the starch industry. Pea meal is also used abroad to a considerable extent and rye flour, and linseed oil in certain foreign countries. America has been the first to introduce an extensive line of specially prepared binders.

Kinds of Binders.—There are two classes of binders as regards their action on the sand. These are the true pastes, which do not flow to the contact points of the sand, and the binders that flow to the contact points as the drying and baking take place. All binders which act as a paste are not affected by clay in the sand. This is also true of resin and pitch. Binders that partake of the nature of an oil are injured and in some cases ruined by the presence of clay in the sand. The advantages of sharp sands and sands of uniform sized grains were never fully appreciated until the complicated problems of the water-cooled automobile engine cylinders required solution. At first intricate systems of mechanically formed vents were used, but later it was discovered that by using clear silica sands and oil as a binder that the vent would find ample passage in the spaces between the rounded grains.

Fitting the Binder to the Sand.—In selecting the core sand for any given location the problem to be solved is the finding of the cheapest finished core. Cores for a given class of work must have a given strength per square inch and must disintegrate when the metal is poured about them, so as to permit ample opportunity for the metal to shrink. Generally in producing a core of this kind a number of courses are open. A local bonded sand may be used with resin, flour, dextrine, black compound, glutrin, or molasses. As a rule black compound or pitch cores are more suited for heavy work than for light. For small work greater strength per square inch of core is generally required than for large work, and for great strength associated with free venting there must be a binder that will hold a sharp sand and at the same time permit the free circulation of the escaping gases. Flour or dextrine tend to a large extent to stop the vent, as do also the black compounds, which contain dextrine as a green binder. This calls for the use of an oil mixture, an oil and glutrin mixture, a glutrin and clay wash mixture, or molasses.

A number of different water soluble by-products from commercial processes have been or are used to some extent as core binders. In some places in the vicinity of rum distilleries a product known as distillery returns, distillery slop, or sour beer, is used; in other locations sour beer from breweries, but both are employed only in limited localities as they are weak adhesives and hence not good binders.

The principal objection to the use of molasses in the core room is the fact that this binder is not uniform in its adhesive properties. First, fermentation has to be dealt with. To test its effect the writer measured out a quantity of molasses, diluted it with twice its volume of water, and let it stand in a crock. The specific gravity of the solution was taken every few days and batches of cores made from it were tested for strength. These fell off rapidly in strength as the fermentation proceeded, losing more than half, and at the same time the specific gravity constantly decreased. Foundrymen have been known to purchase fermented molasses thinking that they were getting a cheap bond. In a case of this kind, however, one has no knowledge of the actual bonding power.

At the time the fermentation experiment was made on molasses a sample of glutrin was measured out, diluted to the same proportions, and allowed to stand in a crock next to the molasses. Cores were made from it each time that cores were made from molasses. Those from glutrin gradually increased in strength with the age of the mixture, due to its slow concentration by evaporation. The molasses mixture was, of course, evaporated just as fast, but the composition was changing so rapidly from fermentation that the effect of evaporation did not show.

Another objection to molasses is the fact that no matter how honest the dealer or how free from fermentation the stock may be at the time it is used, its bonding power must depend upon the source from which it was derived. In making cane sugar the plant is topped in the field and the tops are thrown away because the juices in the upper part of the stalk have not been converted into sugar. If the stalks are topped too high, a large proportion of the juice carrying no sugar enters the fluid and remains in the molasses after the sugar has been crystallised. As the molasses is the residuum of the sugar process it must contain all its impurities, and these vary with the source of material from which the sugar was made, the method of work, the way in which the cane was topped, and many other factors.

The only other water soluble bond extensively used in the foundry is glutrin, a by-product of paper manufacture by the sulphite process. The sap stored in the cells of the spruce wood used in paper making is extracted by boiling with the sulphite solution, and when treated to remove certain undesirable elements, and concentrated, it becomes the binder known as glutrin. While its composition is complex, consisting of tannins, wood sugars, and resin in soluble form, it is a product uniform in composition and hence in binding power, and it will not ferment.

Use of the Microscope.—It has been found that a microscopic examination of the fracture of a core would tell much as to its venting properties and the efficiency of the bond, but thus far, however, it has proved impossible to produce a microphotograph that would show all that the human eye could see in examination of a core, because the focal depth of the micrographic lenses is exceedingly shallow, so that when examining cores at magnifications of 60 or more diameters it is necessary to rack the objective back and forth and examine the top, the middle, and the bottom of a grain of sand, thus giving a clear mental picture of the bonding conditions. A microphotograph taken in the ordinary way does not show this as it has not sufficient depth of focus.

(To be continued.)

THE TEST DEPARTMENT OF A RAILWAY.*

BY E. B. TILT.

In considering the duties of a railway engineer of tests and the work of the railway testing laboratories, it may be well to refresh our memories with a very brief history of the growth of the steam railway and the principal engineering materials used. The year 1801 saw the laying of the first chartered line of rails, a short horse railway in the suburbs of London, and in 1804 the first steam locomotive was used on a small railway in Wales. The first really successful application of the steam locomotive was in 1814 on a mine railway near Newcastle-on-Tyne, with George Stephenson's famous "Puffing Billy." The Stockton and Darlington opened in 1825 and was the first railway to carry passengers. Four years later, in 1829, the famous Rocket fulfilled the requirements specified by the Liverpool and Manchester Railway, for a locomotive to meet the traffic demands of that period. This is only 82 years ago, and the ferrous metals available at that time to build this 12,000lbs. machine and give it a track to run on were cast iron, including malleable, crucible steel and wrought iron. It is probably true that the quality of the metals in use then was as good as the quality of similar metals in use now, but methods of manufacture were largely by hand, the output was small and processes were not completely understood. The advantages of steam traction were early recognised, and we find that about 1850 the demands of service had so increased the duty of tyres and rails that wrought iron was not equal to the task. At this period Great Britain had something over 5,000 miles, Canada less than 100 miles, and the United States over 9,000 miles of railway.

In 1856, the Bessemer process of making steel was invented, but it was not a commercial success until the early sixties. To get an idea of the revolutionary nature of the new way of steel making, it must be borne in mind that before this time steel was in use for practically little else but cutlery, springs, and the small parts of machines. Steel boiler plates were first used in 1860, and permitted the use of a steam pressure of 80lbs., and in 1863 the first locomotive boiler was made of steel. It was only a few years after the commercial perfection of the Bessemer process that the open hearth process of steel making became a success, and if these developments of steel making had not happened the expansion of the railway world could not have been as rapid as it has.

While the development of railways and metal making was taking place, and even earlier, scientific men were endeavouring to keep pace with the study and knowledge of the characteristics of engineering materials, and in the latter part of the eighteenth century Souflat, a Frenchman, had made tests of the strength of iron, as had also two Englishmen, named Reynolds and Bramah. Von Siekingen, a Swede, published the results of iron tests in 1782, and Eytelwein published the results of his experiments on the strength of iron in 1808. There was also data on the same subject published by Tredgold in 1810, and Bandelet in 1814. "The Strength and Stress of Timber" was published by Barlow in 1817, and "Experiments on the Strength of Materials" was published by Prennie in 1818. Systematic and scientific experiments on the strength of wrought iron were carried on by the Frenchman Dulean in 1820, and Tredgold published his "Practical Essay on the Strength of Cast Iron and other Metals" in 1823. Seguin's work on wire bridges appeared in 1824, while Sagerhjelm's valuable experiments on the density, uniformity, elasticity, malleability and strength of wrought iron were also made public in 1824. In 1807, Thomas Young had advocated the adoption of a modulus of electricity, and Karsten in 1826 established the strength of iron of various sections and diameters. Pictet was making extended tests during this period of materials in compression. This data forms part of the records given in Beck's "Geschichte des Eisens." It will be seen then that the first railway engineers had quite a large amount of scientific data relating to the materials available for their use. Woehler began his tests on the fatigue of metals in 1857, which have been continued by Spangenberg and Martens, and Kirkaldy, Fairbairn, and Styffe did much to popularise commercial testing. In more recent times we have had Bauschinger's classic work on the properties of metals under various conditions, and Barba, Osmond, Le Chatelier, Kick, Sir Lowthian Bell, Roberts-Austen, Campbell, Howe, and many others are names which we know in connection with the study of the properties of metals within our own time.

In 1875, the Pennsylvania Railroad established what we believe to be the first railway chemical laboratory in America. The man selected to be the head of this department was the late Dr. Charles B. Dudley, who became a world-wide known authority on railway materials. His own words written some time after taking the position in November, 1875, show how he, a college-trained chemist, and his department were regarded: "So little was the possible use of a chemist appreciated, and so little work was known that he could do, that permission to have a chemist was granted more as a concession and as an experiment than with any faith or belief that the scheme would prove to be permanent or valuable. It is also fair to say that at that time the field for work was as much unknown to the chemist himself as to the railroad officers." Consider the conditions at that time: railways were expanding very fast, much material had to be purchased and the standards of quality desired had largely to be investigated and determined, and suitable specifications drawn up to cover the purchase of these materials. The laboratory staff then consisted of Mr. Dudley and one or two untrained helpers, and this grew until to-day there is a force of over 30 chemists and other assistants, in addition to a staff of about 200 inspectors of various kinds.

The laboratories of the Pennsylvania Railroad report that in 1910 there were 35,872 samples of various materials examined in the chemical laboratories on which there were made 121,970 determinations. In the physical testing laboratory 58,193 routine tests were made which included the inspection of the following material: The inspection of 97,759,972lbs. of bar iron, of which 4,007,049lbs. were rejected; 840,750 pieces of air brake hose, of which 108,300 were rejected; 3,000,480lbs. of waste, of which 1,008,275lbs. were rejected; 33,734,552lbs. of steel castings, of which 1,161,379lbs. were rejected; the inspection of 211,453 wheels, of which 2,519 were rejected. We have given these figures as representing the work done by the largest railway testing department that we know of, and the figures well serve to give some idea of the quantity of materials required by a big railway, and the rejections prove the necessity of inspection. There is not a trunk line in America to-day which has not its testing laboratory in greater or less degree, and we find by enquiry and estimate that railways are spending from £20,000 to £30,000 per year on their testing departments. One railway informs us that as a result of an investigation made by their testing department they effect a yearly saving of £16,000 in the treatment of cross ties as compared with their previous practice.

The principal economies which are being effected by railway testing departments, outside of the economy which results

* Abstract of paper read before the Canadian Railway Club.

from the use of good material, are those relating to the purification of boiler waters, studies on fuel consumption, investigations in connection with rails, tyres, paints, and rubber goods. Some testing departments supervise the manufacture of disinfectants, deodorisers, metal polish, fire extinguishers, boiler compound, and cutting compound; and one railway company makes all of the freight car paint which it uses. The testing of railway materials is now on what may be termed a standard practice basis, and there is a wealth of literature dealing with the technique of inspection and the qualities desired in the materials used. The time is therefore long since past when the question of whether a railway testing laboratory is a necessity or not, and the fact of such a department existing in every progressive railway organisation indicates that it is necessary, and must therefore be a paying investment.

The management of the Canadian Pacific Railway had early recognised the value of a railway test department, and since 1891, when Mr. W. Bell Dawson started the first laboratory, there has been a department of some magnitude, greater or less, depending upon what purchases of supplies were being made. In the purchase of materials of such wide variety and origin as are required for the Canadian Pacific Railway, the question of economical inspection is important, and the present organisation has been found to be a satisfactory and economical one. A great deal of our heavy material is bought in Europe and the United States, and the keeping of our own inspectors at these distant points would entail much expense. Otherwise we would inspect the material on receipt at the point where it is to be used, which is certain to be unsatisfactory if the material is not acceptable, and the equipment waiting for it would be held up. This foreign inspection has been well handled by outside inspection companies who work under our instructions and with our specifications, and who guard our interests, whether the material is offered at Sheffield, Essen, or Pittsburg.

The question of where a railway testing department should fit in or how it should be related to the railway organisation is an important one. It seems that the logical place to look for this department, which questions the quality of materials offered or purchased for all other departments, and which makes reports thereon to the heads of the departments, should be under some general officer. In the case of the Canadian Pacific Railway, the testing department has been successively under the engineering department, the stores department, and the general manager, and is now reporting direct to the vice-president's office; the most satisfactory relations to all have been while under the general manager and the present arrangement. It is believed, then, the test department should be responsible to the management, and while reporting to all other departments, should be independent of them.

The test department must necessarily stand close to the general storekeeper, advising him promptly when the material is not of the desired grade and suggesting its disposal or its rejection. We make all of our reports on the quality of materials to the storekeeper, with copies of the reports to the heads of the departments for which the material is intended, and it is taken for granted by the shops that if material is given to them by the stores, it is of the proper quality, and that it has had the necessary inspection. We have always taken the viewpoint that we should be distributors of information of general interest, and in the making of reports, copies are usually sent to the chief officers in other departments, who are indirectly interested. The test department can also be of much service to the purchasing department, advising it of the merits of samples as compared with what has been previously purchased, and in working out such specifications as will ensure the securing of a reasonably good commercial material or article for the purpose intended, at a fair price. The cost of inspection, outside of the cost of the material which may be destroyed, varies greatly and may be as much as 5 per cent. of the value of the material or as little as ·2 per cent.

The making of a specification is a very important part of the duties of a test department, and the perfect specification should secure the best material at the lowest cost; but in reality the usual specification is very much of a compromise. In drawing up a specification the use of the material should first be carefully considered and the attributes necessary to meet the demands of service well studied. It must then be determined what accelerated or laboratory tests will best show the capacity of the material to meet the service required of it. The departments interested must be consulted regarding the size, shape, or form in which the material is desired, and the stores must decide about the shipping and the storage. The specification must then be submitted to the purchasing department, which sends it out to the manufacturers and after some modification and changes, results in a general compromise which gives a material which will be considered a run of mill product purchasable at a reasonable price. It is often known that material bought in this way is not the best material of the kind made, but it probably is the best material available, price considered.

In the use of specifications, the ideal way is to send them to all manufacturers of that particular line, an open market so to speak, and after quotations are received, buy from the firm submitting the lowest price. While this again is theoretically correct, yet it is impossible to ignore the claims of manufacturing companies situated on a railway company's line, and others who for equally good reasons must be considered, and while the virtues given to materials bought through influence of that sort are of the kind which the engineer of tests is unable to detect, yet where judgment is used and a careful inspection made, this is no doubt good railway politics. Then again, the skill, equipment, tradition, pride, and other factors all have a bearing on the quality of material, and it is a fact that materials bought under the same specification from different manufacturers will differ as to absolute quality, though, of course, the differences are usually of minor importance and are generally those of finish and appearance.

The manufacture of materials, such as disinfectants, boiler compounds, and so forth, by a test department or under the supervision of a test department, is believed to be a questionable procedure, and while the Canadian Pacific Railway are at present making a boiler compound, yet we anticipate at an early date purchasing this material in accordance with our formula and specification. It is believed that a suitable formula and specification will enable the purchasing department to buy any material with greater satisfaction for use than can be given by intermittent manufacture with all its drawbacks due to irregularity of the quality of raw materials, changes in the workmen during the manufacture, and other variable factors. The following definition of a railway given by Mr. Julius Kruttschnitt of the Harriman lines covers the situation: "A railway is a machine designed to manufacture freight and passenger transportation, it makes ton miles and passenger miles." From a limited observation it is believed that the great majority of railway materials can be purchased outside with greater satisfaction and economy than they can be made, and we may mention such things as bronze, brass, and steel castings.

The management of the iron mixtures for the Canadian Pacific foundries is one which has effected a very large saving as compared with previous practice. All mixtures are carefully calculated from the analyses of the materials entering into the mixtures and the uniformity of the product is an evidence of the value of this procedure. In the wheel foundry, the difference between wheels too hard or too soft for use and good wheels is only a few hundredths of one per cent. of silicon or manganese, so that great care must be exercised in the choice of materials. In the grey iron foundry there are produced three different grades of iron each day from the same cupola cylinder, machine, and a common iron for grate bars and such castings. Every car of pig iron and coke received is analysed, as is also the limestone and scrap from time to time, in order to check the quality.

The scrap dock has been a popular source for many test departments to turn in effecting economies, and the following are among the principal items considered in a paper recently read before the Central Railway Club by Mr. J. P. Murphy, general storekeeper of the Lake Shore and Michigan Southern Railway: "All bolts and iron suitable for making bolts are assorted, straightened, cut to length, threaded, and turned into stock for further use; washers are made from old sheet on a punch which is available for the purpose; nuts are sorted to size and retapped; track spikes and bolts fit for further service are returned; tie plates, angle bars, and rail braces are sorted out, the plates often repunched to other sizes, rail braces straightened; coupler pockets sheared from couplers by an hydraulic press and reissued; old bridge channels and angles made into angle iron face plates for cars; frog and

switch parts dismantled, and good parts assembled for use in manufacture of new frogs and switches at the company's rail shops; passenger brake shoes unfit for that service sorted and delivered for use on freight cars; brake beams repaired; forgings capable of being worked over sorted; journal bearings relined; air hose refitted and old couplings used; spliced hose for work equipment; throttle packing made from scrap hose; union gaskets made from old air hose gaskets, and in the handling of scrap the same may be sorted for mill classification, thus allowing the purchasing agent to obtain better prices for it."

There are undoubtedly many things to be learned and economies to be effected from an investigation and study of materials at the scrap dock, and the locomotive and car departments are watching this very closely. Investigations into re-using scrap materials on the Canadian Pacific Railway have been very limited, but one included the recovery of oil from discarded dope, and without entering into details, it may be said that this recovery was an economical proposition when nothing was allowed for the scrap value of the dope, but when the reclaiming process was charged with its market value the proposition was non-paying, to say nothing of the trouble which the use of the reclaimed oil made because of its inferior quality. We have all heard of washed waste, which no one wished to use, and of recut files which it was difficult to have mechanics give a fair trial, and it is believed that if some of these so-called economies are properly investigated, it will be found that if they bear all the charges which should properly be set against them, that the saving is very small.

The inspection of failed material is made together with a representative each from the draughting office and the shops, so that the question of design, and fit or workmanship, can be considered before chemical and microscopic analysis and physical testing are done. The results of these investigations of failed materials are usually the finding of inferior material, otherwise there follows modifications of design, variation in shop treatment of material or a change in the specifications for the materials used. A great deal of testing has been done during the last few years of high-speed steels, and drills of different designs made from these steels. We have made tests of files and are called upon continually to judge as to the merits of different brands of shovels, handles, lanterns, hose, and many other small devices and materials which it is difficult to satisfactorily cover with a specification. Studies are being carried on relating to steel tyres, cast-iron wheels, rubber hose of various kinds, and paints with a view to seeing what improvements can be effected which will result in greater economy to the road.

The sampling of materials is a very important and difficult matter and often does not receive the attention which it should. A sample must be representative of the average quality possessed by the material of which it forms a part, so that judgment and care are necessary to prevent a selection of the best or the worst portion of the material that it is desired to sample. The form for reports is a most important consideration and is something upon which a great deal may be said, for each particular material and condition requires its own treatment. However, without elaborating on something which is not of general interest, it is our practice to make all ordinary reports in letter form as they receive more attention and consideration.

DETERMINING SMALL DIFFERENCES OF DENSITY.

AT a meeting of the Physical Society of London, held on June 14th, at the Imperial College of Science, Prof. A. Schuster, F.R.S., president, in the chair, a "Demonstration of the Use of Specific Gravity Balls for Determining very Small Differences of Density" was given by Mr. T. H Blakesley. The communication was made for the purpose of pointing out that the sensibility of specific gravity balls was, as a matter of fact, vastly underrated by scientific men, and the author quoted passages from Prof. Balfour Stewart and Mr. Fownes which tended to produce the belief that beyond the third decimal place specific gravity balls were not trustworthy. A variety of experiments was quoted which indicated a sensibility a hundred times as great as this, and indeed that the error which might be expected in a properly conducted experiment would be of the order 5 in the sixth decimal place. The author had been in the habit for the last quarter of a century of employing specific gravity balls for the purpose of discriminating between the qualities of potable waters in respect of density and, therefore, of hardness, of testing the efficacy of softening processes, &c., for all of which the specific gravity ball was admirably suited. His process of observation differed from the ordinary rough-and ready use in the fact that a thermometer of fairly open scale was employed to give the temperature at which a specific gravity ball was in equilibrium with a liquid which was being slowly warmed or cooled through that point of temperature. The error in such a temperature observation should not amount to more than three or four hundredths of 1° C. If such a determination was made in distilled water at ordinary atmospheric temperatures it fixed the specific gravity of the ball at the temperature of equilibrium within four or five units in the sixth place of decimals. If a second observation with the same ball was made in a slightly heavier liquid, say, common tap water, the temperature of equilibrium would be considerably higher, perhaps 2° or more, than in distilled water. By applying the coefficient of cubical expansion the density of the ball at the higher temperature could be obtained, and this was the density of the second specimen of water at the second temperature. Reference to a table of densities of distilled water would furnish its density at the higher temperature, and the difference between the two numbers would give what the author called the density excess of the second liquid over distilled water at the higher of the two temperatures. This density excess was best quoted in parts in one million. For example, the density excess for a specimen of London water was found to be 290 at 17° C. For a few degrees on either side of this value this number was sensibly constant, a fact of some value, as it enabled one to employ four or five balls at the same time in one experiment. One noteworthy result of experiments made through a long course of years was that simple glass balls tended to expand, especially in the years immediately succeeding their manufacture. The rise of the zero point of thermometers had led to the belief that glass contracts with age. Mr. Blakesley then proceeded to explain the sort of apparatus which he thought might make the extreme sensibility of the specific gravity ball available for quickly detecting the infusion of fresh water in the ocean due to the presence of icebergs in the neighbourhood. This problem was one which could not be decided without definite experiments made upon water specimens taken from the sea at various noted distances from icebergs, observing direction of wind and current at the times of taking the specimens. These could be quietly submitted to examination, and the results would be of the first importance in settling some of the details of the apparatus for quick practical determination of fresh water infusion.

Electrification of the London and North-western Railway.—The first completed section of the new Euston-Watford lines, viz., between Willesden and Harrow, was recently opened for service. The new local line between Watford High Street and Croxley Green is now also available for traffic. According to "The Electrician," good progress is being made with the laying of the additional tracks between Harrow and Watford, and this section will be ready for opening before the end of the year. At the outset the whole of the new route will be worked as a steam railway, but as soon as the Bill now being promoted by the company has passed through its final stages contracts will be placed for the new local lines between Chalk Farm and Willesden, and for the conversion to electric traction of the North London line from Broad Street to Chalk Farm and the other lines included in the company's scheme. It may be recalled that the intention is to run electric trains from Watford into Broad Street and Euston, and over the Baker Street and Waterloo Railway by means of a junction at Queen's Park. The cost of the whole undertaking is estimated at £5,000,000, of which £2,000,000 will be absorbed in the cost of new permanent way, £2,000,000 in the electrification scheme, while £1,000,000 is to be advanced to the London Electric Railways in connection with the extension of the underground line from its present terminus at Edgware Road to Queen's Park. It will probably take about four years to complete the whole scheme.

DRIVING AND REVERSING MECHANISM FOR PLANING MACHINES.

THE accompanying illustrations show a form of gearing for driving and reversing the table of metal planing machines, the invention of Mr. T. Simpson, Victoria Park, Brookfield, Johnstone, N.B. It is suitable alike for driving by means of a belt or by means of an electric or other motor through reducing gear or toothed wheels. Fig. 1 is a sectional plan showing the mechanism assembled in a gear box. Fig. 2 is a detail elevation of the gravitation control lever and hand starting and control lever. Fig. 3 is a sectional view of the driving pulley and reversing clutches with the gear box broken away.

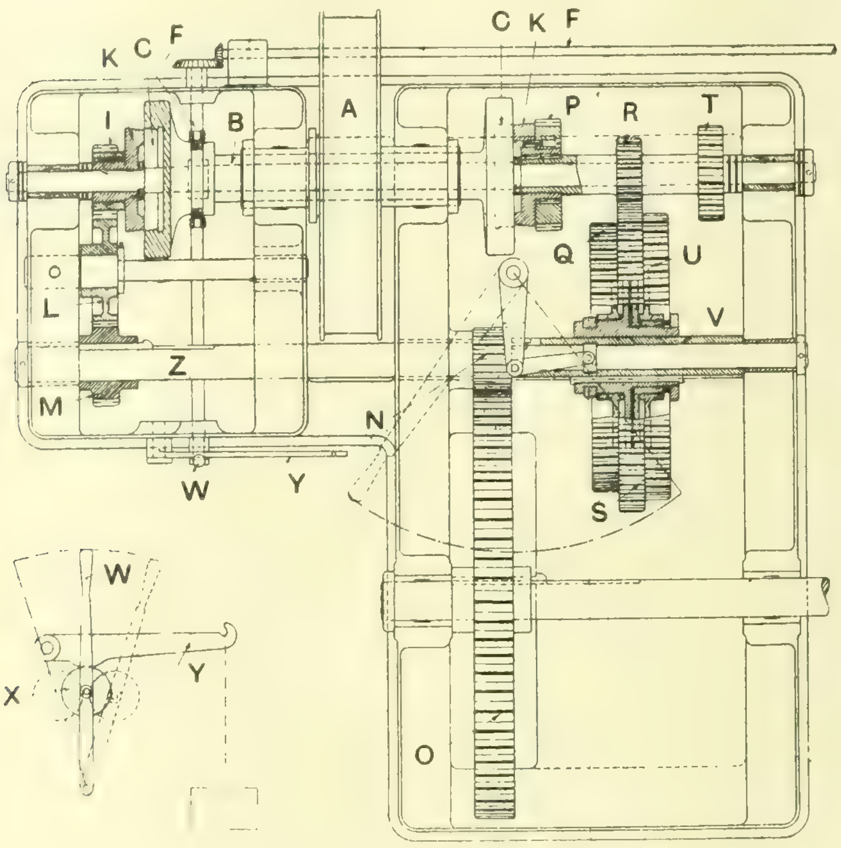


FIG. 2. FIG. 1.
DRIVING AND REVERSING MECHANISM FOR PLANING MACHINES.

In the construction illustrated a pulley A is used mounted to run in self-oiling bearings, one adjacent each side of the pulley so as to impart rigidity thereto and yet allow same to revolve quite freely as a loose pulley. A tubular shaft B passes through the axis of the pulley, and between the two is a sliding feather permitting longitudinal movement of the tube, which is provided at each end with friction clutches C, respectively, these clutches being comparatively large in diameter and heavy to act as flywheels. The tube B, with the two clutches C thereon, is adapted to be traversed in both directions through the axis of the belt pulley A by means of one or more rocking shafts F connected up to the usual tumbler-lever actuated by the tappets on the traversing table of the planing machine. When the clutches are moved in one direction, viz., to the left, in Fig. 1, the clutch C, on the left, engages a fellow clutch K mounted freely on a shaft extending through the tube B. This clutch K is integral with or keyed to a toothed wheel I, which gears with a toothed wheel L, which in turn meshes with a toothed wheel M mounted on a shaft Z, on which is also mounted a pinion N in gear with a wheel O carried by a shaft which may be coupled to the usual rack pinion shaft of the planing machine or may be carried through the bed of the machine to serve itself as the rack pinion shaft. With this train of gear in action the table is operated on the return stroke at a fixed rate of speed. When the two clutches C are moved in the opposite direction, viz., to the right in Fig. 1, the clutch C on the left is disengaged from its fellow clutch K, and the clutches and pulley A are permitted to run idly until the clutch C on the right engages with its fellow clutch K, whereupon a separate train of wheels is set in motion to traverse the table in the direction required for cutting and at the desired rate of speed. This train of gears may be arranged for one or more rates of cutting speed.

In the construction illustrated these change-speed driving wheels are as follows: Integral with or keyed to clutch K on the right is a toothed wheel P, and integral with the latter are toothed wheels R and T, all adapted to revolve freely. Slidably mounted on an extended boss V of pinion N are three toothed wheels Q, S, U, of different diameters, adapted to be put in mesh with the wheels P, R, and T, respectively, so that according to the speed to be imparted to the table three different trains of gear are produced. One of the change-speed wheels for example, S, is provided with means for absorbing shock at the moment of reversing the stroke of the machine, and the driving pulley A may also be fitted with means for absorbing shock and arranged for automatically becoming a loose pulley for a brief period of time when temporarily overloaded. For example, the pulley A may comprise an outer casing consisting of two members secured together by means of rivets or screws, and enclosing two metal discs D and E, with a disc of leather between same. One of the metal discs E is keyed to the shaft B, which it drives, and has an extended boss on either side. The other metal disc D is fitted on the boss on one side so as to revolve loosely thereon, and fits closely to the leather disc, when the discs D and E are pressed together by means of a screwed collar G on the boss of the disc E. Upon each metal disc a sleeve is provided at opposite sides to serve as a bearing upon which the outer casing is mounted. The disc D is provided with one or more projections H, which are housed in a corresponding groove in one member of the outer casing. Corresponding bridges J are provided in the housings to form drivers, so that when the outer casing revolves it will drive the disc D by means of the projections H, and owing to the friction contact between the two discs D and E power will be transmitted to the tubular shaft B, upon which the pulley is mounted, but when the load exceeds the limit for which the discs D E have been adjusted to transmit power by means of the screwed collar G, the discs D E will slip, and the pulley A is released so long as the load exceeds that for which the discs D E have been adjusted to drive by means of friction between their two faces. Spiral springs are placed in the circular housing and arranged so that one spring comes between each of the driving elements H J in such a manner as to absorb shock.

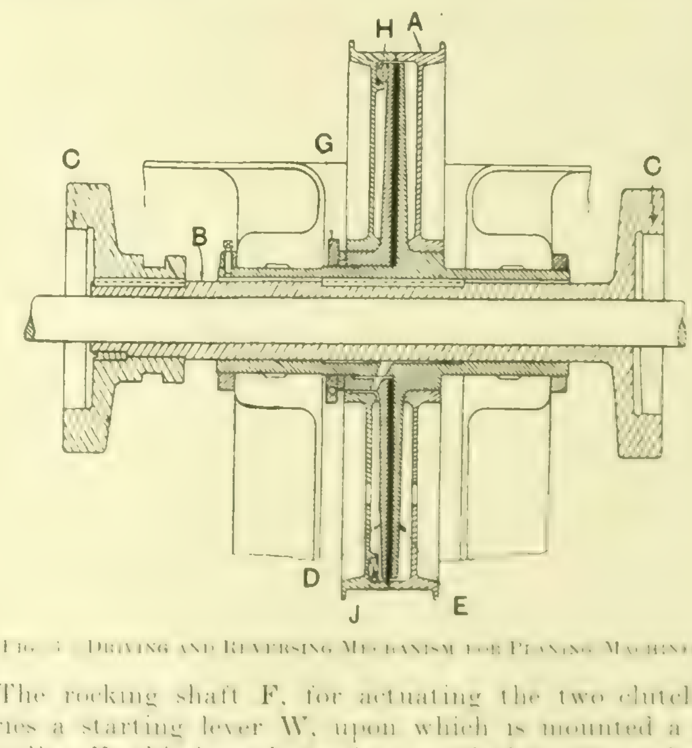


FIG. 3. DRIVING AND REVERSING MECHANISM FOR PLANING MACHINES.

The rocking shaft F, for actuating the two clutches C, carries a starting lever W, upon which is mounted a roller or pulley X, this lever being in a vertical position when the machine is at rest. A horizontal lever Y is located to rest upon the roller X, and a weight is suspended from the outer end of the lever Y so that when the tappets on the planing machine table move the usual tumbler lever out of the vertical the lever W and roller X will also move from the vertical position, whereupon the weighted lever Y will act upon the roller X and force the two sets of clutches C and K into engagement without the necessity for the tappets to do so. These clutches are comparatively large in diameter, and as the contact is metal to metal, they are arranged to run in oil.

A ROPE-DRIVEN COAL-CUTTER.[*]

BY WILFRID L. SPENCE.

To the electrician the idea of a wire-rope driven coal-cutter must at first seem to involve a retrograde step. But with changing conditions one is justified in reviewing past methods, in order to find out whether present methods are really incapable of improvement. It is not suggested that a wire-rope or any other kind of drive will work well in every case where there has been difficulty with electric coal-cutters; but it is submitted that the rope drive is generally more appropriate, and should work better under average conditions, both natural and artificial, than the electric system carried right up the

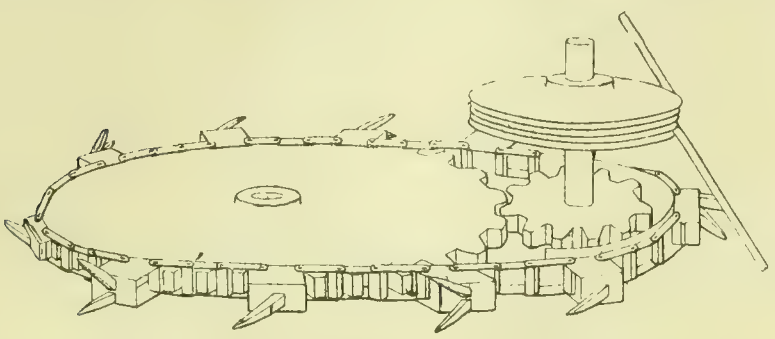


FIG. 1.—DISC-CHAIN MACHINE, AS ORIGINALLY DESIGNED.

working-faces. This point of view did not originate with the writer; it was forced on him gradually during a period of upwards of 12 months prior to February, 1911, by a local colliery manager in Lanarkshire who has been quite successful with electric coal-cutters and incidentally with conveyers. It did not take long to find out that, if the scheme were to be given a trial, it was necessary first to provide the machine; and, as none existed, the writer had perforce to design one. Preliminary sketches were therefore put in hand, when it was soon realised that very great simplification in the coal-cutter was possible, and that ample power could be applied to a very low and exceptionally narrow machine.

Disc-chain Machine. — The original design was for a combination disc-chain machine, as shown in Fig. 1. The cutters were fixed in toolboxes, forming links in a chain which was carried on and driven by a large wheel of the conventional disc type, but with spur teeth. This arrangement had the advantage that the drive to the cutters was not through or along the chain, but directly from the wheel into the toolboxes. The cutters might, therefore, be expected to stand more rigidly up to their work than if driven at the variable velocity of a chain passing over a pinion of comparatively few teeth, as is the case with all chain-driven machines. The haulage in this machine was by a rope drum at each end, both of which were worm-driven through a motor-car type of 4-speed gearbox, without ratchet, so as to be silent.

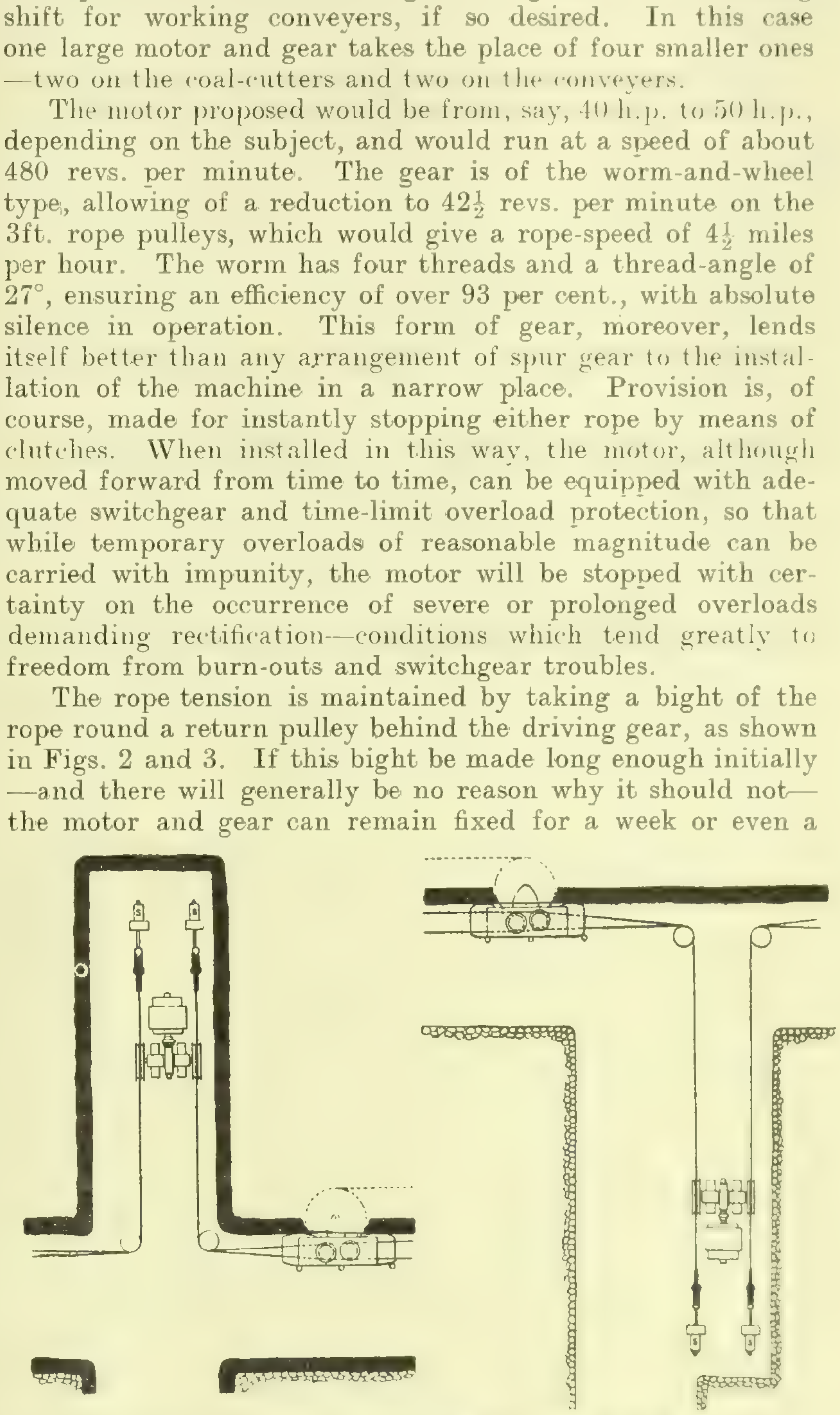
Disc Machine.—The general arrangement of the abovementioned machine appeared to be quite workable, but, for reasons which will be given later, a further careful consideration of the pick question led to its abandonment, and, through several stages, each tending to greater simplification, to the adoption of the machine illustrated in Figs. 2 to 8. This machine is of the disc type pure and simple. It has no independent feed-gear of any description, no ratchet, no drum, and no haulage rope, but it will feed forward into and back out from a holing at all speeds from zero up to 6ft. or more per minute. It has no running shafts, and no bearings as ordinarily understood. The picks require no forging—they are sharpened by grinding only. There is not a key or keyway in the machine, and no cast iron whatever has been used in the whole structure. The machine, however, is not self-contained; it requires an endless rope for the drive, and, having no independent haulage drum, it will not wind itself round a corner from a gate-road to the face. It is open to question whether this is much of a disadvantage, as the haulage rope is sadly abused on such occasions, and in any case a machine should be accompanied by prop drawers and screw jacks when being installed or taken out.

[*] Paper read before the Institution of Mining Engineers, June 6th, 1912.

Premising that the machine is driven by an endless rope, the proposed general arrangement is shown in Fig. 2 for a thick seam and in Fig. 3 for a thin seam. It will be noted that provision is suggested for working two machines from one rope-driving gear. Normally both machines will work in synchronism, that is, up on one shift and down on the next, for which purpose the reversal of the motor alone reverses the direction of the rope-travel in order to bring the machines back along the face. But if one machine be so delayed that a turn is lost, then it is only necessary to take off one rope from the driving gear and put it back the opposite way, so that the machines then work one up and the other down in the same shift. The driving gear is specially arranged with overhanging pulleys so as to expedite this reversal, and the same provision facilitates the gear being used in a following shift for working conveyers, if so desired. In this case one large motor and gear takes the place of four smaller ones —two on the coal-cutters and two on the conveyers.

The motor proposed would be from, say, 40 h.p. to 50 h.p., depending on the subject, and would run at a speed of about 480 revs. per minute. The gear is of the worm-and-wheel type, allowing of a reduction to $42\frac{1}{2}$ revs. per minute on the 3ft. rope pulleys, which would give a rope-speed of $4\frac{1}{2}$ miles per hour. The worm has four threads and a thread-angle of 27°, ensuring an efficiency of over 93 per cent., with absolute silence in operation. This form of gear, moreover, lends itself better than any arrangement of spur gear to the installation of the machine in a narrow place. Provision is, of course, made for instantly stopping either rope by means of clutches. When installed in this way, the motor, although moved forward from time to time, can be equipped with adequate switchgear and time-limit overload protection, so that while temporary overloads of reasonable magnitude can be carried with impunity, the motor will be stopped with certainty on the occurrence of severe or prolonged overloads demanding rectification—conditions which tend greatly to freedom from burn-outs and switchgear troubles.

The rope tension is maintained by taking a bight of the rope round a return pulley behind the driving gear, as shown in Figs. 2 and 3. If this bight be made long enough initially —and there will generally be no reason why it should not— the motor and gear can remain fixed for a week or even a



FIGS. 2 AND 3. GENERAL ARRANGEMENT OF MACHINE IN THICK AND THIN SEAMS.

fortnight on end, the tension sheave alone being advanced daily with the advance of the coal face. As balance weights will be impracticable, it is proposed to use the springs S shown in Figs. 2 and 3 at the tension sheave, and the compression of these springs—which varies with the tension on the rope— can be used as a means of operating overload circuit breakers or throttle valves, as the case may be, in order to prevent breakage of the ropes. Obviously, the rope-driving gear may be run by compressed air if desired.

With reference to the machine itself, the principle of the drive and the feed is shown in Figs. 4 and 5. There are two rope pulleys, A and B, sleeved on vertical fixed (non-rotating) spindles; each carries a 4in. pitch 13-tooth spur pinion, C, C', which meshes with the teeth of the cutter wheel D. The two

pulleys must, therefore, at all times run at equal speeds of revolution (number of turns per minute). The rope is endless, and all parts consequently run at the same linear speed. On the pulley A the coming rope is shown to be on a larger diameter than that occupied on the pulley B by the return rope. It is evident, therefore, that the pulley A is taking in more rope from the left than the pulley B is paying out to the left, and at the same time the pulley B is taking in from the right less rope than the pulley A is paying out to the right that is, the left-hand bight of rope is being shortened while the right-hand bight is being lengthened. But, as the rope-driving gear at one end and the return sheave at the other end of the face are fixed, it follows that the machine itself must travel from right to left, so as to compensate for this difference. That is the feed, and it is variable all the way from zero to 6ft. or more per minute by altering the relative positions of the two ropes on the two pulleys. By reversing the position of the ropes, that is, by having the large diameter on B and the small diameter on A, the feed can be reversed without reversing the direction of rotation of the cutter wheel. Actually the pulleys are double conical, so as to ensure that the rope, irrespective of the direction of travel, may always run on at a large diameter and off at a smaller one. Incidentally, the cutter wheel can always be run without any feed, but there can never be any feed unless the cutter wheel is running.

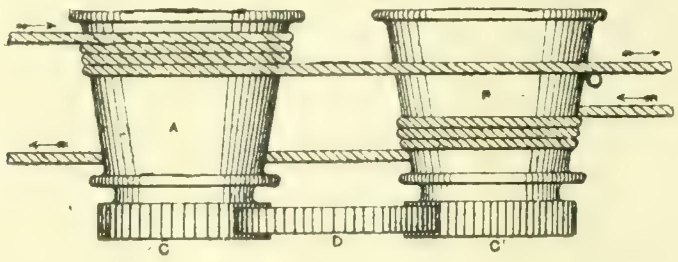


Fig. 4

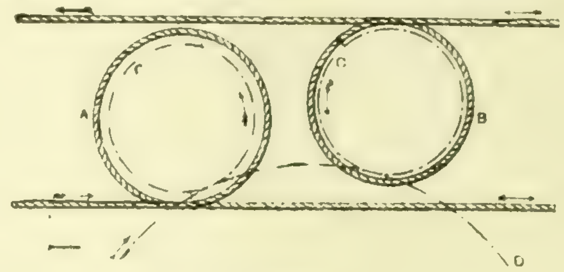


Fig. 5.

Diagrammatic Sketches, Showing the Principle of the Drive.

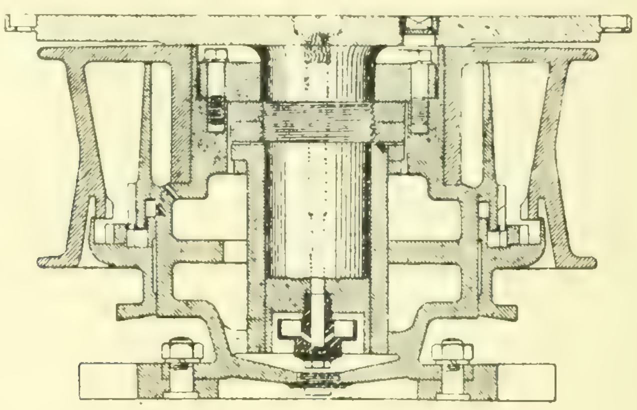


Fig. 6.—Section of Pulley.

Complete controlling gear is provided at both ends of the machine, first to throw the main clutches in and out, and secondly to regulate the feed by altering the relative positions of the ropes on the two pulleys; but the interlocking arrangements are such that, whether travelling to right or to left, the leading end alone, when so set, gives full control. While the machine, however, cannot then be started from the trailing end, and while the feed cannot be increased from the trailing end, it is always possible from that end to reduce the feed and to reverse it, in which case, of course, the trailing end then leads. If, however, on account of exceptional or temporary circumstances, full control be necessary at the trailing end, the locking device can be removed from the front end and used at the trailing end, in which case the front end loses full and retains only partial control. As the natural tendency of the rope will always be to slip down to the smaller diameters, it is guided on each pulley both at entering and at leaving.

The main drive need not be enlarged upon, as it is part of, and inseparable from, the feed system. Only one pulley at a time puts power into the machine; the other pulley, being driven by the machine, acts merely as a controller of the feed. While this is a differential gear system, it is not to be thought that it involves a waste of power. Loss only occurs in those differential or epicyclic systems which have a friction brake as an essential element in the variable speed control; and there is no friction device in the machine described.

The actual construction of the pulleys is shown in Fig. 6. The fixed spindle is cast with and suspended from the cover plate, so that the power-transmission mechanism, comprising the spindle, bearing bush, pinion and sleeve, oil bath, pulley, and clutch, is detachable as a single complete unit. The cast-steel spindle measures 4in. at its least diameter, and the other parts are in proportion. The pinion-sleeve forms an absolutely oil-tight bath, which holds more than $1\frac{1}{2}$ gallons of oil, so that it would need to be filled only once a week, and then only a few ounces at a time, not to make up loss but merely to remove a portion of the old lubricant. Both the pinion-sleeve and pulley-sleeve bearings run on a level pavement fully immersed in oil. The oil removed is not wasted; it is all caught, and serves to lubricate the dog clutch, from which the final overflow goes to lubricate the clutch sleeve. After that no effort is made to save the oil, which then flows away, and in doing so has to pass over the pinion teeth, so that these are not altogether devoid of lubricant.

The spindle is drilled right through, bored out to form a sump, and fitted with an upward-flow filter, so that coal dust and sand, or even carborundum mixed with oil, may be used quite successfully as the lubricant. The thrust bearing at the top of the pinion sleeve, on which the whole weight of the rotating parts is carried, is adjustable. All running surfaces of the pulley sleeve, pinion sleeve, and thrust bearings are lined or faced with white metal. The clutch is a 70-tooth wheel, every tooth of which engages as a dog, so that little time is occupied in putting it in; and as the engaging surfaces are more than generous, it should come out under a load almost as easily as it goes in. The sliding member, the internally and externally-toothed annulus, remains permanently in engagement with the pinion sleeve. The two clutches are operated together by an equalising lever, and the greater part of the dead weight of both is spring suspended, so as to reduce the wear on the collars and the effort in raising the sleeves.

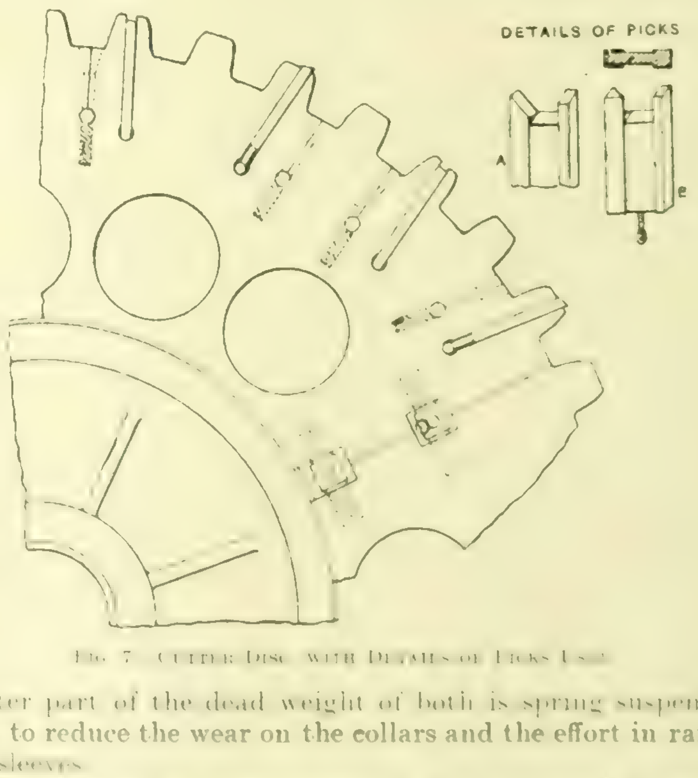


Fig. 7.—Cutter Disc with Details of Picks [illegible]

The cutter disc arrangement, with plain rolled section picks and taper-headed screws, is shown in Fig. 7. The wheel is machined all over, and split and bolted together with a tongued and grooved joint by right and left hand screws, as

shown. The slots for the picks are milled out and ended by drilled holes to exactly the same radial distance from the centre. One side of each pick slot is designed so as to be more or less flexible, while the other side is designed to furnish a solid unyielding abutment. Beyond the flexible side the tightening screw is placed in a radially-drilled hole, with the sides cut through to allow for expansion. On tightening up the screw, the taper head forces the flexible side hard up against the pick and that against the unyielding side, so that it is held securely by friction along its whole length. The inner end of each pick is drilled and tapped, and provided with a long set screw, so that, whether new or whether nearly

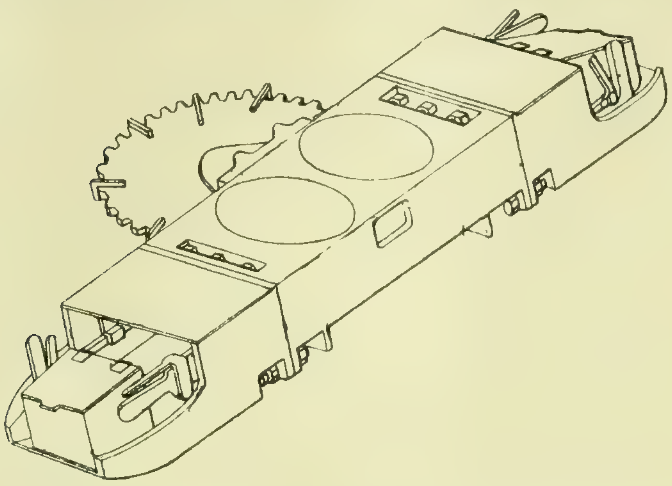


FIG. 8.—GENERAL ARRANGEMENT OF COAL CUTTER.

all ground away, the overall length of the pick and screw projection together is maintained at a constant value. This setting is not to be attempted underground, but should be done to a gauge at the surface, after grinding. Nothing, therefore, should be left to be done at the face in the way of adjustment; indeed, adjustment there must be regarded as interference, and prohibited. By this means it is only necessary to place the pick in the slot with the screw head resting on the bottom, in order to ensure that every pick projects equally, or as intended, and so takes its exact or predetermined share of the work of cutting. So treated, a set of picks should last much longer than when only one or two take the bulk of the work. The picks are sharpened by grinding only, and require no forging. In form they may be pick-pointed or chisel-edged, and right-hand, left-hand, or central in any combination; but while the central portion of the chisel-edge may not project more than $\frac{3}{8}$in. beyond the end of the tooth carrying it, the side portions, right or left, may project another inch.

For working in coal, it is considered that two patterns of picks only are necessary, and these are shown in Fig. 7. In explanation, it is to be noted that the picks project $\frac{7}{8}$in. over and only $\frac{1}{2}$in. under the body of the wheel in order to cut the clearance, and are alternately a pick point (really a chisel presented sideways) and a wedge over the wheel to break off the coal—about half of each—as shown at A and B. By this means it is hoped to bring out a fair proportion of large stuff. For fireclay all the cutters would probably be chisel-edged.

Two sets of slots are provided, one for each direction of cut, and each gives some little cutting angle to the picks. The idle slots are fitted with short dummy picks, so as to maintain solidity all round the wheel. All the picks, both working and dummy, are rolled with a very shallow channel down the front or back faces for location in the wheel slots. Attention is called to the fact that with these picks very little is left to chance; there is a chisel edge, pick point, or wedge surface to deal directly and systematically with every particle of stuff in the holing and to bring it out. The ordinary pick arrangement in sets of three (a single centre and two pairs narrow and wide) merely gouges out five thin grooves, leaving four ribs which are broken out more or less by accident, certainly not by edges specifically designed for that purpose. The jib does not differ materially from standard practice, except that two oil containers, each holding more than a pint of oil, form an integral part of the steel casting. One of these feeds the sweep and the other the centre, each through its own channel.

With regard to the reasons which led to this complete departure from recent practice in cutter-wheel construction, it has been the writer's lifelong experience—as doubtless of every other engineering machinist—that bad work and little work invariably accompany cutting tools loosely held; that good work requires a tool firmly held; and that for the best of work the tool must be rigidly held and heavily backed up close to the actual cutting edge. The loose or weak tool chatters and quickly loses its sharpness, whereas the rigid tool retains its edge until worn away in useful work. The heavy backing serves two purposes: First, to prevent vibration; and, secondly, just as important, to conduct away the heat generated in the act of cutting. If, then, the principles underlying this experience be applied to coal-cutters, it will be seen at once why the chain-driven machine can never compete, as it never has competed, with the disc machine for heavy work. In the one case the whole mass of the disc is behind the cutter to back it up; in the other, there is only the mass of one tool box—a single link in the chain—everything else being flexibly connected. But the argument goes still further; if full advantage is to be taken of the mass of the disc, the cutter itself must be so held as to form part and parcel of the same mass—that is to say, it must be so rigidly secured as to be absolutely free from the least trace of slackness or vibration. It is not sufficient, therefore, to drop the cutter shank into an easy hole and to secure it with a pin that fits only where it touches; nor is it sufficient to carry the cutter in a toolbox which itself is only loosely secured in the disc, because, apart altogether from vibration, the cutter shank is more or less insulated by layers of non-conducting material (coal dust or fireclay) which prevent the free transference of heat from the cutter to the toolbox and from the toolbox to the wheel. To avoid these weaknesses, the writer had adopted a device which provides the entire wheel as a backing and heat dissipator for every cutter.

On the general construction of this wheel, it may be said that it follows closely the lines of a milling machine head or cold saw developed by the writer and his staff some eight or nine years ago for cutting up mild-steel bars measuring from $2\frac{1}{2}$in. to 8in. diam., on which work it proved thoroughly successful and very economical.

The general appearance of the coal-cutter is shown in Fig. 8. Attention is particularly called to the absolutely clean level top and waste side, and to the free channel beneath for any dross carried through by the wheel. Notwithstanding

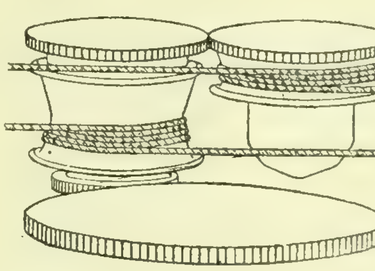


FIG. 9.—RE-ARRANGED DRIVE, TO ALLOW OF SETTING PROPS CLOSE TO COAL FACE.

this large opening, the skid surfaces are abnormally large, being over 5 sq. ft. at each end, which is equivalent to two continuous skids, each measuring $9\frac{1}{2}$ft. in length by $6\frac{1}{2}$in. in width. In addition to the pavement skids, the base of the machine is so planed as to form two shallow channels for skidding along the rails, so that it is not absolutely necessary to have a truck in order to convey the machine from the shaft bottom to the coal face; it can be hauled directly along the rails, and will keep on them without fear of derailment, although precautions will have to be taken at turnouts. The following are the leading particulars of the machine: Overall length, 9ft. 6in.; overall width (coal face to trees), 2ft. 9in.; overall height, 1ft. 3in.; diameter of wheel over cutters, 4ft. 10in. to 5ft.; holing, depth, 3ft. 9in. to 3ft. 10in.; holing, height, $2\frac{3}{4}$in.; rope diameter, $\frac{5}{8}$in., speed, $4\frac{1}{2}$ miles per hour; rope pulley speed, 85 revs. per minute; cutter wheel speed, 25 revs. per minute; total weight, 30 to 35 cwts.

ADVANTAGES OF ROPE-DRIVEN MACHINES.

It now remains to put in the claims, first, for the general scheme of driving coal-cutters with wire ropes, and, secondly,

for the specific advantages which it is hoped the design worked out in complete detail shows that rope-driven machines may possess.

Personal Safety.—While with efficient insulation and efficient earthing there should be no material danger from electrical coal-cutters, the fact remains that the greatest difficulty is still experienced in maintaining efficient insulation, and that the more perfect the earthing the greater is the danger from, say, an abraded trailing cable, cut or punctured so as to expose or give access to water to one of the live conductors. It does not need to be argued that it is safer to end off the electric circuits with the road end, because from that point the conditions immediately change very much for the worse electrically. While efficient maintenance is all but impossible under bad conditions at the face, it is comparatively easy of attainment at or near the road end, where room can be made for the electric equipment.

Safety of the Mine.—In a fiery mine the coal-cutter is liable to be surrounded at least temporarily with inflammable gas. When the cutter is operated electrically, the danger of explosion is only more or less remote; it can never be said to be entirely absent. With the electric driving gear at a road end, in intake air, the explosion risk is completely eliminated.

Appropriateness to Environment.—It is submitted that at the coal face any machinery should be elementary rather than elaborately "fool-proof." Electric coal-cutters may be "fool-proof" for a time when new; they can never be elementary, and as time goes on they are unquestionably becoming more rather than less elaborate. All coalminers are accustomed to wire-rope haulage, and it is believed that they will take more kindly—or, perhaps it would be better to say, less unkindly—to wire-rope transmission, which they do understand, than to electric transmission, which they will never understand. In the one case, the frequent trouble is burn-outs which can only be repaired with highly skilled labour, and usually after quite a prolonged stoppage; in the other, the biggest operation to face after, say, a bad fall of roof, would be the splicing of a ⅞in. rope, a feat probably within the capacity of half the men on the job inside an hour or so.

It is the writer's opinion that a rope-driven coal-cutter may attain almost ideal elementary proportions without either loss of capacity or of mechanical efficiency, and that such a machine will be appropriate to its environment in a way that no electrical machine ever can be for long. For the rope-driven machine it is claimed:—

(1) That it is simple. In addition to the cutting wheel, there are only two pinions, two rope pulleys, and two clutches as the essentials. There are no running shafts and no horizontal bearings; there are no keys or keyways, and there is no feed gear apart from the main drive.

(2) That it is very accessible. All the gearing subject to wear is removable in two single units, and any wear is made good by simply relining with white metal.

(3) That it is easily maintained. The picks are renewed by grinding only, without smith-work, and oiling once or twice a week should be adequate for the machine itself.

(4) That it is a particularly safe machine. The silent operation will tend greatly to the avoidance of dangerous falls. The running ropes are guarded, so that frayed wires in an old rope will not endanger the workers. The machine is completely controlled from the front end. The machine cannot run down on a steeply-inclined working. It is incapable of causing explosion or shock.

(5) That the dimensions (15in. in height by 2ft. 9in. in width) make it of almost universal application; it will go anywhere, and on account of the possibility of applying almost unlimited power, it should cut anything met with in a coal mine. The narrowness in a thick seam facilitates the hutches being run along the face, if desired, and in all cases it is of great advantage as regards roof maintenance and the operation of conveyers. The detachable ends and the special rail-skids facilitate transport and fitting along roadways.

(6) That it is economical. There are no supplies, no brushes, no slip rings, no switch contacts, no fuses, and no trailing cables to renew. But little oil is required, and the perfection of lubrication eliminates wear from the main transmission system.

Rearranged Drive to allow of the Setting of Props close to the Coal Face.

Since the foregoing matter was put into type, the design of the machine has been modified to meet the objection that the rope arrangement would interfere with the placing of props. Fig. 9 shows diagrammatically the rearranged drive as seen from the face side. One rope runs on a short pulley of fixed diameter, which is slightly greater than the least diameter of the other pulley and less than the greatest diameter of the same. The two pulleys are directly geared together, as indicated, and only the double conical one carries a pinion meshing with the cutter wheel. With this arrangement the forward feeds are as before, but a backing-out feed at a very slow rate only is obtainable. The gear is simplified in that there is only one clutch, and the outstanding advantage is that both ropes now run close up against the coal face, so that they interfere very little with operation, and not at all with the fixing of props close to the face. These props are not in the way of the ropes when the machine is moved forward for a fresh cut. When carrying out this alteration, it was found possible to reduce the height by ⅜in., making it 14⅝in., the other dimensions remaining unaltered.

ELECTRIC LIGHTING AND POWER DEVELOPMENT.*

BY GEORGE WILKINSON.

The last few years have seen a conspicuous change in the duties of the municipal electrical engineer. In the earlier years of the industry, his chief concern was to see that the capacity of his generating plant increased at approximately the same rate as the demand. Little, if any, effort was necessary to obtain consumers, and the field of operation was rendered attractive by the presence of considerable numbers of comparatively large consumers. At a later stage, the convenience and adaptability of the electric motor for industrial work were recognised, and, in due course, conversion of horse tramways into electric tramroads gave another impetus to the business. A few years ago, due to the introduction of the gas mantle, it looked as if the gas authorities would regain a part of the lighting business. The advent of the metal electric lamp has, however, effectively neutralised any tendency of this kind.

With regard to street lighting, in the main thoroughfares of our larger cities the old standard of lighting has become insufficient. In such thoroughfares improvements call for the introduction of high-pressure gas lighting or flame arc lamps. In cases where access can be had to the accounts, it is found that flame arc lighting compares favourably with pressure-gas lighting, both in capital cost and maintenance, while the lighting effect is emphatically in favour of the electric lamp.

For side-street lighting, where the local authority controls both the gas and electricity undertakings, the economy of changing from the old illuminant to the new, excepting in new streets, has, I think, yet to be demonstrated. Examples of such conversions from gas to electric lighting may be seen in many streets in Harrogate. Out of a total number of 2,300 ordinary posts in the side streets 650 have already been taken over and converted by the Electricity Department, at an average cost of 32s. per post, including all charges. The metal lamps are maintained by the lamp manufacturers at a fixed price per post per annum, and the cost of the lamp per annum, including lamp renewals, is the same as is paid for gas, excluding renewals.

Service Cables.—In the Board of Trade regulations the minimum size of service cable allowed is stated as the equivalent of seven No. 20 wires and at 1,000 amperes per square inch has a carrying capacity of 7 amperes. At 200 volts such a service cable is capable of carrying 1·4 kw. This regulation has for many years caused an extravagant waste of copper, and with metal filament lamps the case is much worse. One reason given for insisting on large service cable is the plea that conductors of smaller sectional area are mechanically weak. This is not so if such cables are made with the lead and return conductors arranged concentrically and enclosed in a lead tube. I have had experimental concentric lead-covered service cables in continuous use for nearly 15 years with

* Abstract of presidential address delivered at the seventeenth annual convention of the Incorporated Municipal Electrical Association.

uniform success, the inner conductor being made up of 7/22 copper and the outer being made up to the equivalent area by No. 28 S.W.G. copper strands.

For services to small properties, cottages and the like, the Harrogate Corporation have obtained the Board of Trade's permission to use concentric lead-covered cable consisting of 7/22 inner conductor, with an approximately equivalent section in the outer made up of 39/30 S.W.G. copper. For services to street lamps in side streets, permission is also granted to use a concentric lead-covered cable having a single No. 18 S.W.G. inner conductor with an equivalent aggregate section in the outer made up of No. 30 S.W.G. copper strands. The copper contained in these services is ample for all practical purposes. To prevent strain on them they are laid in wrought-iron tubing. One valuable feature of this street lamp cable is that in no case can it develop a short-circuit on the distribution mains. On short-circuiting the service cable the 1/18 inner conductor has, in every case, volatilised and disappeared, at once locating the fault. The early modification of the Government Regulation with regard to service cables is a task to which I think this association may with advantage address itself.

Pressure Regulation. — The Board of Trade regulations relating to permissible variation of pressure at consumers' terminals also call for attention on the part of this and kindred associations. With metal lamps, for the same variation in light as with carbon lamps, the permissible pressure variation (now 4 per cent.) might be increased approximately in the ratio of 4 to 6. Such modification would allow supply authorities to earn 50 per cent. more revenue without additional expenditure on low-pressure mains, provided the increased load is imposed with approximate uniformity.

Further Powers Bill.—It is difficult to see on what grounds Parliament can deny to certain municipal authorities what they have already granted to others. There is no doubt that when the Bill becomes an Act it will prove of substantial benefit to contractors as well as to the other interested parties. The forebodings as to unfair dealing, the starving out of local contractors, the establishment of rate-aided wiring departments, the selling of current-consuming devices and fittings at cost, or less than cost, price in order to increase the sale of current, and suggested abuses of a like nature should be dismissed from the minds of contractors. The money which is being hoarded up for use in contesting the Bill should be devoted to a more useful and beneficial purpose.

In many provincial centres where electricity supply has been established for, say, 15 years, nearly all the big work has been completed, and future developments are to be looked for amongst the smaller tenements of the town. The local contractors are now devoting their energies largely to obtaining and carrying out installations in country houses and institutions outside the lighting areas where they can, in addition to the ordinary installation work, sell complete generating sets at a good profit. They cannot afford to canvass and develop a business in fitting up small properties; but it would pay the supply authority to develop these large areas, and in turn the contractor would benefit by carrying out the work on fair terms under the control of the supply authority.

One of the present greatest evils is that any person or small firm is at liberty to start business as an electrical engineer and contractor. When the municipal authorities acquire the statutory rights foreshadowed by the Bill this iniquity can be effectively dealt with, and, in conjunction with the Contractors' Association, we shall be able to inaugurate a system of registration of certified electrical contractors.

Economies in the Generating Station.—There are few works where present-day knowledge is applied to every detail with a view to generation at the lowest possible cost. Some of the preventable losses are as follows:—

(*a*) It is standard practice in some of our largest works to pass the same amount of cooling water through the condensers irrespective of the load on the plant. The theoretical temperature corresponding to a vacuum of 28in. is 100° Fah. Condenser makers are able to guarantee an emission temperature within 5 per cent. of the theoretical at all loads. The temperature of the condensed steam on a 28in. vacuum ought not, therefore, to be below 95° Fah., and the amount of cooling water passed through the condenser should be regulated in accordance with the readings of a thermometer, so as to maintain the outlet temperature practically uniform under all variations of load. Taking the average of six well-known municipal works in the country, the temperature of emission is 79° Fah. at full load and 69° Fah. at half-load. These figures represent a coal loss of 1½ per cent. at full load and 2½ per cent. at half-load.

(*b*) Another loss easily avoidable is due to employing a hot well or feed tank of too large a capacity. In addition to the loss due to cooling, the pure water from the condensers is absorbing gases and impurities from the atmosphere, which eventually find their way into the boilers.

(*c*) It seems to be a cardinal point with many engineers that the temperature of the water in the hot well or feed tank should be at least 100° Fah., and to maintain its temperature they arrange steam traps to drain into it. Careful consideration will show that the feed water should be no hotter than the discharge temperature from the condensers, and in cases where there are no condensers the water in the feed tank should be cold. The cold water from the feed tank should not be passed through the exhaust steam heaters and then through the economisers in series, but it should be divided in proper proportion between the two routes. Only in this way can maximum efficiency be obtained from the economisers. The necessary minimum initial temperature of the feed water passed through the economisers can be obtained entirely at the expense of the waste furnace gases, by connecting a small pipe from the hot end of the economiser to the suction of the feed pump. Actual experiments have proved that by this re-arrangement the economiser efficiency can easily be raised 10 per cent., which means a saving of approximately 1 per cent. in fuel.

(*d*) It needs no argument to prove that steam traps are exceedingly wasteful. Reliable and simple apparatus is available for passing the whole of the water of condensation from the steam range back to the boilers direct at a temperature closely approximating to that of the steam itself. In this way steam traps, which are the most wasteful devices in a steam equipment, can be entirely dispensed with on the steam range.

(*e*) It is satisfactory to note that the production of boiler furnace draught by means of hot gases ascending tall chimneys is on the wane, and the much more economical fan draught is being substituted, whereby the heat losses from the spent gases may often be halved.

(*f*) Recent enquiries have revealed the astonishing amount of make-up feed water required in present-day power houses. This make-up feed often involves the provision of costly water-softening and purifying plant, and a continuous expenditure on chemicals. Much of the make-up feed is necessitated by blowing off the boilers. This latter is resorted to for two reasons: (1) To remove deposit—this it fails to do excepting over a very limited area; (2) to reduce the degree of concentration of some salts which are in solution in the water, or some mechanical impurities which are distributed uniformly in the water.

If the water put into the boilers were pure at the start, and if all steam were put back to the boilers immediately on condensation, there would be no waste of water, no accumulation of salts. Blowing off would then be unnecessary. Further, no water-softening or purifying plant would be required. This condition cannot be arrived at in practice, but it can be approximated to much more closely than at present. If all the water from the steam range and separaters is taken back to the boilers direct, and if the water from the air pumps of the surface condensers is taken through a closed pipe system direct into the boilers, extra feed water in very small quantity will be required to make up for the losses by leakage from the steam seals on the turbine shaft bearings, glands, and the like.

Such make-up feed could, with advantage and economy, be pumped into closed cylindrical tanks, and there raised to the full steam temperature before passing on to the boiler; in these tanks the suspended matter and scale-forming impurities would be deposited, and they could be readily cleaned out when required. The boilers could then be steamed for long periods with safety and efficiency, and blowing down, almost, if not entirely, eliminated. As to the gradual concentration of destructive salts or acids in the boilers, we should be able to rely upon the chemist to neutralise these in a more direct and economical way than by blowing to waste large quantities of high temperature water from the boilers.

Future Development.—A bulk supply at a price low enough to secure its exclusive use in all domestic and industrial opera-

tions will be possible only by erecting upon the coalfields of the country electric generating stations on a much bigger scale than anything yet attempted. A gigantic scheme of this character calls for the active co-operation of the Government with the existing supply authorities, and there are few home problems that can be more profitably dealt with by the Legislature, or that would confer greater benefits upon the nation. National power houses, built on the coalfields and on other sites to which coal would be cheaply transported by water, would supply the power for all extensions in existing areas, and would gradually assume the whole of the supply as the plants in local works became worn out or obsolete. They would also supply power for all industrial purposes and for locomotion, including the railways of the country. Thus the load and diversity factors would be high, with a corresponding beneficial effect in the reduction of costs.

Such power houses would be equipped with high-pressure steam turbo-generators of, say, 25,000 kw. and 50,000 kw. sizes. The power houses would be interconnected and distribution effected at, say, 100,000 volts to sub-stations, which in municipal areas would, in many cases, be located on the sites of the existing generating stations.

It is the generation of steam that calls for a radical change on present-day practice. We have too long been content to use boiler plant furnishing an average of from 2lbs. to 3lbs. of steam per hour per square foot of heating surface. Reference to the plans of modern works equipped with from 10,000 kw. to 20,000 kw. power units show a separate boiler house for each generating plant. These boiler houses are built end-on to the power house, and impose a heavy capital cost for boilers, buildings, flues and chimneys. They also involve heavy losses in boiler, steam pipe and flue radiation.

The solution of these difficulties appears to lie in the introduction of gas firing, by means of flameless surface combustion on the lines first discovered by Sir Humphry Davy and more recently developed and set out by Prof. Bone in his lectures before the Royal Institution of Great Britain in 1911. So far as investigations have gone at present it is shown that an evaporative duty from boilers exceeding 20lbs. of steam per square foot of heating surface can easily be obtained with a thermal efficiency corresponding to the transmission to the water in the boiler of nearly 95 per cent. of the energy represented by the net calorific value of the gas. At a slightly lower efficiency the evaporation may be increased from 20lbs. to 30lbs. of steam per square foot. On these high duties the internal boiler surfaces are stated to be self-cleaning, and the scale in thin flakes becomes detached and is deposited in the bottom of the boiler. The boiler installation would be comparatively small and the steam range short, as all the auxiliaries would be driven by internal-combustion engines. No objectionable chimneys will be required, as the necessary mixture of gas and air will be applied to the boilers under slight pressure, and the products of combustion issue to the atmosphere through small flues entirely free from smoke. The new boiler equipment will thus become compact, simple, and of great flexibility.

If in the future a gas turbine of larger power is developed, which proves more efficient than the steam turbine, it can be brought into use without waste of capital or extensive scrapping of plant. The manufacture of the gas will take place adjacent to the power house, and the by products will form a valuable asset against the cost of gas production. The coke will find a ready market, as will also the tar, benzol and sulphate of ammonia.

A national electric power supply on the lines indicated would greatly minimise the disastrous effect of a coal strike. Low grade fuel could also be profitably employed, which at present is dumped upon the pit banks as useless. The coal consumption of railways would be considerably reduced by electrification, and the railway companies would be saved the capital outlay involved in the provision of power plants.

Steam for such industries as the cotton, woollen, dyeing, chemical, distilling and brewing trades could be supplied from the national power houses at less cost than it can be produced by the manufacturers themselves; moreover, it would at once eliminate the enormous losses involved in condensers. Thus, just as the Niagara and other large hydro-electric schemes, by reason of cheap power, attract and promote industries in their immediate vicinity, so national electric power houses, able to supply vast quantities of low-pressure steam at cheap rates, would attract and promote in their immediate vicinity those industries wherein steam forms one of the chief items in the manufacturing process. It is remarkable that business in this direction has not already been developed by power stations operating in the textile districts; in many areas it would be much better business to invest capital in thus selling the condenser losses, than upon the erection of costly cooling towers and condensing plant. The two loads could be co-ordinated by the introduction of a reasonable amount of thermal storage in each building supplied with heat. There are many district steam-heating schemes already in operation in America, and in numbers of instances the revenue from the heat distribution is larger than that from the sale of electric power.

ELECTRICAL CONTROL OF A LARGE MINE HOIST.*

BY H. W. CHENEY.

THE most serious problem encountered in the application of an electric drive to large mine hoists is that of electrical control, and it is necessary to furnish a system which is absolutely reliable at all times. All parts of the apparatus must be designed to withstand severe and unreasonable service conditions without giving trouble and without requiring repeated attention and repairs, and it should also be impossible for the operator to damage the controller or any part of the machinery by a wrong movement of the operating handle. While this is true of electrical control in general, it applies with particular force to mine hoists, since they are generally located remote from supply centres and are operated by men who are as a general thing unfamiliar with electricity. In the electrical control of the large induction motor driven hoists conditions are unusually exacting.

The hoist described in this paper was installed at the No. 3 iron mine of the Woodward Iron Company, at Woodward, Ala. It is of the unbalanced type, and consists of a single drum 8ft. diam. and 40in. long, with a winding space for 2,500ft. of 1½in. wire rope. The drum has a band brake which is automatically applied by a weight and released by air pressure under the control of the operator. It is driven by a 500 h.p. 3-phase, 25-cycle, wound-rotor induction motor, operating at a speed of 375 revs. per minute through a flexible coupling and reduction gear and an air-operated friction clutch. The hoist is designed for a maximum rope speed of 750ft. per minute and a maximum pull of 25,000lbs. An important feature of the hoist consists of means for automatically applying the brake in case the supply of current to the hoist motor fails. This consists of an alternating-current solenoid energised from the supply circuit through a potential transformer, arranged so that when the solenoid circuit fails the core drops and actuates an air valve on the brake cylinder, thus allowing the brake to be set by gravity in the usual way.

The mine is approximately four miles from the power-house of the company, and electrical energy is transmitted at a voltage of 3,300 and a frequency of 25 cycles over a 3-phase system. The hoisting engine and the electrical control equipment are housed in a brick building which is located on the slope of the hill just above the mine entrance. The 3,300-volt lines are brought into the hoist-house and connected to high-tension bus-bars. Two switchboard panels are installed, consisting of the main motor panel, upon which are mounted an overload, no voltage release oil switch and an ammeter with a current transformer, and a line panel upon which a non-automatic oil switch and ammeter with a current transformer and three 3-pole, single-throw fused knife switches are mounted. Two transformers of 50 kw. capacity, having a ratio of 3,300 to 220 and 110 volts, are connected in delta to furnish energy for lighting, for running an electrically-driven air compressor used as an auxiliary and a circulating pump for the liquid rheostat. An electrolytic lightning arrester is also installed.

After the transformers have been excited by closing the non-automatic oil switch, the 3-pole, single-throw knife switches are closed, thus supplying alternating current at 220 volts to the motor of the water-circulating pump, to the air compressor motor through a pressure regulator switch, to the no-voltage coil of the main oil switch on the motor

* [illegible] read before the American Institute of Electrical Engineers, [illegible]

panel, and to the terminals of a switch connected to the brake solenoid. This latter switch is mechanically connected to the overload no-voltage release oil switch, so that both are opened and closed simultaneously. This switch is now closed and the hoist is ready for regular operation. A forward movement of the operator's control lever closes the primary switch and makes final connection to the primary winding of the induction motor for hoisting, while a reverse movement of the lever closes the primary oil switch, making reverse connections with this winding for lowering. This arrangement was necessary, since the slope of the mine near the engine was not sufficient for the empty cars to unwind the drum of the hoist by gravity.

The secondary windings of the motor are connected to the terminals of the liquid rheostat for varying the resistance of the secondary circuit and controlling the speed of the motor. The operation of this rheostat is controlled by the same lever that is used to open and close the primary switch. The limit switch is a special feature, and is placed on the tipple in such a position that if the cars over-run it will be mechanically opened by a track lever. The circuit of the no-voltage release coil of the main oil switch passes through this limit switch, and in case the car passes the limit of travel the oil switch and the solenoid switch are automatically opened. A push button which is normally open is provided on the motor panel for closing the circuit of the no-voltage release coil after the cars have over-run in order to back them into position again for regular operation. This arrangement was purposely made so that an extra man will have to be called upon to help. Another safety feature worthy of notice is the provision for the automatic opening of the overload no-voltage oil switch in case the non-automatic transformer switch is open, thus cutting off the supply current to the auxiliary apparatus and making it impossible to hold the overload switch closed.

The controller consists of a primary switch for opening, closing, and reversing the 3,300-volt primary connections to the motor and the resistance in the secondary circuit limits the line current for the required torque for starting and for speed regulation during regular operation. The primary switch is immersed in oil, and is so arranged that when turned in a clockwise direction, connections are made for forward rotation, while if turned in the opposite direction the motor is reversed. The liquid rheostat consists of a concrete tank in which stationary cast-iron plates are suspended as electrodes, the electrolyte being mechanically raised to vary the resistance. The electrodes, which are ribbed to give maximum contact area with a minimum amount of space, are made of a special form to give a smooth speed and accelerating curve, and are mounted on insulating supports set in a recess in the concrete tank near the top. Four electrodes are used for the 3-phase circuit, the two outer ones being connected together and to one phase. By proper spacing the correct amount of resistance in a balanced 3-phase star-connected resistance is obtained at all times. The electrolyte used consists of ordinary well water, which has a small quantity of salt dissolved in it, 9lbs. per 1,000 galls. giving the best results.

A cooling tank is located in the basement directly under the rheostat tank, and a centrifugal pump serves to pump the liquid from the cooling tank into the rheostat tank and to keep it in continuous circulation. This pump is driven by a 220-volt squirrel-cage induction motor and is run continuously. A gate valve is placed in the discharge pipe of the pump to regulate the rate of flow into the rheostat tank. The height of liquid, and consequently the amount of resistance in the secondary circuit of the motor, is regulated by means of two movable weirs in the form of pipes which are raised or lowered through an opening near the bottom of the tank. By the use of the pipe construction for the weirs, all friction, due to side pressure of the liquid, is eliminated. The arrangement is such that all the liquid cannot escape through the weirs when in their lowest position. The lower ends of the electrodes are thus always immersed and the secondary circuit is never opened. The areas of the opening through the weirs is approximately double that of the inflow pipe, and is sufficient to allow the maximum amount of liquid in the rheostat tank to escape into the cooling tank in 10 secs., including the continuous discharge from the pump. With the gate valve wide open and the weirs raised to the highest point, the rheostat tank will fill in approximately 20 secs. This time may be increased as much as desired by adjusting the opening of the gate valve.

Since compressed air is utilised for actuating the clutch and brake mechanism of the hoist, the control mechanism was designed for air operation throughout. A double-acting air engine is connected to the weirs through a rock shaft and levers and to the primary oil switch through a reversing clutch in such a manner that the first part of the upward piston stroke closes the oil switch, and a continuance of this movement raises the weir. This engine is provided with an adjustable oil cataract and a floating lever valve device, by means of which the air piston may be stopped and held at any point corresponding to the position of the operator's lever.

The operator's lever, which is located on the cage or platform of the hoist, rests at the central point of a notched sector when the controller is at "off" position. When the lever is moved away from the operator, the first movement sets the clutch on the primary oil switch for clockwise movement of the rotating member of the switch, and a further movement of the lever opens a valve and admits air to the air cylinder, which first closes the switch and then raises the weirs to any desired height. To stop the motor the lever is returned to the "off" position. A mechanical interlock is provided at this point to prevent the operator from throwing the lever to reverse position until the weirs reach the lowest point and the maximum secondary resistance is inserted. In case it is desired to run the hoist motor in a reverse direction, the operator's lever is moved towards the operator when the clutch on the primary switch is first set for counter-clockwise movement of the rotating member of the switch, and the balance of the operation is the same as before described, except that the motor runs in the reverse direction. The by-pass of the oil cataract on the air piston is adjusted for maximum allowable piston speed at which no jar or shock to the mechanism occurs when the operator's lever is thrown quickly from one extreme to the other. The gate valve is set for minimum time of acceleration for a given primary current with an average load of ore on the average grade. Semi-automatic acceleration is thus obtained; that is, if the operator throws his lever to the extreme position, the acceleration of the hoist is automatic, and will be accomplished in as quick a time as can be done without too heavy a draught of current from the line, while if it is desired to regulate the rate of acceleration the operator may allow the operating handle to remain at any intermediate point between the off and the full-speed position, which allows regulation anywhere inside of the limits for which the controller is set. During the tests which followed the installation of this controller every conceivable movement that could be given the operator's lever was tried, and it was found that no damage whatever could be done to any part of the outfit by improper manipulation of the control lever.

Owing to the lack of reliable data from the experience of others it was found necessary, before designing this controller, to make preliminary tests to determine the necessary data to be used. A large number of tests were made to determine the proper surface area of electrodes per ampere of current. It was found that with alternating current two amperes per square inch could be used as a fair average, and that the area could be varied between one ampere per square inch for continuous service and three amperes per square inch for intermittent service, without undue deterioration of electrodes or excessive generation of gases. Although other substances were tried, the conclusions reached were that good average results could be obtained by the use of common salt solution, and that its use would be preferable for a mine hoist controller, on account more particularly of the ease with which it can be obtained and on account of its mild action on the metal electrodes and piping.

Our Locomotive Exports.—Our locomotive exports during May show a decided tendency to decline. The value of the shipments in May was only £138,596, as compared with £221,328 in May, 1911, and £167,589 in May, 1910. Argentina was the largest importer, the engines forwarded to that quarter in May being valued at £37,382, as compared with £40,226 and £65,746. The aggregate value of the locomotives exported to May 31st this year was £851,752, as compared with £930,315 and £759,126 in the corresponding periods of 1911 and 1910 respectively.

CRABTREE'S GAUGE FOR GEAR WHEELS.

To determine the pitch and other data of spur, bevel, helical, or other gearing it is usual to take certain dimensions from the gear wheel with an ordinary rule, and by the aid of certain standard formulæ work out the calculations. With this method the measurements are not always obtained with sufficient accuracy. The accompanying illustrations show a scale or gauge, the invention of Mr. W. S. Crabtree, 11, Pearl

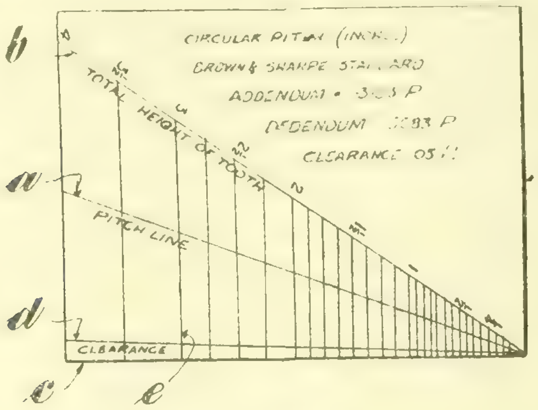


FIG. 1.

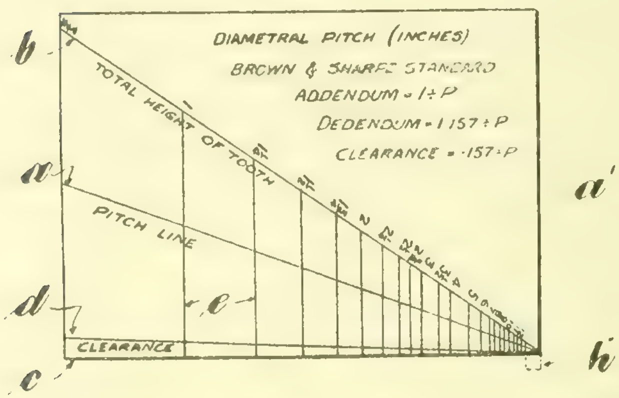


FIG. 2.
CRABTREE'S GAUGE FOR GEAR WHEELS.

Street, Saltburn, Yorkshire, which, on being applied directly to the gear gives at once the desired measurements, and also shows to which pitch the teeth are cut or made without necessitating the working out of any formula. Fig. 1 illustrates one side of the gauge marked according to what is known as the Brown & Sharpe "circular" pitch standard, *i.e.*, with the readings of teeth measurements cut on the basis of the 14½ angle of thrust. Fig. 2 illustrates the reverse side of the gauge marked according to what is known as the Brown and Sharpe "diametral" pitch standard.

Referring first to Fig. 1, *A* is the diagonal marking representing the pitch line of the teeth, *B* the diagonal marking representing the addendum of the teeth, *C* the edge representing the dedendum of the teeth, and *D* the diagonal marking representing the clearance of the teeth, all according to the Brown & Sharpe circular pitch standard with the angle of

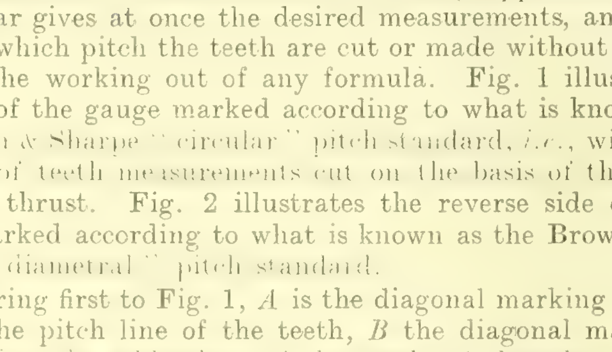


FIG. 3.—CRABTREE'S GAUGE FOR GEAR WHEELS.

obliquity 14½°. *E* are the vertical markings representing height above and below pitch line and clearances for various pitches. These dimensions are marked in inches or millimetres alongside, say, the dimensions of the diagonal marking *A* as shown. The plate is preferably of a size about 3in. by 4in. The line *E* is provided with figures referring to the pitch.

As shown in Fig. 3, the gauge, on being used to determine the data of the teeth of a given wheel, is caused to lie with its edge A^1 against, say, the face of one tooth of the wheel and with its edge *C* across the end of the next tooth upon the pitch circle. The user then reads off the data indicated by the vertical marking representing the distance between the two teeth which in the example given is 2in., which signifies that the teeth of the wheel are cut or made to 2in. circular pitch. The diagonal markings *A*, *B*, and *D* crossing the vertical 2in. marking represent the depth of the teeth above and below the pitch line respectively and the clearance. If desired, the diagonal markings *B* and *D* may also be marked in inches or millimetres.

Referring to Fig. 2, similar diagonal and vertical markings are used to those in Fig. 1, and the gauge is used in exactly the same manner for ascertaining the pitch and other data of the teeth of the wheel cut or made according to the Brown

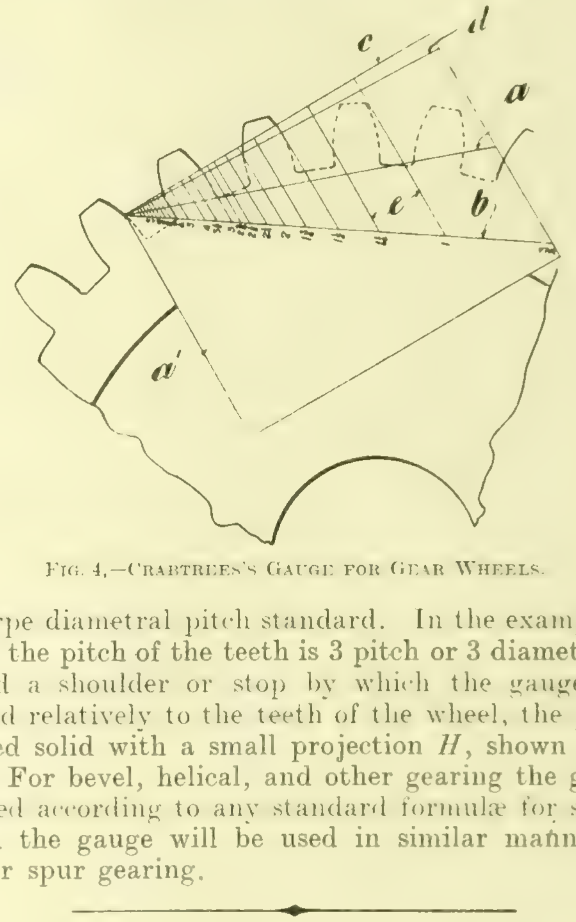


FIG. 4.—CRABTREE'S GAUGE FOR GEAR WHEELS.

and Sharpe diametral pitch standard. In the example shown in Fig. 4 the pitch of the teeth is 3 pitch or 3 diametral pitch. To afford a shoulder or stop by which the gauge may be positioned relatively to the teeth of the wheel, the plate may be formed solid with a small projection *H*, shown dotted in Fig. 2. For bevel, helical, and other gearing the gauge will be marked according to any standard formulæ for such gearing, and the gauge will be used in similar manner to the gauge for spur gearing.

CASTING PURE COPPER IN SAND MOULDS.

FROM the viewpoint of the electrical engineer, the application of boron marked a new era in the production of copper castings for electrical purposes, as by its use the standard of conductivity of cast copper has been raised to a point hitherto impossible to attain. The announcement of the discovery and its application excited widespread interest, as well as considerable scepticism among brass founders generally, but time has shown that the claims then made had a foundation of fact, and that practically pure copper castings have become a commercial possibility.

Pure, untreated copper cannot be cast in sand moulds without obtaining defective castings. It is absolutely necessary that it undergo some treatment to eliminate the gases absorbed during melting, otherwise the castings will be honeycombed; the metal is so wild, that after the moulds are poured it will flow back again out of the pouring heads, or the latter will swell and liquate to such an extent that they resemble cauliflowers. The porosity of the ensuing castings may vary in degree from minute pinholes to large holes, according to the amount of the impurities contained in the copper, and their influence thereon. This difficulty can only be overcome by adding to the copper some metal or element that will combine with the oxygen and remove it as a slag or oxide, and with the exception of boron, nothing has been discovered that will do this and will not at the same time alloy with the copper if added in excess of what is required to remove the oxygen. In all cases the alloy so formed will be lower in electrical conductivity than the original copper.

This lowering of conductivity necessitates an increase in

the cross-sectional area of the casting, to carry the same current, over that required in the case of pure copper, and this increase in the size of the casting increases its cost in proportion to the added weight. Therefore, if the conductivity of the cast copper is only 50 per cent. of the theoretical efficiency of pure copper, this means a casting twice as large, and hence twice as costly, as would have been required in the case of copper of the highest electrical efficiency. The consumption of copper castings for electrical purposes is large and is continually increasing, several hundred pounds being frequently used for one switchboard in the shape of bus-bars, studs, and other castings. Consequently, any improvement in the electrical conductivity of the castings is greatly to be desired, as it would be followed by great economies due to the reduction in the consumption of copper, and many advantages from the reduction in weight.

Many patents have been granted for making solid copper castings, and many curious methods have been proposed, but the old and reliable method is the use of zinc, in quantity dependent on the skill with which the copper is melted. The result is an alloy of low conductivity, but easy to cast and useful for many purposes where conductivity is of no importance. Phosphorus is also used for the same purposes as zinc, but with no better results as far as conductivity is concerned. The first real step forward came with the advent of silicon-copper about twenty years ago. This alloy is a product of the electric furnace, but its introduction was a slow process, and it is only within the last few years that it has come into general use. Silicon-copper, however, left something to be desired from the viewpoint of electrical conductivity. With skilful manipulation high conductivities are stated to have been obtained, but generally speaking, this property ranges only from 50 to 60 per cent. of that of pure copper, and is sometimes less when a large quantity of the deoxidiser is used.

For a time magnesium seemed to offer great possibilities in the way of obtaining copper castings of high conductivity. Unfortunately, however, its use requires such skilful manipulation, that the average founder experiences so much trouble from unsound castings, that in spite of the excellent conductivity of such of the castings as are sound, this deoxidiser has failed to supplant silicon-copper to any large extent.

Boron is added to molten copper in the form of a powder consisting of boron, boric anhydride and magnesium. Boron is allied to carbon, and occurs in the same modifications, namely the crystalline, graphitic, and charcoal forms. It is in the latter condition that it exists in the powder used for deoxidising copper, and which is known as boron suboxide. The magnesium is originally used to reduce the boron from the boric anhydride, and a certain proportion of both these substances remain as a residue, and apparently exercise no harmful influence, as by the use of this material as a deoxidiser, sound and perfect castings are obtained by ordinary methods of moulding. The chief drawback to the use of boron suboxide at present is its cost, which make it almost prohibitory and may so restrict its use that boron will be forgotten and the place it might occupy will be taken by some other element capable of producing closely similar results at a reasonable cost. There may be numerous elements that will produce copper castings, sound and of high conductivity, as there are many primary substances to be investigated, but as far as present developments have gone the most promising is titanium. This element is better known to steel and iron foundries than to brass foundrymen, but it is now being introduced as titanium-copper, one-fourth of 1 per cent. of which will produce solid copper castings, possessing conductivities ranging from 90 to 96 per cent. This is considerably higher than is usually obtained by the use of magnesium.—"The Foundry."

The Institution of Municipal Engineers.—A joint meeting of the North-eastern and Eastern Districts of the Institution of Municipal Engineers will be held at Peterborough on July 3rd. After arrival at Peterborough the members will proceed by train to Yaxley, where a visit will be paid to the Fletton Brick Works of Messrs. Eastwood & Co., Ltd. After this visit a short business meeting will be held, at which the officers for the year 1912-13 will be elected. A return will then be made to Peterborough, in which town visits will be made to various places of interest.

MEANS FOR SECURING RELIABILITY AND MAINTAINING CONTINUITY OF ELECTRICITY SUPPLY.

At the recent annual convention of the Incorporated Municipal Electrical Association a paper on the above subject was read by Mr. Frank Ayton. In most stations, he said, it was necessary to keep one or more boilers banked during a considerable portion of each 24 hours, simply for use on the "peak," or in case an unexpected period of gloom should descend. It was often necessary that these boilers should be very quickly fired up; the drop in pressure whilst the boiler was standing was therefore important. At Ipswich, large marine boilers of the dry-back type were installed. It was found that a boiler taken off the range, and fires banked at 9 p.m. or 10 p.m., showed only about 80lbs. pressure on the gauge early next afternoon, and it was necessary to allow at least two hours before the pressure was again up to that of the range. On the suggestion of Mr. W. H. Fairhead, the station superintendent, experiments were commenced to ascertain whether it would not be possible to reduce the drop in pressure during the banking hours. It was found that by making the damper such a fit in its frame as to be practically air-tight—a feature which many ordinary dampers did not possess—and taking great care to keep the brick settings also air-tight, the drop in pressure was reduced to a matter of, at the most, only 10lbs. Under these conditions the mere opening of the damper and the turning over of the fires sufficed, in about 20 minutes, to bring the boiler up to pressure, with an appreciable saving of fuel and a valuable saving of time in emergency.

With the introduction of turbine-driven generating plant into a station, the need at once became apparent for some method of conveying instructions from the switchboard to the drivers. The principle of the illuminated sign had been employed for this purpose, and it was possibly the cheapest arrangement, although, as a matter of safety, it seemed desirable to have duplicate lamps and to supply the current for lighting them direct from the battery, if there was one. This system cost from £60 to £100 to instal for a station containing from 6 to 10 generating units. It was also worth considering whether proper signalling arrangements should not be provided between the engine room and the boiler house.

The author next referred to a breakdown due to gritty dust in an oil cup. He had now had the plugs of all flushing cups and sight-feed lubricators fitted with brass petticoats arranged, when the plug was screwed home, entirely to cover the cup or funnel. It would be a good thing if the makers would fit these petticoats in the first instance. One could not be too careful to see that all utensils which contained or would contain, oil, were provided with dust-protecting covers.

The author had known cases where a big "short" on the mains had resulted in reversing the polarity of the direct-current generators connected to the bus-bars, and where a considerable period elapsed before the machines could be demagnetised in the right direction. On the switchboard at Ipswich a set of battery excitation bus-bars ran the length of the generator panels. On each of the latter a pair of links was provided in the shunt field circuits, by means of which the latter could be separately excited, if desired, by the mere throwing over of the links on to the battery terminal studs. On more than one occasion this arrangement had demonstrated its great utility. A red board, with the words "Not excited" written thereon, was at Ipswich always suspended across the circuit breakers of dead machines to prevent the latter being inadvertently switched in. It would, perhaps, be a useful precaution to paint the apparatus on adjacent panels different colours, alternating, say, red and black, so as clearly to distinguish them.

It was, he observed, a good plan to have every part of the plant thoroughly inspected frequently and periodically; the author found that the most satisfactory arrangement was to divide up the plant between the charge engineers and the switchboard attendants, making each responsible for inspecting, maintaining, and reporting the condition of a definite portion of it. None of the inspections were made less frequently than weekly, and printed forms were provided.

The usual method of earthing the middle wire by a maximum current circuit breaker, shunted by a resistance, resulted in a momentary dead "short" before the breaker opened, in

the case of a fault on the outer of sufficient magnitude. The momentary rise of pressure on the other side was a danger and was liable to damage lamps, &c. The author discarded this arrangement nearly nine years ago, and had since employed only a large resistance, carrying 50 amperes with 230 volts across it, as the earth connection—and no circuit breaker or switch. It had proved a perfectly satisfactory arrangement since, when the outers were clear of faults, there was no current through the resistance, and the middle wire stood at earth potential.

In the case of 3-phase alternating-current systems the advantages and disadvantages of earthing the centre point of star-connected generators was discussed. The author had come to the conclusion that greater reliability was ensured by not earthing the centre point when working with pressures up to 6,600 volts. Above that pressure, the cost of insulating the cables to stand the full-line pressure (*i.e.*, the pressure between phases) between any conductor and earth became a serious item; so that for the higher pressures it was a question as to how far, on commercial grounds alone, it was desirable to dispense with earthing the centre point. There were several systems at 6,000 volts working now without the earthed centre point and, as far as the author could learn, the omission had been entirely advantageous.

The majority of interruptions to supply were, he said, connected with the distribution system. On direct-current systems some engineers preferred to connect up solid, without either automatic circuit breakers or fuses, from the bus-bars to the consumers' cut-outs. On the other hand, some engineers preferred to protect each feeder at the switchboard by either a fuse or an automatic circuit breaker. Others went further and inserted fuses in the connections to the distributors themselves, whilst some went even further and fused each individual distributor at every point where it was connected to adjacent distributors. In his own undertaking there were no protective devices, but his experience led him to think that such an arrangement, from the point of view of maintaining continuity of supply, was not altogether desirable, especially in connection with a 3-wire system. In his opinion, feeders should be arranged, by means of time limit maximum circuit breakers or fuses, to free themselves from the bus-bars in case of any serious fault.

There was, he considered, much diversity of opinion as to whether pillars or underground disconnecting boxes were the best. Fuses for dividing the mains into feeder districts should, he thought, be placed in pillars. In connection with the ventilation of pillars, it was important to see that it was not possible for the mischievously disposed urchin to thread a piece of wire through the ventilation holes, or even the lock key hole, and touch a live part. He had a pillar delivered recently by a well-known firm where this danger had been entirely overlooked.

The small services to street lamps were generally taken direct to the fuses in the lamp switch, and in case anything happened to the latter, necessitating its removal for repair or replacement, there was considerable risk of the service conductors being "shorted," or one of them earthed, unless the main to which they were connected was made dead for the operation. It seemed absurd to have to make a main dead every time one wanted to tinker with the switch of a street lamp. Therefore, the practice of fixing a pair of high-rated fuses inside the service box was a good one. The author had employed this method of connecting street lamp services in Ipswich for nearly three years. Fuses were also provided in the lamp fitting on the post. On only 3 occasions had the 25-ampere fuses in the service boxes blown.

The systematic and periodical testing of the mains and feeders for insulation resistance was most important if efficient service was to be maintained. The system which the author had practised in Ipswich during the past 8 years consisted in disconnecting and testing each feeder once a month, while every main was disconnected and tested once a year, this latter work being carried out during the summer months. He agreed that it would be more desirable to possess means by which the fault resistance of the mains could be ascertained continuously and without interrupting the supply. Apparatus was obtainable which was said to meet such requirements, and it would be interesting to hear from those engineers who had employed it the results attending its use.

ELECTRIC COAL-CUTTER FATALITY.

THE inquest was concluded at Hoyland Common on the 20th inst. on a youth, who met with his death at the Wharncliffe Silkstone Colliery as the result of an electric shock whilst working an electric coal-cutting machine. The foreman machineman of the colliery said he was in charge of the machine which the deceased was working. He felt a shock to his toes, and saw the plug which forms the connection between the machine and the electric current begin to burn. As soon as he could he went to the switches, some 24 yards away, to cut off the current. As he went he fell over the body of the deceased, which he found across the steel haulage ropes to which the coal-cutting machine was attached. Replying to the Coroner, witness said the work was dangerous, and they were liable to receive shocks. It was more dangerous in wet places, and they were working in a wet place at the time. He thought the wet was responsible for the plug burning. The foreman electrician at the colliery, in answer to the Inspector of Mines, declared he was aware of the new rules which had come into force in March. These required that an earth wire connected with an earthing system on the surface should be fixed to the framework of electrically-driven machines. Although the steps for complying with this new rule had been taken before the accident they had not got the earth wires fixed to the machines at the time. The Inspector, at the request of the Coroner, outlined the new regulations, which provided for the provision of an earth wire to be attached to the machines in order to secure the safety of those who worked the machines. He said he was of the opinion that to have carried out all the work, if the materials had been ready, and to have fixed the wires to the machines in this part of the workings would have required only about two days, and had that been done the accident would not have happened. The manager of the colliery said that immediately the rules were out his company had taken steps to put them into effect. They had secured the services of a consulting electrical engineer from London. Their system of switches was rather obsolete, and they had been working hard to carry out the Home Office requirements in this respect. The Inspector pointed out that the time allowed to put into effect the requirements respecting the switches referred to was up to January 1st, 1920, but the earth wire should have been fixed at once, as it was the most important. The Coroner said the matter was a serious one. He was quite sure that the Wharncliffe Colliery Company had not been criminally neglectful, as everybody appreciated those collieries were intelligently and carefully governed; but whether they were guilty of indifference was another thing. The jury returned a verdict of "Accidental death," but added that the colliery company should have taken steps to have earlier complied with the new regulations.

Proposed Engineers' Club for Manchester.—It is proposed to form a club in Manchester for engineers and others who are intimately connected with engineering. A committee, composed of members of the councils of local technical societies, have agreed that such a club is desirable, and it is considered that a membership of 500 persons would justify its formation. The objects of the club are: (1) To provide a means of social intercourse and the usual club facilities for those who are concerned with engineering; (2) to meet the convenience of members whose business causes them to visit Manchester; (3) to provide a hall for technical and social meetings; and (4) to establish a home for a technical library. It is proposed that the entrance fee shall be £3. 3s., and the subscription £3. 3s. per annum. Those who signify their intention of becoming members before July 1st, 1912, and are duly elected and pay their subscriptions within one month of their election, shall be deemed original members, and admitted without entrance fee. A meeting will be called at an early date of all those who may have intimated their desire to join, and a committee will then be appointed to draw up a constitution and undertake the initiation and management of the club. The secretary (pro tem.) is Mr. A. L. Green, of 8, Westminster Avenue, Manley Park, Manchester.

MODERN WELDING PROCESSES.*

With Special Reference to Flame Welding.

BY H. R. COBLEIGH.

Welding may be divided into two general classes, pressure welding and casting. The oldest and commonest process, where the forge is used for heating and the uniting of the metals effected by hammering, belongs to the first class, and only one of the newer processes, electric resistance welding, comes within the same classification. The pioneer in the second class was "burning on," a process of local casting where the parts to be united were first preheated to a state to amalgamate with molten metal poured in to complete the joint. Another electric process, arc welding, and all of the gas or flame-welding processes, belong also to this second class.

A distinction in procedure differentiating the older from the newer processes is, in a measure, the greater portability of the latter; more exactly, in the older processes the work is brought to the heat, or the source of the heat is apart from the immediate vicinity of the place where the welding is done, while in the newer processes the reverse is true.

Autogenous welding has become the accepted name for arc, flame, and sometimes thermit welding, but it is a misnomer. Strictly speaking the term means either self-welding, which is ridiculous, or welding with the same metal, whereas two different metals are often united, sometimes with a third metal, and the result is not comparable with brazing or soldering, as there is a more intimate molecular union. In the real sense of the word it is not welding, for there is no compression or hammering, except incidentally as practised by some in the belief that it improves the structure of the added metal. It is more analogous to casting, since the union is made by the flowing together of the metals, but that word alone is even more ambiguous. Fusion welding would be a good term, but it has been appropriated by another new process abroad which is more akin to brazing. However, as that process does not appear to have taken any important place in the arts, there is probably no reason why it should not be applied to what is now called autogenous welding, or auto-welding for short. One of the simplest definitions of autogenous welding is the uniting of metals by heat alone.

Thermit Welding.—Thermit welding is the outcome of the discovery in Germany about the beginning of this century that a mixture of finely divided metallic oxides and aluminium, when ignited at one spot, react to form a new combination of aluminium oxide and free metal, formerly in the oxide form, due to the greater affinity of the aluminium for oxygen. This reaction is accompanied with an evolution of heat in which a temperature of 5,400° Fah. is obtained. In the resulting molten mass the lighter aluminium oxide rises to the top, where it can be skimmed off as slag, leaving the other metal in a superheated state, which, when poured into a mould surrounding the parts to be joined, contains sufficient excess heat to bring those parts to the point where they will amalgamate with the added metal, so that the whole solidifies as a homogeneous mass. Usually, however, it is advisable to preheat with a gasolene torch the parts to be joined, and thus by eliminating the gases produce a better casting. The commoner form of thermit contains iron oxide and aluminium, and the reaction follows the formula $Fe_2O_3 + 2Al = 2Fe + Al_2O_3$.

Electric Welding.—Beyond the fact that electric current is used for obtaining the welding temperature, the two kinds of electric welding, arc and resistance, have no similarity. Comment on the electric processes will be limited in this paper to the electric resistance welding. The principle discovered by Elihu Thomson involves the passage of electric current through the abutting ends of the pieces of metal to be welded, thereby generating heat at the point of contact, which also becomes the point of greatest resistance, while at the same time applying pressure to force the parts together. As the current heats the metal to the welding temperature at the junction the pressure follows up the softening surface until a complete union or weld is effected. It is claimed that in all other processes, the heat, not being generated in the metal or in the joint to be welded, is largely dissipated and wasted. In the Thomson process the heat is generated in the metal itself at the joint, and practically confined there; the energy is therefore economically employed. When the weld is made, the structure of the metal at the joint is the same as elsewhere. The metal can be held at any temperature desired for any length of time and the heat increased or decreased at will. The metal while heating is visible in the open air. Being unattended with smoke, heat or dirt, the apparatus employed can be located wherever convenient or desirable.

Various forms of machines are built, but the main essentials in all of them are a transformer provided with a pair of clamps aligned with and insulated from one another to hold the pieces to be welded, and mechanical, hydraulic, or other means to force the abutting ends of these pieces together. In some forms there are additional mechanical features for shaping the weld after it is completed to remove the fin, as by striking between two dies. Contrary to ordinary welding, the heat begins at the interior and travels to the exterior, impurities thus being expelled. There is no current expense except when heating, little to wear or occasion repairs, and unskilled labour can operate the machines. A reactive coil is used for controlling the current in the welder for varying sections of stock to be welded. In the smaller types the pressure is applied and the current shut off automatically. In all but the smaller types provision is made to maintain a circulation of water in the secondary circuit for cooling purposes. By means of a break-switch the circuit is opened and closed in the primary of the welder; in some types automatically.

The apparatus is built in sizes and types suited to the kind and section of the metal to be welded, these usually ranging from small wire to sections of 3 sq. in. Only alternating current is used, taken from a single phase of any constant potential, 40 to 60 cycle, between 100 and 500 volts. In general the process is particularly applicable to the butt welding of relatively small and similar sections, *i.e.*, the parts to be joined should be of approximately equal cross-section. Among the most common in the very wide range of applications of this process are the welding of metal tyres of all kinds and other parts in the running gear of wagons and carriages, bicycle parts of all kinds, parts of tools, wire of all kinds for such purposes as hoops, fencing, &c., pipe chain, parts used in street railway construction, miscellaneous automobile parts, and the like.

Table I.

Approximate Normal Power and Time for Various Sections.

Iron-steel Round Rod	Area.	Horse-power.	Kilowatt.	Seconds.	Approximate Kw.-hour 1,000 Welds.
$\frac{1}{4}$	0·05	5	4	2	2
$\frac{3}{8}$	0·11	8	6	3	5
$\frac{1}{2}$	0·20	12	9	6	15
$\frac{5}{8}$	0·31	16	12	10	30
$\frac{3}{4}$	0·44	20	15	15	65
$\frac{7}{8}$	0·60	24	18	18	90
1	0·79	26	20	20	113
$1\frac{1}{8}$	0·99	33	25	24	167
$1\frac{1}{4}$	1·23	40	30	33	275
$1\frac{1}{2}$	1·77	50	38	40	422
$1\frac{3}{4}$	2·41	64	48	48	640
2	3·14	80	60	60	1,000

The output of a single machine varies according to the size of the weld and the shape of the pieces to be welded, and depends in a great measure upon the operator. If the work is light and takes little time to adjust in the machine, very large outputs are possible. The horse-power and time required to make a given weld vary nearly as the cross-sectional area. Within certain limits the greater the power the less the time, and vice versâ. With 15 kw. a $\frac{3}{4}$in. round can be welded in 15 secs., and with 23 kw. in 6 secs. Endless pieces like rings take more power as the diameter decreases; copper more power and less time than steel or iron. Table I. gives the approximate normal power and the time (for the application of the current only) for various sections. Multi-

* Abstract of paper read before the American Society of Mechanical Engineers.

plying the kilowatt-hours by the cost of the current per kilowatt-hour will give the current cost for 1,000 welds.

One of the latest applications of the process is the welding of platinum points on steel and brass pins. The manufacturers' principal line of endeavour now is to increase the rapidity of working and reduce the cost of operation. At present butt machines are operating at a rate of 20 welds a minute, and point welders making five to ten welds at a time and working automatically. Spot, point, ridge, and jump welding are inventions of the Thomson Company, which is now building machines for this work. A rather new commercial development in electric welding is that of welding halves of casters, handles, &c., in semi-automatic machines to make the whole article. The smallest Thomson machines weld No. 23 wire and the largest sections of 3 sq. in.

Flame Welding.—Of the different kinds of torch or blowpipe welding, the two of the greatest present commercial importance are oxy-hydrogen and oxy-acetylene. Air-gas and oxy-gas (coal gas) torches are also used, but they do not give as high temperatures as either the oxy-hydrogen or oxy-acetylene torches, and are generally considered not well adapted either to welding or cutting, but useful mainly for soldering and brazing. Another flame process uses "liquid gas," discovered by M. M. Wolf, of Basseldorf, Switzerland. The oxy-liquid gas flame is claimed to give a temperature of 7,000° Fah., which is even higher than oxy-acetylene (6,300° Fah.). It is declared to contain 2,500 more thermal units per cubic metre than acetylene. The flame of the oxy-liquid gas torch has much the same appearance as the oxy-acetylene flame. Blau gas seems to be closely analogous to liquid gas and gives the same temperature. Its possibilities for welding and cutting give great promise.

Liquid gas is obtained by distilling heavy oils such as paraffin oils, crude petroleum, and the like. The distilling and cleaning processes are the same as in the manufacture of any oil gases. Wolf's special process involves the abstraction of heat and the employment of pressure to separate the gases that are the hardest to liquefy, as hydrogen, methane, &c., from those liquefied more easily, such as ethane, propane, pentane, &c. It is charged into steel bottles at 1,200lbs. to 1,500lbs. pressure, making it again liquid, from which state it gasifies readily at atmospheric conditions into dry inflammable gas, containing none of the poisonous hydrocarbons. It consists principally of ethylene and ethane, with small quantities of methane, benzol, air, and carbon dioxide. It is explosive only in mixtures containing 4 to 9 per cent. of gas, hence is much less likely to explode than city gas or acetylene. Being 1·027 times heavier than air it does not easily mix with air, which still further reduces danger of explosion.

The torch with which this gas is used does not require as great provision against back-firing as the oxy-acetylene torch. An air chamber keeps the handle cool, through which the gas and oxygen are passed to a mixing chamber in the front half of the body of the torch. At the rear of this chamber the gas is carried through a pipe coiled around the stem of the torch, and in this way is preheated. Oxygen passes out the forward end of this chamber through another pipe which meets the gas pipe at the nozzle of the torch. Through the central stem is carried the mixed gas, and the three are combined at the nozzle into a good mixture for combustion. Only three tips are needed for welding or cutting any thickness. The cutting torch has the usual high-pressure oxygen supply, and does not require the preheating coil for the gas. Neither the gas nor the products of combustion attack metal, hence the burners, torches, and fittings last a long time, and the gas does not injure the metal in the joint, so that strong welds result.

The Oxy-hydrogen Process. The oxy-hydrogen process, although older than the oxy-acetylene process, has not been developed quite as rapidly, although for certain applications it has the advantage of its competitor. The torch is simpler because flame propagation in hydrogen is not as rapid as in acetylene, and less precaution is necessary to prevent flash back. In fact, all that is necessary in such a torch are two conduits for the gases with a common nozzle from which they are discharged mixed. In its simplest form we are all familiar with the oxy-hydrogen blowpipe. Any refinements that have been introduced since the industrial application of the torch has been appreciated have had for their object greater convenience in handling, directing, or controlling the flame, according to the work to be done. For all purposes where the greater heat intensity of the oxy-acetylene torch is of no advantage, the oxy-hydrogen torch with its temperature of about 4,000° Fah. is as good, or even better. For example, it is capable of cutting greater thicknesses of steel and wrought iron, on account of the greater penetration of the flame, and for thin welding and the welding of metals of the lower fusibilities less skill is required in its handling. Another advantage is that it makes use of a by-product of electrolytic decomposition of water, one of the best methods of procuring the purest oxygen, and a process that is becoming of important commercial significance for making oxygen for the acetylene torch as well. Further, the hydrogen can safely be compressed directly into tanks for carrying on outside operations or supplying any portable outfits, whereas acetylene, as will be explained later, must be dissolved in acetone to be handled safely when compressed above two atmospheres.

Perhaps the reference to hydrogen as a by-product of the electrolytic production of oxygen should be modified so far as the oxy-hydrogen process is concerned, for the fact is that more hydrogen is required than the proportion of two to one as found in water, so that there is an excess of oxygen, making this gas in that sense the by-product. The reason for this is that although hydrogen in burning returns to the form of water (or its vapour), part of the oxygen is obtained from the surrounding air, hence to prevent the flame from oxidising the work, the supply of pure oxygen through the torch is proportionately reduced. However, the excess oxygen, if not all needed for cutting operations, will find a ready market among the users of oxy-acetylene apparatus not making their own oxygen. Then, too, it has been reported quite recently that means have been found for carburetting the hydrogen, so that where welding alone is done the consumption of oxygen and hydrogen leaves no excess of either and the flame produced is of greater heat intensity than with the plain hydrogen. The ideal arrangement would seem to be the providing of all three gases, oxygen, hydrogen, and acetylene, in plants of a size to warrant it, employing apparatus for the electrolytic production of the first two gases and an acetylene generator, and using the oxy-hydrogen and the oxy-acetylene torches on the work for which each is the best adapted. There is a sufficient overlap in the profitable applications of each to introduce no difficulty in the proper relative consumption of the several gases.

The American Oxyhydric Company, Milwaukee, Wis., is responsible for the following rather interesting definitions and divisions of welding: "Welding may be divided into two classes, autogenous and heterogeneous. The former term applies when metals are united without either flux or compression, the latter when the union is effected by interposing an alloy, usually more fusible than the metal which is to be welded. Autogenous welding may again be divided into two classes, one welding by forging, and the other by fusion with the aid of a blowpipe, electricity, or alumino thermite." It further states that autogenous welding is particularly effective when applied to iron, steel, and lead, and heterogeneous welding is used most effectively on zinc and copper, its argument being that metals which oxidise at a temperature close to the fusion point should be welded by the heterogeneous process.

Oxy-acetylene Welding. Le Chatelier has the credit of having first called attention to the high temperature obtainable in the combustion of acetylene with oxygen. This was in 1895. The discovery was not taken advantage of until 1901, when Fouché and Picard brought out a torch in which they diluted the acetylene to prevent back flashing. The following year they overcame the necessity of dilution by employing a high pressure torch which emitted the gases at such a velocity that the flame could not strike back. This, however, was difficult to use because it blew the metal away as fast as it was melted. In 1903 Fouché introduced the

low-pressure torch still familiar as such, in which the oxygen only is under appreciable pressure and the acetylene is drawn in by injector action. About the same time Camille Rodrigues-Ely and Emile Gauthier announced their intermediate pressure torch.

Torches.—What are commonly spoken of as low-pressure and high-pressure torches are better classified as injector and pressure, or positive-mixture types, as this is the chief distinction, indicating the manner in which the acetylene is taken in. As explained above, the Fouché is an injector torch. The oxygen admitted under pressure draws in the acetylene after the familiar action of a steam injector, and by the law governing the action the quantity drawn in depends on the square of the velocity of the oxygen jet. It is argued by advocates of the other type that it is not easy to maintain the proper relative proportions of the two gases with this torch since any variation in the diameter of the final outlet of the nozzle (as by expansion, if it becomes heated during use, or by the adherence of molten particles to the end) alters the velocity of the oxygen and so the amount of acetylene injected.

The pressure-type torch introduces both gases under pressure and the proportion of the mixture can be varied by varying either pressure. The pressures on the gases, never over a few pounds, will depend on the size of the torch, which in turn is determined by the character of the work and the size of flame needed. These torches must either be supplied with dissolved acetylene or from a pressure generator, whereas the injector torches can take their supply from an ordinary lighting generator.

The handles of all torches are now packed with porous material such as asbestos or mineral wool, or by some other means secure finely divided openings for the passage of the acetylene. An interesting construction is that of the Goodyear torch, which has a piece of clock pinion wire inserted in a bore of its outside diameter, giving a number of small parallel holes for passing the acetylene. The principle is that of the Davy safety miners' lamp in preventing propagation of the flame backward, that might lead to the explosion of the acetylene generator if it happened to contain air. There are other safety provisions, however, between the torch and the generator, so that practically all danger of acetylene explosions has been eliminated except where gross carelessness in the use of the apparatus is practised. The first low-pressure Fouché torch prevented flash-back by passing the acetylene through a relatively small bore tube coiled in the handle. Some favour a torch with its end at right angles with the body to allow wrist motion, but most torches have the tip inclined at about 45° or 60°

The Torch Flame.—For the complete combustion of acetylene there is required two and one-half times its volume of oxygen, as shown by the formula, $C_2H_2 + 5O = 2CO_2 + H_2O$. This is not the proportion, however, in which the two gases are supplied to the torch, for the reason that the complete reaction takes place in two stages represented by the two parts of the flame, the intensely luminous inner cone at the tip of which the maximum temperature of about 6,300° Fah. is reached, and the pale, almost transparent envelope of the flame where the temperature is very considerably lower. In the inner cone the reaction is $C_2H_2 + 2O = 2CO + 2H$, and its high temperature is accounted for by the liberation of heat both by the dissociation of acetylene and the formation of carbon monoxide, the acetylene being endothermic and the monoxide exothermic. The carbon monoxide and the hydrogen cannot combine with more oxygen in the inner cone, because its temperature is above their disassociation points, so this further combination occurs as a second stage in the reaction in the envelope of the flame, and is represented by the equation $2CO + 2H + 3O = 2CO_2 + H_2O$. Most of the oxygen for this second reaction is taken from the surrounding air, hence the smaller quantity required through the torch. It is a singular fact that the injector type of torch uses oxygen in the proportion of 1·5 or 1·7 to 1 of acetylene, while the pressure torch requires only 1·28 of oxygen to 1 of acetylene. The old high-pressure torch used the gases in the theoretical proportions for the inner cone reaction of 1 to 1, indicating that it evidently accomplished a perfect mixture of the gases before their discharge.

The tip of the inner cone is the working point of the torch. Although its temperature is so much higher, the total heat in the inner cone is less than that in the outer envelope, the latter being very much larger. It might seem that the heat in the envelope is wasted, but such is not the case, for it serves two functions, to pre-heat the work for the inner cone, and to prevent the latter from being cooled by the inert nitrogen forming about 80 per cent. of the air. Further the envelope is a protection for the molten metal from oxidation, the combining monoxide and hydrogen having a greater affinity for oxygen than the metal.

In the use of the torch it is very important to maintain a neutral flame, that is, one having neither an excess of acetylene nor of oxygen, as the first would carbonise the work and the second oxidise it. The proper condition of the flame is easily determined by observation, and the gases can be regulated accordingly. With an excess of acetylene there will be two inner cones, one extending beyond the other and less luminous. By reducing the acetylene pressure the second cone will recede, and when it finally coincides with the first, or disappears, the flame is neutral. When the adjustment is exact the inner cone will have a sharply defined contour and a slightly rounded point. With an excess of oxygen the flame has a violet cast and the end of the inner cone is feathery. Excess of either gas can also be detected by the appearance of the work. If the flame is carbonising the metal will glow intensely, and if oxidising the metal will boil.

(To be continued.)

METAL QUOTATIONS.

TUESDAY, JUNE 25TH.

Aluminium ingot	70	per cwt
„ wire, according to sizes, &c. ......from	102/-	„
„ sheets „ „ ...... „	120/-	„
Antimony ...... £27/-/- to	£28/-/-	per ton
Brass, rolled	$8\frac{1}{4}$d.	per lb.
„ tubes (brazed)	$11\frac{5}{8}$d.	„
„ „ (solid drawn)	$9\frac{7}{8}$d.	„
„ „ wire	$9\frac{1}{4}$d.	„
Copper, Standard	£77/2/6	per ton.
Iron, Cleveland	56/-	„
„ Scotch	62/-	„
Lead, English	£18/7/6	„
„ Foreign (soft)	£18/-/-	„
Mica (in original cases), small	6d. to 3/-	per lb.
„ „ „ medium	3/6 to 6/-	„
„ „ „ large	7/6 to 11/-	„
Quicksilver	£8/-/-	per bottle
Silver	$28\frac{1}{16}$d.	per oz.
Spelter	£25/17/6	per ton.
Tin, block	£206/16/-	„
Tin plates	14/7½	„
Zinc sheets (Silesian)	£29/5	„
„ (Stettin; Vieille Montagne)	£29/7/6	„

New Irish Shipyard.—The Londonderry shipyard, which has been lying derelict for about 10 years, has been acquired by a syndicate composed of English shipowners and shipbuilders, to be known as the North of Ireland Shipbuilding Company.

Scientific Aviation. — The Report of the Advisory Committee for Aeroplanes for 1911-12, just issued, gives a general survey of the work of the Committee for 1911-12, leaving the detailed accounts of experiments for later publication. It is announced that arrangements have been made, with the co-operation of the War Office, for the systematic prosecution of experiments on full scale aeroplanes, both with a view to determining the effect of variations of constructional details, and to obtaining, if possible, during flight, reliable measurements of the various quantities, a knowledge of which is essential for the explanation of the behaviour of a given type of machine. These full scale experiments are proceeding at Farnborough, under the direction of the Superintendent of the Royal Aircraft Factory.

INDUSTRIAL AND TRADE NOTES.

South Wales Tinplate Trade. The South Wales Tinplate Conciliation Board, at Swansea on the 18th inst., agreed upon a new wage agreement for the coming year. Altogether, 28,000 people are affected, and the renewal of the agreement ensures peace throughout the trade for 12 months.

Amalgamation of Scottish Bar Iron Makers.—The arrangements for the amalgamation of the West of Scotland bar iron manufacturers are, we learn, virtually complete, and the new company will probably be registered in the course of the next week or two. Mr. C. F. Maclaren, of Messrs. C. F. Maclaren & Co., will be chairman, and Mr. William Downes, of Messrs. Downes & Jardine, vice-chairman. The new company will have a capital of approximately £1,000,000, and will embrace 13 individual producers, owning 15 works, with an annual output of 250,000 tons.

Accidents with Explosives. — His Majesty's Inspectors of Explosives, in the annual report for 1911, just issued, state that last year there were 13 deaths from accidents by fire or explosion in the manufacture of explosives. This number is considerably above the average for the decade (7·3). As the number of accidents in the use of explosives (515, with 56 deaths and injuries to 548 persons) is also large—being, in fact, the highest number recorded for a year—it has been suggested that the abnormal heat of last summer may have had something to do with the increase. In the opinion of the Government inspectors of explosives there is, however, little foundation for this. In 1904, when the same relatively large number of deaths in manufacture occurred, all the fatal accidents took place in January and February.

The Letters Patent Insurance Company. — This company has been formed with a capital of £250,000, to undertake insurances to cover the liability of patentees and others so far as the law allows for the costs and expenses of prosecuting and defending actions in connection with letters patent, designs, trade marks, and other monopolies, including any damages awarded against defendants in such actions. It is intended to issue policies not only to patentees, but also to licensees. The company, in order to safeguard itself to a reasonable extent, will, so far as may be necessary prior to acceptance of an insurance, submit the matter to one or more of its experts and specialists, and will also make the necessary investigation as to the value of the patent in accordance with the importance of the insurance, and thereby the marketable value and negotiability of a patent insured by this company will, it is claimed, be greatly enhanced, independent of the additional value conferred by the life policy. A number of leading experts have consented to act as examiners.

Foster Pyrometers.— The Foster Instrument Company, of Letchworth, Herts, send us a copy of their new descriptive catalogue and price list dealing with pyrometers, in which we notice several novelties—more particularly a recorder for drawing an automatic temperature chart on a time basis. The feature of this is a pen which swings freely in front of the chart, and which is pressed upon it by a clock driven presser bar at short intervals, and so produces a series of dots which join into a continuous line showing temperature fluctuations. Another instrument which will be appreciated by steel makers is the Foster recalescent outfit, which has proved its advantages in the workshop and in the laboratory. As is well known, each grade of steel has a critical temperature above which it must be heated before quenching will harden it, and to find the recalescent point is therefore the first step to laying out a satisfactory hardening programme, and it is to determine this the instrument has been specially adapted. Full explanations are given, so that users need have no hesitation or doubt in applying the instrument.

The Board of Trade and Co-partnership Schemes. — The "Board of Trade Labour Gazette" states that for the purposes of an enquiry into profit sharing and co-partnership which is now being made by the Labour Department, it will be of much advantage if firms having in force schemes of this character, but with which the Department has not hitherto been in communication, will send their names to the Comptroller General, Labour Department, Gwydyr House, Whitehall, London, S.W. It should be observed that any particulars which the firms supplying information state that they desire not to be published in connection with their names will be referred to in the report subsequently to be published in such a manner as not to be capable of being identified as relating to the firms in question. Although, owing to the extent of the ground to be covered, it will not be possible to bring the enquiry to a close and publish the report embodying the whole of its results for some little time, an examination of the returns already received has shown that the schemes adopted in different firms exhibit a very interesting variety of type, and it is proposed to publish in the July issue of the "Board of Trade Labour Gazette" a concise epitome showing the leading features of a large number of these systems, the investigation of which has been completed.

Machinery Users' Association. — The council of the Machinery Users' Association report that during the last year there was an addition of 195 new members, making a total approximating 2,000, among whom are representatives of many of the largest and most widely known industrial undertakings in the kingdom. In the last report the council stated that the state of politics rendered it impossible to introduce into the House of Commons with any chance of success a Bill to deal with the question of the rating of machine tools, but that they trusted that when the highly controversial matters which were then occupying the attention of Parliament were disposed of it would be possible to bring forward this important question. Unfortunately the prospects of successfully introducing any private legislation seems, in the present state of affairs, to be impossible. The National Insurance Act must materially add to a manufacturer's cost of production. The council can but trust that it will result in improving the health and well being of the working classes, and thereby bringing about more stability and efficiency in labour. Another important measure which has become law is the Coal Mines Regulation Act. The council are very strongly of opinion that legislation affecting the cost of production requires close attention on the part of the manufacturing industries of the kingdom.

Results of the Shipyard Conference. — The results of the conference held at Edinburgh on Wednesday last week between representatives of the Shipbuilding Employers' Federation and the Standing Committee of the Shipyard Trades, and to which we briefly referred in our last issue, have now been made public. At the close Mr. Thomas Biggart and Mr. James Cameron, joint secretaries of the Employers' Federation, gave the following summary of the business done: The request for a 4 per cent. advance by the Boilermakers' Society was rediscussed, and the employers intimated that they were unable to alter their previous decision that they could not grant this advance. With respect to the request for a reduction of the working hours, this question was also rediscussed, and the employers intimated their inability to modify the reply already given—that they could not grant it. The question of the apprentice card which has been introduced by the Boilermakers' Society was the subject of considerable discussion. The views of both parties were presented to the conference, but parties failed to agree. As regards the amendment of the shipyard agreement, the representatives of the workmen are not yet in a position to submit the proposed amendments, and the subject was carried forward to a later meeting. It was formally intimated that the various unions had accepted the offer of a general advance of wages, and this matter is now closed.

Trade Opportunities in Western Canada. — Mr. F. T. Fisher, the Imperial Trade Correspondent at Edmonton, Alberta, considers that the opportunity for United Kingdom manufacturers to get business there is constantly improving. The building trades promise to be particularly active during 1912, it being estimated that building operations in Edmonton alone will aggregate over seven million dollars. This will involve the use of considerable quantities of structural steel, galvanised sheet iron, sanitary fittings, heating boilers and radiators, steam pipes, &c. A most active era of railway construction is in sight, with Edmonton as its centre. It is expected that the construction of something like 2,000 miles of branch lines will be arranged for during the present session of the Alberta Legislature, and consequently a large amount of construction supplies and bridge material will be needed. Development in the coal industry also promises to be very active. While the production of coal in and around Edmonton has increased in the last dozen years from about 100 tons to 3,000 tons per day, it is still only a fraction of what the accessible market would consume. A considerable amount of new equipment, including hoisting machinery, cables, &c., is being installed, both in new mines and in many of those previously worked. Very extensive additions to all the public services in Edmonton, such as water supply, sewers, electric light, &c., are proposed, the expenditure of something like six million dollars being contemplated. There is similar activity on a smaller scale in many of the other towns, which will lead to a demand for steel or iron pipe, engines, boilers, pumps, electrical equipment, &c.

The Settlement of Trade Disputes. The Labour Department of the Board of Trade have issued the 15th abstract of labour statistics of the United Kingdom. A section is devoted to trade disputes, conciliation and arbitration, and the work of the permanent boards, from which it appears that in 1911 the total number of trade disputes was 864, as compared with 531 in 1910, 248 of last year's disputes being in the metal, engineering, and shipbuilding trades. The number of workpeople directly and indirectly

involved was 931,050, compared with 515,165. The aggregate duration of the disputes in working days reached a total of 7,552,100 so far as regards those which commenced during the year. Taking figures for 1910, the percentage proportion of workpeople directly involved in disputes of the various classes were for wages 19·9, hours of labour 23·9, employment of particular classes of persons 29·8, working arrangements 16·1, trade unionists 8·5, other causes 1·8. The results as based on the number of disputes in the same year were, in favour of workpeople 25·4, in favour of employers 36·9, compromised 37·3, indefinite or unsettled 0·4. Dealing with the methods of settlement of trade disputes, the report states that 359 were by direct arrangement or negotiations between the parties or their representatives in 1910, and in the same year 25 were settled by arbitration and 31 by conciliation or mediation. There was a return to work on employers' terms without negotiations in 68 cases, whilst in 41 others the workpeople were replaced. Two resulted in the closing of works, and with two more classed as indefinite a total was made up of 531, as against 436 in 1909. The number of workpeople directly involved in the disputes was 385,085, as against 170,258 in the previous year.

Trade Circulars and Catalogues. Messrs. W. T. Glover & Co., Ltd., Trafford Park, Manchester, send us a copy of their new cable price list, No. 10. The catalogue is neatly arranged with thumb index for quick reference to any special type of cable, and gives a good deal of useful information bearing on cable construction. The same firm also send us a copy of their wall calendar, an issue which provides a daily compendium of wit and wisdom on matters electrical. From the General Electric Company, Ltd., 67, Queen Victoria Street, London, E.C., we have received a copy of their catalogue and price list of electrical accessories for motor cars. The present edition contains many new and useful lines of proved value, and covers almost every item which a motorist is likely to require.—The Power-Gas Corporation, Ltd., of Stockton-on-Tees, have favoured us with a copy of their new catalogue of Mond gas producer plant, with and without ammonia recovery. The catalogue gives an interesting resume, with photographs, of installations which have been installed, along with a good deal of useful and technical information which should be valuable to anyone contemplating the erection of such plants or desirous of familiarising themselves with their operation. We may add that the firm will be willing to send a copy to anyone who is interested in the subject.—From Perkin & Co., Ltd., Lord Street Works, Leeds, we have received a copy of their catalogue of machine tools in the shape of lathes, drills, grinders, hack saws, &c., and also a catalogue of their vertical and horizontal petrol and paraffin engines.

Train Lighting.—We have received from Messrs. Mather & Platt an interesting illustrated pamphlet, descriptive of their electric system of train lighting. The problem has been attacked in many ways, and several methods have been tried, each with its own special advantages and disadvantages, and a consideration of them seems to show that the best solution lies in the direction of a separate generating and storing apparatus on each coach. This is the system the firm has adopted, and the crux of it is the production of a dynamo or system of dynamos which will deliver current at constant voltage, independent of the speed at which it may be driven, and this desideratum, it is claimed, is reached in the machine employed. This is effected without the use of any external regulating "devices" whatsoever; the direction of its voltage is constant and independent of the direction of rotation of the armature, thus dispensing with the necessity for any form of pole changer. No compound windings for demagnetising purposes, nor shunt resistances with sliding contacts, are required. The belt tension is normal, and the slip therefore only such as is usual with any belt-driven machine. The dynamo may consequently be suspended directly from the coach bogie, thus avoiding distortion and fraying of the belt when negotiating curves. The system is adapted for working with either a single or double battery. Where the number of lamps in the coach is large, or the stoppages of long duration, necessitating a battery of large capacity, a double battery is recommended. The size and weight of the individual cells are thereby reduced, and they can be more easily handled. Where the coach is required for intermittent service, or for a service of very varying character, a double battery is also recommended. With small coaches and where the service is regular, a single battery is advantageous on account of its smaller initial cost. Further, excess current cannot be passed through the battery owing to the perfectly self-regulating properties of the machine, the output of which can be adjusted to suit the demands of any class of service. The dynamo is of lighter weight and higher efficiency than is usually the case, and its construction is so exceedingly simple that there is practically nothing to get out of order or give trouble. There is only one moving part, *i.e.*, the armature, which being of very robust construction, has been proved to be capable of withstanding the rough usage which it receives under a coach, with a negligible repair bill. There are no switches to be operated mechanically on the dynamo, no pole changing apparatus, no brush rocking device, no slipping belt, no demagnetising coils or other auxiliary devices which are common to most other systems. The cells are charged at full rate only when the dynamo is supplying current to the lamps, and, by means of the shunt regulator, the charge can be so adjusted once for all, that whatever current is given out by the cells when the train is standing is restored whilst it is running, thus keeping the cells at a constant point of charge. A small charging current is passed through the battery when the coach is running with "no lights" to make up for the polarisation losses. Attention at very infrequent intervals only is required to see whether on the whole the battery is under or over charged.

Chambers of Commerce and the Labour Unrest.—An important deputation from the Associated Chambers of Commerce waited upon the Prime Minister on the 21st inst., in connection with the industrial unrest. Lord Furness emphasized the point that whereas in the old days of strikes and lock outs a settlement was accepted and adhered to by both parties, there was to-day no possible sort of loyal observance, certainly in the majority of instances, of any award given by an arbitrator. As a preliminary, legislation would be required to make it illegal for any group of employers or any group of employés to tie up the whole of any industry throughout the entire country. To call a strike in any one entire federated industry throughout the country ought, in his judgment, to be made legally impossible by making it punishable as a conspiracy in restraint of trade. Continuing, he said that the head of the Department of Labour (which, he urged, should be created) should be the Minister to have power either himself to arbitrate or to appoint arbitrators, and he should be the authority to enforce awards. The Government was bound to end the unrest by legislation and by setting up such machinery as a Labour Department, which might guide the country clear of the industrial chaos into which it seemed to be drifting. Until both strikes and lock-outs were made impossible, and trade unions and their members and leaders took a more rational view of the economic facts, neither co-partnery nor any other mutual scheme could be expected successfully to regulate the interests of labour and capital. Other speakers also contributed to the discussion. In reply, the Prime Minister stated that he would convey the various considerations and arguments they had put before him to his colleagues in the Cabinet Committee which was at present engaged in investigating this most important and urgent problem. He entirely subscribed to the view, expressed by more than one speaker, that it was extremely undesirable that the Government as a government should concern itself in industrial disputes. It ought not to become the function of those who were responsible for the administration of affairs, that whenever a great industrial controversy arose or was threatened, they should be expected to assume the post of conciliators or arbitrators. He had never undertaken any such duties except at the last resort. He was hopeful, in view of some recent experiences, that those who represented the workmen in trade unions would more and more come to see that those who entered into industrial agreements should be expected to enter into them with the assurance on one side and the other that they would adequately and faithfully be observed. When they came to compulsory arbitration he knew they were getting into troubled waters. He was not surprised to hear from several of the speakers that they were not prepared to enter into such a scheme, nor did he believe it would be advisable. The Canadian Act, referred to by Mr. Baird, did not provide for compulsory arbitration, but it did provide for compulsory investigation by an impartial authority before either the masters on the one hand lock out their men, or the men on the other hand strike. They were told that in practice it had not worked badly in Canada, and the penalty clause, such as it was, had rarely, if ever, had to be invoked. The Government proposed to make a very careful enquiry as to how this machinery was working in Canada, with a view to seeing whether it was not possible to adapt it to the conditions of this country. There was one other topic—profit-sharing. The Government were very anxious that the applicability and expediency of any of the various schemes which had been either postponed or practically launched under that category should become thoroughly well known. The Board of Trade had been engaged for some time past in investigating them, and in a few months—by September—they would be publishing a complete, so far as they knew, account of all the various systems of profit-sharing and co partnership now to be found. He would not go into the thorny question of the merits or demerits of the Trades Disputes Act. He had listened to what had been said on the subject, and would take care to communicate it to his colleagues.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1911.

Gas turbines. Shouls & Allcock. 10462.
Internal combustion engine. Giles. 10563.
Rotary fluid pressure engines and pumps. Jerrard & Jerrard. 11001.
Hydraulic clutches for the transmission of power. Jerrard and Jerrard. 11002.
Turbines. Blake. 11288.
Apparatus for compressing air and other gases. Hessling. 12656.
Internal combustion engine. Shannon. 13270.
Jet propulsion apparatus for ships. Duke. 13312.
Carburetters for internal combustion engines. Byrom. 13370.
Superheated steam jacketed pans. Bynoe, and Balchin, Schulz, and Co. 13391.
Processes and apparatus for extracting metals from their ores. Mackay. 13499.
Lift bridges. Blondel. 13625.
Combined ahead and astern turbines. Ridsdale & Cook. 13683.
Pistons. Model Engineering Company, and Wight. 13703.
Elastic diaphragm pressure gauges. Gerard & Herrmann. 13711.
Furnaces. Pellegrino & Pellegrino. 13719.
Water softening and purifying apparatus. Boby. 13765.
Arrangement of ignition apparatus, cooling water pump, and lubricant pump in internal combustion motors. Daimler Motoren Ges. 13788.
High pressure gas lighting systems. W. M. Still & Sons, Ltd., and Still. 13814.
Furnaces of steam boilers. Ray & Forward. 13913.
Gas heated furnaces. King & Burnett. 14277.
Valves for fluid pressure engines. Soc. Anon. des Etablissements Delaunay Belleville. 14338.
Construction and working of double acting internal combustion engines. Holmes. 14708.
Motor-vehicles. Vining. 14712.
Carburetters for internal combustion engines. Charles H. Pugh, Ltd., and Bull. 14805.
Roller bearings. Wright. 15167.
Device for accelerating the application of pneumatic brakes. Chapsal & Saillot. 15378.
Means for indicating position of trains and for signalling to trains. Hein & Copp. 15431.
Automatic railway signalling apparatus. Webster. 15640.
Couplings for hose pipes. Morcom, and Belliss & Morcom, Ltd. 15710.
Protective paints for metal surfaces. Continental Caoutchouc und Gutta Percha Cie. 15886.
Instrument for measuring the density of smoke from factory chimneys. Owens. 16256.
Hermetic packings for the distributors of internal combustion engines. Tartrais. 18855.
Governing mechanism for prime movers. Warwick Machinery Company (1908), and Cox. 18948.
Chucks for rock drilling apparatus. Holman & Holman. 20325.
Screw shackle coupling for railway vehicles. Gresham. 20522.
Metallurgy of zinc. Thierry. 20913.
Gas turbines. Holzwarth & Junghans. 21268.
Roller stays of lathes and boring machines. Hulse & Co., Adams, and Lowthian. 22132.
End thrust bearings. Rennerfelt. 22524.
Starting mechanism for engines. Talbot. 23355.
Sockets and twist drills. Robertson. 23361.
Construction of ships' hulls. Von Koppen. 24038.
Cementation furnaces. Soc. Anon. Italiana Gio. Armstrong and Co. 24635.
Lubricators. Bain. 25209.
Process of roasting ore and apparatus therefor. Schertenberg. 25413.
Calorimeters. Cambridge Scientific Instrument Company, and Whipple. 25587.
Governors for marine steam engines. Fancy. 25771.
Rotary internal combustion engines. Diamant, Jellinek, and Jellinek Mercedes. 25959.
Means for discharging sand and castings from flasks more especially for use in casting apparatus. Johnson. 26410.
Method of and machine for milling flat metal bars. Lake. [illegible]
Clutches. [illegible] & Lake. 2796[illegible].
Forced feed lubricators. Wakefield. 28191.
Detachable propelling installations for ships and boats. Soc. G. Daimon et Cie. 28201.
Rock drills. Williams. 28385.
Apparatus for recording gaseous volumes. Ingeniorsfirma Fritz Egnell. 28616.
Self lubricating sheaves and loose pulleys. Bonthrone. 28790.
Vertical retorts for the carbonisation of coal. Duckham. 28852.
Clutches. Bishop. 29007.
Heat exchangers. Rud. Otto Meyer. 29094.
Fluid pressure apparatus for operating bulkhead doors. Pike and Neville. 29310.

1912.

Construction of ships' hulls. Von Köppen. 727.
Liquid injection devices for internal combustion engines. Rundlof. 1152.
Tube scrapers. Thorsen. 1189.
Safety devices for oil or gas fired steam boilers. Geb. Hardy. 1398.
Gas engines. O'Connell. 2326.
Flying machine. Trossin & Michaelis. 2345.
Starting devices for flywheels. Egeling. 2352.
Steam turbines. Schofield. 9387.

ELECTRICAL, 1910.

Contrivance for automatically intercepting or regulating the flow of an electric current from a dynamo. Hazelhurst & Longstreths, Ltd. 28161.

1911.

Telephone systems. Dicker. 10926.
Transmission of electric power. Kryshtofovich. 13492.
Remote controlling apparatus for electrically actuated travelling winches. Bleichert & Bleichert. 13574.
Magneto ignition for internal combustion engines. Cambessédès. 13633.
Detachable coupling for electrical connections. Thomas. 13886.
Primary electric batteries. Huizer. 14050.
Selective signalling systems for party lines. Western Electric Company. 15321.
Controlling the speed of electro motors. Electromotors, Ltd., and Greenhalgh. 16343.
Protecting insulated conductors against fire. Muller. 16533.
Electro mechanical change-speed and reversing device. Gasnier. 16641.
Electrical heating and air circulating appliances. Rippingille. 18324.
Electric arc lamps. Ges. fur Maschinen u. Metall Industrie. 19435.
Circuit arrangements for automatic telephone systems. Siemens and Halske Akt. Ges. 19573.
Signalling systems for railways. British Thomson Houston Company. 19970.
Protective device for dynamos and motors. Schiödt. 20636.
Dynamos. Inrig & Inrig. 20965.
Electric vibrators. Nicholson. 23191.
Storage battery electrode. Morrison. 23261.
Incandescence electric lamps. Carangelo. 23725.
Sparking plug. Cadé. 25947.
Manufacture of metallic filament incandescent lamps. Deutsche Gasgluhlicht Akt. Ges. 28576.
Field magnets for multipolar dynamos having external stationary armatures. Volkers. 29160.

1912.

Variable speed dynamos. Leitner. 1474.
Controlling electrical switches from a distance. Siemens Schuckertwerke Ges. 1541.
Electrically driven hydraulic lifts. Boddam. 1829.
Driving of lighting dynamos for motor cars. Sieber. 2739.
Electrically driven fans. Schaeffer. 3556.
Electromagnetically operated circuit breakers. Schroeder. 4792.
Apparatus for electric welding of tubes. Ges fur Elektrotechnische Industrie. 5962.

New Water Supply for Fraserburgh.—The new water supply for the town of Fraserburgh was formally inaugurated this month. The work involved an expenditure of £52,000. A reservoir, containing about 65 million gallons of water and covering about 25 acres of ground, has been constructed in the Federate district, whence the water is conveyed into a service reservoir at Bogensourie. This reservoir is capable of containing half a million gallons, and acts as a clear water tank for the mechanical filters adjoining. The filters, which were constructed and installed by Messrs. Mather & Platt, Ltd., of Manchester, are capable of treating [illegible] gallons per 24 hours. The water is conveyed from the clear water tank to the town of Fraserburgh and connected to the existing mains with a series of valves, whereby, in the event of a temporary breakdown in the new supply works, the present supply can be turned on. It is expected that the new water supply will effect a vast improvement in the health of the community.

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